frontiers | Research Topics

Economic and social factors affecting the health of older adults

Edited by
Colette Joy Browning, Katherine Henrietta Leith and Shane Andrew Thomas

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Economic and social factors affecting the health of older adults

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Editorial: Economic and social factors affecting the health of older adults

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Editorial on the Research Topic
Economic and social factors affecting the health of older adults

The world is undergoing a period of global population aging; in 2020, over 1 billion of the world's population was over 60 years old, and this number is expected to double by 2050 (1). The UN has promoted the UN Decade of Healthy Aging to transform the lives of older people by "adding life to years" and reducing health inequalities (2). Healthy aging policies are responses to the potential to optimize health and wellbeing as we age and to challenge the "burden of aging" rhetoric (1). Such policies promote the consideration of social and economic factors including adequate income through work or pension schemes, social support and social engagement, knowledge of personal health issues, and access to quality healthcare to improve healthy aging. In this Research Topic, we have gathered 28 original articles that examine the relationships between socioeconomic factors, including income, rurality, social support, health literacy, and health expenditure, and the health status of older adults.

The Research Topic report is organized into four broad topic areas with studies from a range of countries, including the United States, China, the Republic of Korea, India, Switzerland, Japan, Northern Ireland, Australia, and Mexico. The groupings are:

- Health Conditions, Health Behaviors, and Health Literacy;
- Loneliness, Social Support, and Social Capital;
- Mental Health and Wellbeing; and
- Service Use, Access, and Expenditure.

The majority of the articles presented secondary analyses of major international aging research datasets including the Survey of Health, Aging and Retirement in Europe (SHARE), the China Health and Retirement Longitudinal Study (CHARLS), Chinese General Social Survey (CGSS), Chinese Longitudinal Healthy Longevity Survey (CLHLS), China Household Finance Survey (CHFS), Korean National Health Insurance (KNHI) database, Korean Community Health Survey (KCHS), Korean Longitudinal Study of Aging (KLoSA), Longitudinal Aging Study in India (LASI), and Northern Ireland Cohort for the Longitudinal Study of Aging (NICOLA). Some cross-sectional studies, a qualitative study, and a commentary are also included. We now review the evidence provided by the articles for each of the four themes.

Health conditions, multimorbidity, health behaviors, and health literacy

Three studies focused on the prevalence of health conditions and multimorbidity, which increase with age and are higher in low socio-economic status (SES) communities. Nwadiugwu discussed how the management of multimorbidity in older people requires appropriate paradigms and protocols that incorporate the consideration of socio-economic burden and the risk of polypharmacy. Medication use was also explored in Qin S. et al.. Using the 2018 wave from CHARLS, they found that women, those with higher education levels, and participants with poorer self-rated health or multimorbidity were more likely to self-medicate for a self-diagnosed illness. Sinha et al. estimated multimorbidity prevalence at 45.3% in older adults in the lowest economic quintiles using data from Wave 1 of the Longitudinal Aging Study in India (LASI). With each additional condition, personal expenditure increased, as did health insurance claims.

Lifestyle risk factors including smoking, exercise, diet, and sleep quality (3) are important contributors to the onset of health conditions and their management of health as we age. Yuan et al. studied 6,966 Chinese participants aged 60 and above to analyze differences in smoking prevalence and the knowledge, attitudes, and factors associated with smoking among rural and urban participants. The overall prevalence of smoking was 25.6%, with a much higher rate among rural men. The researchers advocated education campaigns focused on older rural men based on their data.

While smoking, diet, and exercise are routinely promoted as key preventive health behaviors, sleep quality is now considered to be an under-estimated key factor affecting the health of older people (4). Zhang M. et al. surveyed 1,189 residents aged 60 and above in China. Measures included self-rated health, sleep quality, mental health, smoking, alcohol, consumption, body mass index, risk of falling, hospitalization, non-communicable diseases, and various socioeconomic measures. Self-rated health was found to be influenced by the number of non-communicable diseases, hospitalization, alcohol consumption, and participant sleep quality. Xue et al. investigated the impact of SES and sleep quality on multimorbidity in a cross-sectional study in Shanxi Province, China. They found, among all SES groups, that older adults with poor sleep quality and low SES had higher multimorbidity. Ayaki et al. studied the onset of wearing presbyopic eyeglasses and their lifestyles among Japanese participants aged between 40 and 59 years. Earlier commencement of near correction was significantly associated with hyperopia, sleeping in, poor subjective sleep quality, and lower annual income. The researchers concluded that healthy sleep may delay the need for near correction and myopia and that sleep disruption might exacerbate presbyopia. These three studies support the importance of sleep quality for the health of older adults.

Health literacy and how we access health information are also important drivers in the prevention and management of health conditions in aging populations (5). Ma et al. examined productive aging in 995 older Chinese adults in a newly urbanized community. They found that education attainment and income had a direct positive effect on health literacy. Based on these findings, they concluded that it would be beneficial to target health education and health promotion for older adults, especially those with a lower SES. Liu et al. studied the impact of frailty among older people in China. They collected data from 637 patients aged 65 and above in Sichuan Province, China, with diabetes and hypertension. To mitigate frailty in this population, they suggested that social support and health literacy education should be provided.

Access to the Internet by older people influences the propensity to access health information and their levels of health literacy (6). Three studies focused on Internet perceptions and use. Guo et al. investigated participants' perceptions of the Internet's importance in obtaining information and the role of learning and social activity in the physical health of older Chinese participating in four waves of the CFPS. The health of women and rural residents and exercise frequency were impacted positively by perceptions of the Internet. Gao et al. examined the perceived importance of the Internet and mobile messaging in life satisfaction as information channels and the self-rated health of older people using two waves of data from the CFPS. Perception of the importance of the Internet positively impacted family atmosphere, life satisfaction, and self-rated health. During the COVID-19 pandemic, online interaction became a more common form of social activity and searching for treatment information. Zhang, Liao et al. conducted a cross-sectional study of 646 people aged 55 and above about their risk perceptions (probability, severity, controllability, and familiarity) during the pandemic and their health information searching behaviors. They found that when facing severe health risks such as COVID-19, older people will search for health information via the Internet.

Loneliness, social support, and social capital

In previous research, social capital has been linked to better health for older people (Xu Z. et al.). Loneliness and social isolation have been identified as significant issues for older adults impacting on quality of life and risks for dementia, stroke, depression, and anxiety (7). The UN Decade of Healthy Aging (2021–2030) included social isolation and loneliness as key themes.

Bai et al. examined the role of social capital in the self-rated health of older Chinese people living in Anhui Province, surveying 1,810 participants aged 60 and above. Social capital was measured across six dimensions (social participation, social support, social connection, trust, cohesion, and reciprocity). The relationship between social capital and self-rated health (SRH) was not consistent across all the dimensions. Among those with health conditions, poor SRH was associated with lower social participation, cohesion, and reciprocity. Among those with no health conditions, poor SRH was associated with lower social support. Zhou et al. studied the association between social capital and depression among 1,042 older Chinese adults. Reciprocity and social network were significantly negatively correlated with depression among men. Trust, reciprocity, and social participation had a positive effect on reducing depression risk. Among women, social networks and social participation had a negative effect on depression. In the Republic of Korea, Hong et al. studied almost 2 million participants aged 50 and above from the Korean National Health Insurance (KNIHS) database and the Korean Community Health Survey (KCHS). Social capital was measured

on one dimension using responses to the question, "Do you trust members of your community?" Dementia was measured using medication data and the ICD-10 classification. Those participants, both men and women, within the highest quintile of trust had the lowest risk of dementia. Comorbidities did not impact this relationship. The authors suggested that trust may support better stress management and hence reduce the risk of dementia.

Wu et al. using data from the SHARE and CHARLS studies, examined the role of income inequality and welfare support in loneliness in Europe and China. They proposed that country income-level inequality may reduce social cohesion and trust, thus increasing loneliness, but providing welfare services and benefits may increase social capital and reduce loneliness. They found that individual socio-economic status (SES) impacted loneliness more in countries with higher income inequality but had a weaker impact in countries with high welfare support. Using data from the CGSS, Qin Y. et al. focused on older Chinese people living alone and found that leisure activities had a positive impact on their physical and mental health but not their social health. Older rural-dwelling people showed lower physical health but higher social health than urban-dwelling people. The authors contended these differences may be driven by lower economic and health service resources and higher neighborhood ties. Burns et al. studied loneliness and its relationship with healthcare use. They analyzed a representative sample of 8,309 community-dwelling adults aged 50 and above from the NICOLA study. They found that the association between loneliness and healthcare usage (HCU) was not significant when health status and health behaviors were controlled.

In a cross-sectional study of 865 participants aged 65 and above in Hubei Province, China, Li et al. examined the relationship between cognition, as measured by the Mini-Mental State Examination (MMSE), and social support, as measured by the Social Support Rating Scale (SSRC). Social support was found to be an important contributor to the quality of life of older people. Using CHARLS, the impact of adult children rural–urban migration on their parents' health was investigated (Zhang, Lyu et al.). Physical health was measured using self-rated health, IADL, and physical activity ability. Other health measures included depression and subjective wellbeing. It was found that the migration of adult children had a positive effect on physical health but not on mental health. The health of fathers but not mothers improved with the migration of adult children.

Mental health and wellbeing

Four of the Research Topic articles examined social and economic impacts on mental health and wellbeing.

In China, Cheng et al. investigated the impact of residential location on depression using 2018 CHARLS data. The study included 8,210 participants aged 65 and above. Depression was measured using the CES-D, and residential locations were classified as urban (lived in urban areas for 10 years or more), rural–urban (had migrated from rural areas), and rural (lived in rural areas). Depressive symptoms were higher in those who had migrated from rural areas to urban areas. This group often has insufficient income to live well in urban settings with higher living costs. Higher education levels, higher income, and greater engagement in physical activity were associated with lower depressive symptoms. The authors recommended more investment in rural areas to attract people back to these locations and to increase mental health services in urban settings.

Zhao et al. using data from Wave 7 (2018) of the Korean Longitudinal Study of Aging, investigated the relationship between the SES, mental health, and long-term support needs of 5,527 older Koreans aged 60 and above. Mental health was measured using health status satisfaction, quality of life satisfaction, and the CES-D depression scale. The need for long-term care support was measured using ADL (Activities of Daily Living) and IADL (instrumental Activities of Daily Living), activity limitations caused by health issues, hospitalization, and bodily pain. Lower SES and poorer mental health were associated with a higher need for long-term care. The impact of mental health on long-term care needs was higher in men.

Zhang A. et al. analyzed the impact of retirement on happiness for participants in the 2012, 2015, and 2017 waves of the China General Social Survey (CGSS). They found that retirement is associated with increases in men's happiness, but the effects were influenced by level of education (lower education brings greater happiness) and family structure (more children bring greater happiness), and greater health status provided less improvement. The authors argued for a delayed retirement policy.

In an Australian study, Worrall et al. investigated factors associated with depressive symptoms in older adults. Their analyses revealed that life satisfaction, self-esteem, and purpose in life were associated with fewer depressive symptoms. They suggested that depression among older people could be addressed by focusing on enhancing life satisfaction, self-esteem, and purpose in life.

Service use, access, and expenditure

Ingram et al. investigated potential health inequities in African-American older adults residing in South Carolina, USA. Forty-seven people aged 50–85 years participated in telephone interviews during the early stages of the COVID-19 pandemic. The participants commented on the efficacy and convenience of telehealth consultations, their reactions to the vaccine, its availability, and vaccine hesitancy, as well as the need for more engaged physicians and family support. The authors concluded that more qualitative lived experience research is needed.

Bachmann et al. studied 60,209 Swiss community-dwelling patients aged 75 and above who had been hospitalized with a chronic health condition. They modeled the impact of social and regional factors on the odds of a nursing home admission after hospital discharge, which occurred for 7.8% of all patients. They found that higher education level, insurance status, and living alone altered the chance of being admitted to a nursing home. They suggested that social care and healthcare could work together to reduce institutionalization rates.

The impact of population aging on health expenditure has been hotly debated globally (8). Many health conditions are age related, and health spending is driven by chronic illnesses such as heart disease and mental health conditions (9). In its latest report, the OECD highlights the increase in expenditure on health by governments in response to the COVID-19 pandemic (10). Using

data from the China Household Finance Survey (CHFS), Xu X. et al. concluded that age, income, family size, self-rated health, and the old-age dependency ratio influenced household health expenditure in China, with greater impact in eastern China.

Salinas-Rodríguez et al. studied out-of-pocket (OOP) healthcare costs for an older sample of 735 community-dwelling Mexican adults aged 60 and above with IADL and ADL dependence. They found that ADL and IADL dependence are highly influential for annualized OOP healthcare expenditures. Their findings highlighted the economic implications of the dependence on individuals, their families, and the health system in Mexico and the importance of policies to address them.

Conclusion

While articles from China were strongly represented, this Research Topic incorporated studies from a wide range of countries. A strength of this collection is the inclusion of analyses of high-quality gold standard longitudinal studies. However, greater commonality in and standardization of measurement tools and domains would permit better quality cross-country comparisons. There was limited treatment of urban–regional differences in health outcomes among the studies. Rural populations are often disadvantaged in terms of health access and health outcomes (11). The Research Topic included articles with inconsistent application of multimorbidity and disease burden concepts, which are critical for addressing the UN Sustainable Development Goal of reducing premature death due to non-communicable diseases (12). Our submissions did not take advantage of the strengths of using harmonized datasets from the Gateway to Global Aging Data initiative, which permits cross-country comparisons of core content areas.[1] In a recent article, we have argued for the use of health economics concepts and interdisciplinary co-operation, including biomedical and psychosocial markers, to transform approaches to chronic disease prevention and management across the lifespan (3). We repeat that call in this editorial. An integrated approach utilizing health economics concepts and based on high-quality, large-scale data collections will deliver the best quality and usable results to inform health and social policies and outcomes.

1 Gateway to Global Aging Data. Available online at: https://g2aging.org/survey-overview.

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The Relationship Between Health Literacy, Social Support, Depression, and Frailty Among Community-Dwelling Older Patients With Hypertension and Diabetes in China

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Population aging is one of the major challenges facing modern society and has attracted global attention. With population aging becoming a global phenomenon, the impact of age-related diseases on health is increasing rapidly. Frailty is one of the most pressing issues facing older adults. The purpose of this study was to explore the interrelationship between health literacy, social support, depression, and frailty among older patients with hypertension and diabetes in China. No studies have investigated the mediating effects of social support and depression between health literacy and frailty. The findings of this study can be applied to help ameliorate frailty in older hypertensive and diabetic patients. Data were collected from 637 older hypertensive and diabetic patients aged 65 years and older in Sichuan Province, China. We used structural equation modeling (SEM) to test the hypothesized relationship among the variables. The results showed that 42.4% of the participants suffered from frailty. The mean scores for health literacy, social support, depression, and frailty were 13.6 ± 5.7, 35.7 ± 6.5, 4.0 ± 3.4, and 3.5 ± 2.1, respectively. Social support had a direct negative association with frailty ($\beta = -0.128$, 95%CI: [−0.198, −0.056]), and depression had a direct positive association with frailty ($\beta = 0.326$, 95%CI: [0.229, 0.411]), while social support had no direct association with depression. Health literacy had a direct positive association with social support ($\beta = 0.151$, 95%CI: [0.077, 0.224]) and a direct negative association with depression ($\beta = -0.173$, 95%CI: [−0.246, −0.1]), while health literacy had an indirect negative association with frailty through the mediating effect of social support and depression. To mitigate frailty in older patients with hypertension and diabetes, measures that provide social support, and enhance health literacy, while alleviating depression, should be considered, along with greater attention to patients who are divorced, widowed, or unmarried, those with comorbidities, and those with lower socioeconomic status.

Keywords: frailty, social support, depression, health literacy, older, hypertension, diabetes, China

INTRODUCTION

Population aging is a major challenge facing modern society and has attracted increasing global attention. It is estimated that by 2050, one in six people will be over 65 (16%), and the number of people aged 80 and over is expected to triple from 143 million in 2019 to 426 million (1–3). China has the largest older population and has become one of the fastest aging countries in the world (4). According to current projections, China's population will peak in 2028, with a shrinking labor force and an over-65 population of 240 million.

Frailty is one of the most pressing challenges facing older adults as they age (5). Frailty is a comprehensive concept that must consider the complex interplay among multiple factors, and can normally be reflected in three aspects: physical, psychological, and social frailty (6). Frailty can increase the risk of adverse health outcomes, including falls, disability, hospitalization, poor quality of life, and eventually mortality (7–10). In China, hypertension and diabetes affect at least 57 and 26.5% of the older population, respectively (11, 12). The prevalence of frailty is 80% in older patients with hypertension, and is 3–5-fold higher in older patients with diabetes compared with that in those without these conditions (13, 14). Diabetes often coexists with hypertension among older adults in China. In addition, previous studies have shown that frail older adults with hypertension and diabetes have worse physical performance, mental status, and prognosis, as well as higher mortality, compared to non-frail older adults with hypertension and diabetes (15, 16). The above findings emphasize the importance and need for concern about frailty in older patients with hypertension and diabetes within the context of a rapidly aging population.

Health literacy is defined by the WHO as a cognitive and social skill that determines an individual's motivation and ability to access, understand, and use information in a way that promotes and maintains health (17). The results of China's first survey on health literacy showed that older adults had a low health literacy level, with only 3.81% of people over 65 years of age showing adequate health literacy skills (18). Low health literacy has been reported to be associated with a poor understanding of one's medical condition, poor self-care, delayed care-seeking when symptomatic, and lower use of preventive services, and can also affect disease management and outcomes in chronically ill patients (19, 20). Adequate health literacy can prevent frailty in older adults and plays a positive role in the management and intervention of community-dwelling frail older population (21). Health literacy is also associated with social support, and low health literacy limits an individual's ability to access resources from social networks (22).

Social support is a multidimensional concept, usually defined as "perceived and received social resources or help." These can be instrumental, emotional, or informational (23). As a developing country, China is experiencing rapid urbanization and economic development (24), which has led to changes in the cultural norms of filial piety in eldercare as well as in traditional family size (25). The geographical distance between older adults and their children and the proportion of female participation in full-time employment are increasing. In addition, since the implementation of the "One Child Policy" from 1979, the rate of population aging has increased and traditional Chinese large-sized households have gradually been replaced by the nuclear family (24). All these factors have made it increasingly difficult for family members to provide care and support to older relatives. Woo et al. found that increasing social support among older adults was associated with reduced frailty (26). Strong empirical evidence suggests that people with better social support are less likely to suffer from physical and mental illness and that sufficient social support can help alleviate the frailty condition of community-dwelling older people (27, 28). In addition, Patra et al. argued that social support can effectively reduce patients' psychological distress, such as depression (29). Social support was found to be a significant predictor of depression among older hypertensive patients and adults with diabetes (30, 31). Furthermore, Stewart et al. demonstrated that social support could be a mediator of the relationship between health literacy and depression among smokers (32).

Globally, depression is one of the most common psychiatric disorders among people aged 65 and above, which affects one in seven older adults (29). It has been suggested that depression and frailty often coexist, and the prevalence of depression is as high as 46.5% among older people with frailty (33). Depression was proven to be a strong predictor of frailty in a study of women with disabilities (34). A prospective cohort study demonstrated that depressive symptoms were associated with an increased risk of becoming frail after adjusting for antidepressant use and other important covariates in women 65 and older (35). In addition, evidence has linked higher depression levels with limited or poor health literacy in older adults, and depression is found to mediate the relationship between health literacy and health outcomes among breast cancer patients (36, 37).

Most previous studies in this area have investigated the associations between social support, health literacy, depression, and frailty, but the combined effects of these factors on frailty and the underlying mechanisms of these relationships remain unclear. In addition, few studies have examined the frailty status of a particular group—older patients with hypertension and diabetes. Therefore, the aim of the present study was to examine the frailty status and the interrelationships, as well as potential underlying mechanisms, between social support, health literacy, depression, and frailty among community-dwelling older individuals with hypertension and diabetes living in China.

A structural equation model was constructed to explore the relationship between health literacy, social support, depression, and frailty among older hypertensive and diabetic patients. Based on previous research, we proposed 10 hypotheses (shown in **Table 1**) and a theoretical model (**Figure 1**). The findings of this study identified the key factors that contribute to the prevention and control of frailty in older patients, which is of great significance for decreasing frailty and improving the health of older patients with hypertension and diabetes.

MATERIALS AND METHODS

Ethical Considerations

The study protocol was approved by the Ethics Committee of Sichuan University. The survey was voluntary, and informed

TABLE 1 | The theoretical hypotheses.

Hypotheses
1. Health literacy has a direct positive effect on social support.
2. Health literacy has a direct negative effect on depression.
3. Health literacy has a direct negative effect on frailty.
4. Social support has a direct negative effect on frailty.
5. Social support has a direct negative effect on depression.
6. Depression has a direct positive effect on frailty.
7. The relationship between health literacy and depression is mediated by social support.
8. The relationship between social support and frailty is mediated by depression.
9. The relationship between health literacy and frailty is mediated by social support.
10. The relationship between health literacy and frailty is mediated by depression.

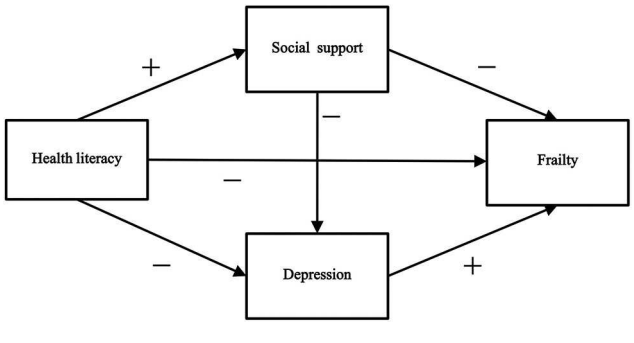

FIGURE 1 | The theoretical model and hypotheses.

consent was obtained from each participant before the interview was held. The participants were informed that their anonymity will be guaranteed.

Participants and Procedure

This cross-sectional study was conducted between December 2017 and May 2018 in Sichuan Province, China. All community-dwelling elders aged 65 years and older who had been diagnosed with hypertension and diabetes were eligible to participate.

A multistage stratified random sampling process was used to acquire the sample. In the first stage, we randomly selected a city in Sichuan Province. In the second stage, 10 communities of the city were randomly selected as survey areas. In the third stage, systematic sampling was used to obtain 70 subjects from the database of hypertensive and diabetic older patients established by each community hospital. A total of 700 patients were surveyed face-to-face by professionally trained investigators. To ensure the quality of the investigation, we set the following exclusion criteria: (a) patients who could not adequately answer questions due to cognitive impairment; (b) those unable to cooperate for personal reasons (e.g., migration, rejection). Ultimately, we obtained and analyzed 637 (91%) valid responses.

Measures

Sociodemographic data and information on health literacy, social support, depression, and frailty were collected using the questionnaires.

Sociodemographic Characteristics

The sociodemographic characteristics assessed included gender, age, marital status, education level, individual annual income, per capita annual household income, smoking status, drinking status, and comorbidities. Age was categorized as 65 – 69, 70 – 74, 75 – 79, and ≥80 years. Marital status was defined as a binary variable: "Married" or "Divorced, widowed, or unmarried." Education level was classified as "No formal education," "Primary school" "Middle school," or "High school and above." Individual annual income and per capita annual household income were both divided into five categories: <$750, $750 – 1,499, $1,500 – 4,499, $4,500 – 7,499, and ≥$7,500. Current smoking status, current drinking status, and presence of comorbidities were binary variables ("Yes" or "No").

Health literacy

The health literacy scale was constructed by referring to the Chinese Citizen Health Literacy Questionnaire developed by the National Health Commission of the People's Republic of China (38). The expert consultation method was used to select representative questions that are closely related to health literacy for older adults. To improve the questionnaire, we added further questions assessing knowledge of common chronic disease prevention. The full scale contained three dimensions: knowledge and belief literacy, behavior literacy, and skill literacy, with 33 items and a total score of 33. The respondents who correctly answered 80% or more of the questions were regarded as having good health literacy. In the current study, Cronbach's α of the scale was 0.832.

Social Support

Social support was measured using the Social Support Rating Scale (SSRS) (39) designed by Xiao et al. This scale consists of 10 items and contains three subscales: objective support, subjective support, and support utilization. Responses are given on a 4-point Likert scale, and the total score can range from 12 to 66, with higher scores indicating stronger social support. Objective support includes three items, with a total score ranging from 1 to 22; subjective support includes four items, with a total score ranging from 8 to 32; and support utilization includes 3 items, with a total score ranging from 3 to 12. The total score is divided into three levels: low (12–22), moderate (23–44), and high (45–66). The SSRS has demonstrated good to excellent reliability in prior studies, with a Cronbach's α of 0.89 and a test–retest reliability of 0.92 (39). In the current study, Cronbach's α of the scale was 0.735.

Depression

The short version of the Center for Epidemiologic Studies Depression Scale (CES-D-10) was used to measure depressive symptoms during the survey; this scale consists of 10 items from the original 20-item CES-D developed by Anderson et al. (40).

The CES-D-10 includes depressive affect (three items), somatic symptoms (five items), and positive affect (two items) (41). Each of the 10 items is rated on a 4-point Likert scale, ranging from "rarely (<1 day) = 0" to "most or all of the time (5–7 days) = 3," and the summed scores of the items can range from 0 to 30. Higher scores represent greater levels of symptom frequency, and a score of 10 or higher indicates significant depressive symptoms (40). The CESD-10 has shown excellent reliability (Cronbach's α of 0.70 and composite reliability of 0.72) (42). In the current study, Cronbach's α of the scale was 0.714.

Frailty

Frailty was assessed by the Chinese version of the Tilburg Frailty Indicator Scale (TFI) designed by Dong et al. (6), which is a standardized self-reported questionnaire containing 15 items addressing three domains: physical, psychological, and social. The physical domain (0–8 points) consists of eight items related to physical health, unexplained weight loss, difficulty walking, balance, hearing problems, vision problems, strength in hands, and physical tiredness. The psychological domain (0–4 points) comprises four items corresponding to cognition, depressive symptoms, anxiety, and coping. The social domain (0–3 points) includes three items related to living alone, social relations, and social support. The scale items are scored using a binary scoring method that ranges from 0 to 15 points; the higher the score, the higher the patient's frailty. Two items of the scale have three response categories (yes, no, and sometimes). "Yes" or "sometimes" responses are scored one point each, while "no" responses are scored zero. The cutoff for frailty in the Chinese version of the TFI is 4. The Chinese TFI has good validity and reliability (Cronbach's $\alpha = 0.71$) as an integral instrument to measure the frailty of Chinese community-dwelling elders (6). In the current study, Cronbach's α of the scale was 0.597.

Statistics Analysis

The data were entered using the Epidata3.1 database. Statistical analyses were conducted using IBM SPSS Statistics 20.0 (IBM Corporation, Armonk, NY, USA) and AMOS 24.0 (IBM, New York, NY, USA). First, we used descriptive statistics to examine participant characteristics. Proportions and frequencies were calculated for the sociodemographic characteristics, and means and standard deviations were calculated for the study variables. Second, Spearman's correlation coefficient was used to analyze the correlations between health literacy, social support, depression, and frailty. Third, a linear regression model was also used to analyze the influence of sociodemographic factors, in addition to health literacy, social support, and depression on frailty status. Fourth, a structural equation model (SEM) was constructed to further test hypothesized relationships among social support, health literacy, depression, and frailty of older patients with hypertension and diabetes.

The SEM used bootstrap maximum likelihood estimation. To evaluate the overall model fit, we applied the following model fit criteria: an adjusted goodness of fit index (AGFI), goodness of fit index (GFI), comparative fit index (CFI), and Tucker–Lewis index (TLI) of 0.90 or above; a standardized root mean square residual (SRMR) and a root mean squared error of approximation (RMSEA) <0.08; and an χ^2/df of <3. These criteria indicated an acceptable model fit. Statistical significance was set at $p < 0.05$.

RESULTS

Sociodemographic Characteristics of the Participants

The sociodemographic characteristics of the 637 elder patients with hypertension and diabetes are presented in **Table 2**. In the sample, there were more females (64.8%) than males (35.2%). The average age of the participants was 72.21 years ($SD = 5.76$), and the highest proportion was people aged 65–69 years (38.8%). Most were married (75%), had an education of primary school or less (81.2%), had an individual annual income of $1,500–4,499 (58.6%), and did not currently smoke (87.1%), or drink (85.4%). Overall, 35.3% of the participants had a per capita annual household income of $1,500–4,499, and 25% had chronic diseases other than hypertension or diabetes.

Descriptive Analysis of Study Variables

The score of each variable is shown in **Table 3**. The mean scores for health literacy, social support, depression, and frailty were 13.6 ± 5.7, 35.7 ± 6.5, 4.0 ± 3.4, and 3.5 ± 2.1, respectively. The proportion of individuals who had good health literacy was only 3.9% (25). Based on the score, 2.2% (14), 87.8% (559), and 10% (64) of older hypertensive and diabetic patients experienced low, moderate, and high social support, respectively. In addition, 8.3% (53) had depressive symptoms, and 42.4% (270) suffered from frailty.

Correlations of the Study Variable

Spearman's correlations for the study variables are presented in **Table 4**. Health literacy had a positive correlation with social support and a negative correlation with depression, while social support had a negative correlation with frailty. Depression was significantly positively correlated with frailty.

Linear Regression Analysis

We used frailty as the dependent variable and sociodemographic variables, social support, health literacy, and depression as independent variables in a multiple linear regression model. **Table 5** presents the statistically significant variables in the analysis ($p < 0.05$). The results showed that in addition to health literacy, social support, and depression, eight sociodemographic factors were influencing factors of frailty in hypertensive and diabetic elders. These included age, marital status, educational level, individual annual income, per capita annual household income, current smoking status, current drinking status, and presence of comorbidities.

The frailty score of patients aged 70–74 years ($p = 0.045$) was on average 0.37 points higher than that of patients aged 65–69 years. The frailty score of divorced, widowed, or unmarried participants ($p = 0.034$) was on average 0.402 points higher than that of married participants. The frailty scores of patients who were educated to primary school level ($p = 0.004$) and those of patients who were educated to middle school level ($p = 0.001$)

TABLE 2 | Sociodemographic characteristics of the participants ($n = 637$).

Sociodemographic characteristics	*n*	%
Gender		
Female	413	64.8
Male	224	35.2
Age, Group		
65–69	247	38.8
70–74	193	30.3
75–79	118	18.5
≥80	79	12.4
Marital Status		
Married	478	75.0
Divorced, widowed, or unmarried	159	25.0
Education Level		
No formal education	207	32.5
Primary school	310	48.7
Middle school	77	12.1
High school and above	43	6.8
Individual Annual Income ($)		
<750	106	16.6
750–1,499	60	9.4
1,500–4,499	373	58.6
4,500–7,499	82	12.9
≥7,500	16	2.5
Per Capita Annual Household Income ($)		
<750	57	8.9
750–1,499	54	8.5
1,500–4,499	225	35.3
4,500–7,499	200	31.4
≥7,500	101	15.9
Current Smoking Status		
No	555	87.1
Yes	82	12.9
Current Drinking Status		
No	544	85.4
Yes	93	14.6
Comorbidities		
No	478	75.0
Yes	159	25.0

were on average 0.529 and 0.916 points lower than the frailty scores of patients who were educated to less than primary school level. For individual annual income, the frailty scores of patients in the 750–$1,499 ($p = 0.004$), 1,500–$4,499 ($p = 0.023$), 4,500–$7,499 ($p = 0.009$), and ≥$7,500 ($p = 0.003$) income groups were on average 0.724, 0.63, 0.929, and 1.745 points lower than that of patients in the <$750 income group, respectively. The frailty score of subjects who had a per capita annual household income of 750–$1,499 ($p = 0.029$) was on average 0.898 points lower than that of subjects who earned <$750. The frailty score of subjects who currently smoked ($p = 0.001$) was on average 0.834 points higher than that of non-smokers, and the frailty score of subjects who currently consumed alcohol ($p = 0.019$) was on average 0.556 points lower than that of those who did not. In addition, the frailty score of older patients with two or more chronic diseases ($p = 0.013$) was on average 0.446 points higher than that of patients with none.

TABLE 3 | Description of social support, health literacy, depression, and frailty scores ($n = 637$).

Contents	Range	Mean (*SD*)
Health literacy	0–33	13.6±5.7
Knowledge and belief literacy	0–22	7.9±4.3
Behavior literacy	0–9	4.5±1.7
Skill literacy	0–2	1.2±0.5
Social support	12–66	35.7±6.5
Objective support	1–22	7.5±2.2
Subjective support	8–32	21.5±4.1
Support utilization	3–12	6.7±2.0
Depression	0–30	4.0±3.4
Frailty	0–15	3.5±2.1

TABLE 4 | Correlation coefficients among study variables.

Variable	(1)	(2)	(3)	(4)
(1) Health literacy				
(2) Social support	0.168**			
(3) Depression	−0.166**	−0.003		
(4) Frailty	−0.061	−0.102**	0.180**	

**$p < 0.01$.

Test of the Study Model

By establishing the SEM, the four research variables were connected with each other, and the data and the established theoretical model were fitted by the maximum likelihood estimation method. The results showed that the link between health literacy and frailty and the link between social support and depression were not statistically significant. Therefore, we modified the model by removing these two paths. With the addition of sociodemographic factors as covariates, the arrow direction among the core variables in the SEM remained unchanged, and the corresponding coefficients did not change significantly. Thus, the sociodemographic factors were not confounding factors. **Figure 2** shows the final model and the correlation and effect paths among the key variables. The goodness of fit tests showed AGFI, GFI, CFI, TLI, SRMR, RMSEA, and χ^2/df values of 0.992, 0.998, 1.0, 1.0, 0.0179, 0.011, and 1.075, respectively, indicating that the model fit the data well.

Table 6 presents the test results of the hypothesis model, and each path adopted bias-corrected bootstrapping with 2,000 replications using maximum likelihood estimation. As expected, health literacy had a direct positive association with social support ($\beta = 0.151$, 95%CI: [0.077, 0.224]) and a direct negative association with depression ($\beta = -0.173$, 95%CI: [−0.246, −0.1]). These two results support Hypotheses 1 and 2. However,

TABLE 5 | Linear regression of factors associated with frailty.

Factor	Unstandardized coefficients		Standardized coefficients	*t*	*p*-Value
	B	*SE*	*β*		
Constant	4.267	0.563		7.961	<0.001
Gender (ref: female)					
Male	−0.351	0.193	−0.080	−1.819	0.069
Age (ref: 65–69)					
70–74	0.37	0.184	0.081	2.009	0.045
75–79	0.101	0.215	0.019	0.473	0.636
≥80	0.471	0.257	0.074	1.83	0.068
Marital status (ref: married)					
Divorced, widowed, or unmarried	0.402	0.189	0.083	2.126	0.034
Education level (ref: no formal education)					
Primary school	−0.529	0.183	−0.127	−2.889	0.004
Junior middle school	−0.916	0.262	−0.143	−3.493	0.001
High school and above	−0.428	0.374	−0.051	−1.145	0.253
Individual annual income (ref: <750, $)					
750–1,499	−0.724	0.353	−0.101	−2.055	0.04
1,500–4,499	−0.63	0.277	−0.148	−2.275	0.023
4,500–7,499	−0.929	0.353	−0.149	−2.635	0.009
≥7,500	−1.745	0.582	−0.131	−2.999	0.003
Per capita annual household income (ref:<750, $)					
750–1,499	−0.898	0.41	−0.12	−2.192	0.029
1,500–4,499	0.273	0.36	0.062	0.76	0.448
4,500–7,499	0.17	0.352	0.038	0.481	0.631
≥7,500	0.618	0.396	0.108	1.561	0.119
Current smoking status (ref: NO)					
YES	0.834	0.259	0.133	3.218	0.001
Current drinking status (ref: NO)					
YES	−0.556	0.237	−0.094	−2.346	0.019
Comorbidities (ref: NO)					
YES	0.446	0.18	0.092	2.481	0.013
Health literacy	0.026	0.016	0.07	1.659	0.098
Social support	−0.025	0.013	−0.079	−2.034	0.042
Depression	0.179	0.023	0.292	7.792	<0.001

$R^2 = 0.237$, $F = 8.655$, $p < 0.001$.

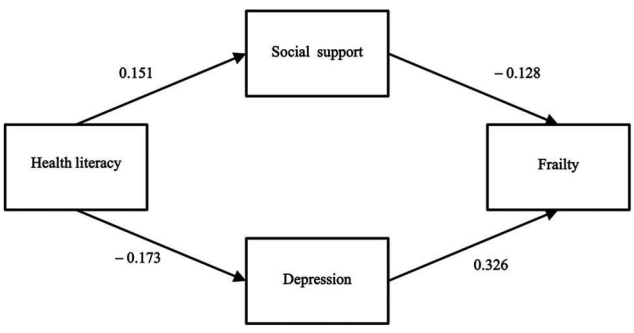

FIGURE 2 | The final model and standardized model paths.

health literacy had only an indirect negative association with frailty ($\beta = -0.076$, 95%CI: [−0.113, −0.046]), rather than a direct association, leading us to reject Hypothesis 3. Social support had a direct negative association with frailty ($\beta = -0.128$, 95%CI: [−0.198, −0.056]), thus supporting Hypothesis 4. Depression had a direct positive association with frailty ($\beta = 0.326$, 95%CI: [0.229, 0.411]). Hypothesis 6 was also supported. The results showed that social support had no direct association with depression, leading us to reject Hypotheses 5, 7, and 8.

Table 6 shows that the total effect and indirect effect between health literacy and frailty are statistically significant, which means that mediating effects exist. **Table 7** presents the results of significance testing of the mediating pathways. If the 95% confidence interval does not include zero, the mediating effect is statistically significant. The results illustrated that the relationship between health literacy and frailty was mediated by social support (95%CI: [−0.013, −0.002]) and depression [−0.031, −0.011], thus supporting Hypotheses 9 and 10. Based on the above, social support and depression could directly affect frailty, and health literacy could indirectly affect frailty through social support and depression.

TABLE 6 | Direct, indirect, and total effects and 95% confidence intervals for the final model.

Model pathways	Estimated effect	95%CI
Total effects		
Social support<–Health literacy	0.151	[0.077, 0.224]
Depression<–Health literacy	−0.173	[−0.246, −0.1]
Frailty<–Health literacy	−0.076	[−0.113, −0.046]
Frailty<–Social support	−0.128	[−0.198, −0.056]
Frailty<–Depression	0.326	[0.229, 0.411]
Direct effects		
Social support<–Health literacy	0.151	[0.077, 0.224]
Depression<–Health literacy	−0.173	[−0.246, −0.1]
Frailty<–Social support	−0.128	[−0.198, −0.056]
Frailty<–Depression	0.326	[0.229, 0.411]
Indirect effects		
Frailty<–Health literacy	−0.076	[−0.113, −0.046]

TABLE 7 | Significance tests of mediating pathways.

Model pathways	95%CI
Frailty<–Social support<–Health literacy	[−0.013, −0.002]
Frailty<–Depression<–Health literacy	[−0.031, −0.011]

DISCUSSION

This study aimed to clarify the interrelationships between health literacy, social support, depression, and frailty among older patients with hypertension and diabetes in China. To the best of our knowledge, this is the first study reporting the mediating roles of social support and depression between health literacy and frailty in older patients with hypertension and diabetes. The findings here can provide possible clues and propose directions for the development and implementation of intervention strategies and measures to ameliorate the frailty of older hypertensive and diabetic patients.

Overall, we found that 42.4% of older hypertensive and diabetic patients suffered from frailty, which is higher than that reported for studies on the older population in Padua, Italy (21.9%) (43), and Northern Germany (41.4%) (44). The higher prevalence of frailty found in this study is understandable. Physiological function and the ability of the body to respond to various external stresses declines progressively with age, making frailty more likely to occur in older individuals (2, 4). Additionally, hypertension and diabetes can increase vulnerability by compromising the metabolic balance and cardiovascular performance (1). Moreover, 25% of the patients in this study had multiple comorbidities; these chronic diseases and conditions can collectively accelerate frailty through distinct mechanisms (45, 46).

This study found that only 10% of older hypertensive and diabetic patients have high social support. Of the three dimensions of social support, the objective support and the support utilization were relatively poor, achieving mean scores of 7.5 ± 2.2 and 6.7 ± 2.0, respectively, which is similar to a previous study (47). As the cultural norms of filial piety in eldercare have changed, the younger generations are increasingly likely to provide financial support to compensate for their inability to offer physical support or companionship to their parents (24). Meanwhile, social changes and demographic changes are eroding traditional family support networks by altering the family structure and the size of the older population, many of whom have been long separated from their children and do not have other avenues of emotional support (48). In addition, as people age, their physical activity is restricted and social networks further shrink, leading to few sources of social support in daily life except for visits from their children (47).

As predicted, older hypertensive and diabetic patients who have stronger social support were found to be less subject to frailty, consistent with existing studies (26). Berglund et al. (49) and Strawbridge et al. (50) state that satisfying the increasing physical and psychological requirements of older people can improve their life satisfaction and may help to alleviate frailty. One possible explanation for this may be that better social security and welfare, facilitated medical and sanitary conditions, and more resources and social interactions can be offered by effective social support. Moreover, older people can develop the necessary social companionship, instrumental aid, and emotional comfort from social networks to alleviate their negative feelings and more effectively nurture their ability to deal with disease (51, 52). Therefore, providing sufficient social support represents an effective strategy to mitigate frailty in older hypertensive and diabetic patients.

The results of this study showed that in the 637 enrolled patients, 8.3% developed significant depressive symptoms, which is significantly higher than that of the general population (0.56%) (53). The increase in the aging population is expected to give rise to a range of challenges. First, social security and financial support for older people have become relatively limited. Second, being separated from their children or partners can cause older people to become depressed and isolated and to lack emotional comfort (54, 55). Finally, may problems can occur with aging, [e.g., cognitive decline, sleep disturbances, and malnutrition (56)]. Previous studies have reported that hypertension and diabetes are characterized by a long course, a poor prognosis, and are difficult to cure. These conditions continuously reduce a person's quality of life, leading to emotional disorders, a psychological burden, and reduced happiness, thereby causing depression over time (57, 58). Thus, it is expected that older hypertensive and diabetic adults experience a relatively high level of depression.

Our findings support the existence of a specific association between depression and frailty (59). This finding in line with previous studies showing that depression is linked to the onset of frailty and that people with depression are more likely to experience frailty (15, 60). Depression commonly manifests as cognitive impairment, with insufficient coping resources in psychological and social areas, and older adults can lose interest in physical and social activities, elevating the risk of decreased physical function and falls. As indicated by a meta-analysis, depression and frailty may share common risk factors and

pathophysiological pathways, and patients subject to depressive disorder often exhibit frailty at significantly high levels (33), revealing that depression may be a vital target to mitigate and prevent frailty and its consequences. Previous studies have indicated that social support is a significant predictor of depression (30, 31). In this study, however, poor social support was not identified to be associated with higher levels of depressive symptoms, which is in agreement with Ang et al. (61). These discrepancies require further interpretation and reflection.

Consistent with existing findings, the participants showed rather low health literacy, with a mean score of 13.6 ± 5.7. Only 3.9% of the older hypertensive and diabetic patients achieved good health literacy, suggesting that low health literacy was a widespread phenomenon (62, 63). Health literacy can depend on age, education level, and economic status (64). In China, the health literacy level was shown to decline with age in older adults (65). Participants with a lower education level were inclined to have lower health literacy, probably due to their limited ability to acquire health information and poor acceptance of knowledge (65). In our sample, 81.2% of participants had a primary school level of education or below. Participants with lower income levels achieved lower levels of health literacy for their lower social status and material level, and they showed low use of health education resources (66). In the present study, the proportion of the participants with individual annual incomes and per capita annual household incomes below $4,500 were 84.6 and 52.7%, respectively.

The findings here support the hypothesis that health literacy acts as a direct predictive factor for both social support and depression, consistent with previous studies (22, 32). Earlier studies reported that individuals with lower health literacy often hide their health problems from family, friends, and healthcare providers because of shame, thereby causing them to likely experience isolation and to perceive less available support (67). Moreover, another study indicated that health literacy can act as an asset and empowerment tool that helps individuals access education about mental health services and utilize existing mental health services (68). Accordingly, to decrease depression and boost social support among older hypertensive and diabetic patients, efforts should be made by health care providers and policymakers to improve the health literacy of these patients.

This study also investigated whether higher levels of health literacy are negatively correlated with frailty. In contrast to our predictions, the model fitting the conceptual model was acceptable. Health literacy was not a direct predictor of frailty, whereas it could impact frailty by intermediating social support and depression. This finding is in accordance with the results of Shah et al. who studied male veterans (69). The lack of association of health literacy found in this study compared with existing studies may have arisen owing to differences in the characteristics of the participants.

We also identified that older hypertensive and diabetic patients who were divorced, widowed, or unmarried or those with two or more chronic diseases were more likely to experience frailty, which is consistent with existing studies (15, 70). Additionally, six other sociodemographic characteristics of the older hypertensive and diabetic patients, namely, age, education, personal and family incomes, drinking status, and smoking status, showed associations with frailty. Education and income were the two socioeconomic status (SES) factors that were most strongly inversely associated with frailty. Poli et al. (71) highlighted that older subjects with higher SES had a significantly lower risk of being frail, indicating that practical ways to assist older hypertensive and diabetic patients subject to lower SES may help relieve their frailty.

A strength of this study was that we focused on a rapidly growing vulnerable population—older patients subject to hypertension and diabetes—and the findings here stressed the mediating roles of social support and depression between health literacy and frailty. This study also had some limitations. First, the participants were representative of patients that had hypertension and diabetes in the Sichuan province of China and the findings might differ according to population or geographic region. Second, the cross-sectional and self-reporting nature of the study may have introduced measurement and/or recall bias. Some selection bias also existed as the participants were $\geq$65 years old. In addition, to draw further inferences from the data, a more extensive and explanatory longitudinal study is required.

CONCLUSIONS

This study used structural equation modeling to clarify the intermediary paths between health literacy and frailty among community-dwelling elder hypertensive and diabetic patients in China. The results suggest that although health literacy is not a direct predictor of frailty, it could impact frailty by intermediating social support and depression. Thus, far, no studies have investigated these two mediating effects, and this study may help to elucidate the pathogenesis of frailty. The critical sociodemographic variables that indicated higher levels of frailty in older hypertensive and diabetic patients included being divorced, widowed, or unmarried, the presence of comorbidities, and lower levels of education and income. To mitigate frailty in elderly patients subject to hypertension and diabetes, measures that could act effectively to improve social support, depression, and health literacy should be considered. Good health literacy can support the possibility of strong social support and reduced depression, resulting in a low level of frailty. Furthermore, a greater emphasis should be placed on elder hypertensive and diabetic patients who are divorced, widowed, or unmarried, those with comorbidities, and those with lower SES.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found in the article/supplementary material.

AUTHOR CONTRIBUTIONS

DL conceived the study and prepared the study protocol. YL performed the data analysis and drafted

the first manuscript. All authors contributed to content revisions, approved the final version, and agreed to be responsible for all aspects of the current work.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Out-of-Pocket Healthcare Expenditures in Dependent Older Adults: Results From an Economic Evaluation Study in Mexico

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Background: Dependence is a significant health-related condition for older adults (OA) and implies that self-care is transferred to other people, the community or institutions. Recent studies have analyzed the relationship between out-of-pocket (OOP) healthcare expenditures and dependence. Nonetheless, these studies were not specifically designed to estimate the economic impact of dependence. Our aim was to estimate the total adjusted annual OOP healthcare expenditures in dependent older adults compared to independent ones. Additionally, we explore the potential combined effect of basic activities of daily living (ADL) and instrumental activities of daily living (IADL) dependence on OOP healthcare expenditures.

Methods: Data comes from the cross-sectional study "Economic impact of physical dependence in older adults and the burden of informal care" conducted in 2018 with a sample of 735 community-dwelling older Mexican adults ages 60 and older. We used direct (medical and non-medical) and indirect costs to estimate the OOP healthcare expenditures associated with dependence. We applied the Katz scale to assess dependence in ADL and the Lawton scale to assess dependence in IADL. Two-Part regression models were used to analyze the relationship between dependence and OOP health expenditures.

Results: Presence of ADL dependence represented a higher level of expenditure, 107% compared to non-dependent OA ($\beta = 1.07$, CI95%: 0.43–1.71), and 97% for IADL dependence ($\beta = 0.97$, CI95%: 0.49–1.45). The combined effect of ADL and IADL dependence (132%) was greater ($\beta = 1.32$, CI95%: 0.74–1.90) than the effect of ADL or IADL dependence alone. In monetary terms, OA with ADL dependence had a total annualized mean OOP healthcare expenditure of $31,865 (Mexican pesos), OA with IADL $26,912, and combined ADL and IADL $39,520.

Conclusions: ADL and IADL dependence are associated with the total annualized OOP healthcare expenditures. This association is even higher when both conditions are present together. These findings highlight the economic implications of the dependence for individuals, their families, and the health system. Given that current evidence on

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effective interventions to prevent dependence in OA is insufficient, future studies should be conducted to estimate their costs and determine what interventions work, as well as their effectiveness and cost-effectiveness in different sub-groups of the population, and how these might be appropriately implemented.

Keywords: dependent older adults, OOP healthcare expenditures, two-part regression model, basic activities of daily living, instrumental activities of daily living

INTRODUCTION

Dependence is a significant health-related condition for older adults (OA), and its presence implies that self-care is transferred to other people, the community or institutions (1). The World Health Organization (WHO) defines dependence as an event that occurs when the functional or intrinsic capacity has decreased to a point where the person is no longer able to carry out the basic tasks of daily life on their own (2). Dependence in OA is a complex and multidimensional concept that goes beyond a single physical component, encompassing a psychological, and socioeconomic dimension (3). Even so, the dimension of dependence that has been most analyzed in gerontological literature is the physical or functional dependence, and particularly that focused on the functional loss of bodily or sensory abilities (4).

The prevalence of dependence for OA populations in high-income countries ranges from 15 to 17%, while in low and middle-income countries it ranges from 3 to 16%. In Mexico, by 2012, 21.7% of OA had basic activities of daily living (ADL) limitations, and 5.1% were dependents (5).

Dependence has a variety of consequences at different levels. At an individual level, dependence can generate feelings of depression, low self-esteem, and hopelessness (6). At the level of family, it can generate a cycle of impoverishment and reallocation of care roles (7), while at the societal level, dependence can increase demand for health and care services (8). This increase demand for health and care services can also increase the costs associated with healthcare of dependent older people.

The aging process in Mexico (similar to other low- and middle-income countries) has occurred amid a fragile economy marked by high levels of poverty and limited access to health services and resources (9). In that context dependency in old age is one of most critical challenges facing by the social health protection system. Given this scenario, the Mexican Health System, a mixture of public-private schemes, has sought to achieve universal access to health, as well as universal coverage of health services, through three public insurance schemes mainly: The Mexican Institute of Social Security (IMSS by its Spanish acronym), the Institute of Security and Social Services of State Workers [ISSSTE (9)], and by the *Seguro Popular*, today converted into the Institute of Health for Well-being [INSABI (9)]. Despite this, none of these schemes specifically covers the potential health-related costs of physically dependent OA.

In 2012, 13% of older adults (60 years or older) did not have health insurance and 53.5% did not have an economic pension (10). However, since 2009 Mexico has a non-contributory pension program (formerly known as *70 y más*—70 and over, and now as the *Programa para el Bienestar de los Adultos Mayores* -Program for the Welfare of Older Adults) which consists of the bimonthly payment of 2,750 Mexican pesos (115 US dollars approx.), and is intended to be universal to all individuals 68 years of age or older (11, 12).

Recent studies have analyzed the relationship between out-of-pocket (OOP) healthcare expenditures and different health outcomes related to the functional capacity of the OA, namely frailty (13), multimorbidity (14), and disability (15). Some other studies have also examined the relationship between dependence and OOP healthcare expenditures (16–19). Yet, other studies have treated functional dependence as a covariate, rather than the main exposure of interest (20–22). Despite this evidence, some gaps remain, because findings on dependence and healthcare costs have been produced from studies that were not explicitly designed to estimate the economic impact of dependence in older adults.

Also, the combined effects of basic activities of daily living (ADL) and instrumental activities of daily living (IADL) dependence on OOP healthcare expenditures has not been explored. We have designed a study that expressly seeks to better understand the economic implications of dependence in the elderly. Our main objective was to estimate the total adjusted annual OOP healthcare expenditures in dependent older adults compared to independent ones. Additionally, we explored a potential combined effect of ADL and IADL dependence on OOP healthcare expenditures.

MATERIALS AND METHODS

Study Design and Sample

Data comes from the cross-sectional study "Economic impact of physical dependence in older adults and the burden of informal care" conducted in 2018 with a sample of community-dwelling older Mexican adults age 60 and older (23). According to a previous study in which the costs associated with frailty among older Mexican adults were estimated (13), a sample size of 735 OA would have sufficient power to detect significant differences in healthcare costs when comparing individuals with and without dependence based on a significance level of 5%, power of 90%, and one-sided tests. OA in this study were residents of two urban and three rural communities in the Mexican state of Estado de México, located at the central part of Mexico. We defined the analytical sample according to the following criteria: we included all older adults aged ≥60 and were excluded those with hearing or speech impairment. Also, a key informant (proxy) was considered if the OA reported severe memory problems (present

if the answer was yes for the question: Have you had difficulties with your memory that are a problem for you?). In that case, the caregiver provided the information (9.7% of the sample). The final analytical sample was comprised of 735 older adults.

We administered an extensive questionnaire to study participants to collect data on the expenditures related to medications, consultations, hospitalizations, laboratory studies, devices, prostheses, and loss of labor productivity. Direct (medical and non-medical) and indirect costs were both used to estimate the economic burden of dependence.

MEASURES

Out-of-pocket Healthcare Expenditures

We calculated total healthcare expenditures based on the estimation of cumulative costs found through the questionnaires. All costs were annualized for 2018. We grouped data in direct and indirect costs as described below.

Direct Costs

Medical and non-medical expenditures were estimated using a micro-costing analysis, which allows monetary valuing of the individual use of health resources and services by study participants. Medical costs included medical consultations, specialist consultations, medications (including vitamins), laboratory tests, and hospitalization. Non-medical costs included nursing services, devices (visual, hearing, orthopedic), prostheses, and other costs (personal hygiene, healing material, traditional medicine).

Indirect Costs

We operationalized the indirect costs considering the monthly loss of productivity for the OA and his/her carer/relative as follows:

a) Loss of labor productivity (OA). We determined the economic loss of labor productivity in working OA by asking about the number of days of work they had missed due to health-related reasons.
b) Loss of labor productivity in the household (caregiver or relative). We quantified the loss of labor productivity at the household level by asking relatives how much they thought they had lost on income due to caring for the OA.

Dependence

We applied two widely known instruments to evaluate the functional capacity of the OA: the Katz and Lawton scales. The Katz scale (24) assess difficulties in ADL, which include bathing, dressing, using the toilet, incontinence, and feeding. The Lawton scale (25) assess difficulties in IADL, including using the phone, going shopping, managing drugs and money, and using public or private transportation.

Based on the information about ADL and IADL, an OA was considered dependent if: (1) they were unable to perform at least one of the ADL or IADL, (2) he/she had a primary caregiver who provided assistance for ADL or IADL, and accompanied him/her to health facilities. Using these criteria, we generated two variables that define either ADL or IADL dependence combining the difficulties in performing ADL or IADL and the presence of a caregiver. These were operationalized as binary variables, where 0 = independent, and 1 = dependent.

Covariates

We included factors associated with healthcare expenditures in the literature (26, 27) as potential covariates and categorized them as follows:

Socio-Demographic Characteristics

Sex (female = 1), age, health insurance (yes = 1), retirement pension (yes = 1), schooling (years of formal instruction), paid job (yes = 1), marital status (married/cohabited = 1), area of residence (urban = 1 vs. rural = 0).

Health

We included 19 indicator variables for each of the following conditions that were obtained from participants' self-report (1 = present, 0 = absent): hypertension, diabetes, hypercholesterolemia, heart disease (angina pectoris, heart failure), embolism, stroke or cerebral thrombosis, arthritis or rheumatism, bronchitis, or pulmonary emphysema, osteoporosis, kidney chronic disease, tuberculosis, cataracts (one or both eyes), urinary incontinence, prostate disease (men only), and cancer (skin/melanoma, cervix, breast, prostate, stomach, leukemia / blood). With this information, we generated a count variable to express the total number of chronic conditions in each participant. This variable was included in our regression models as a proxy for the general health status.

Use of Health Services

We measured this variable using two indicators: number of outpatient visits in the last 6 months, and the number of hospitalizations in the last 12 months.

Socioeconomic Status (SES)

For SES measurement, we created an asset index following a standard approach proposed by the WHO to estimate the permanent income of the household through the ownership of goods and some characteristics of the housing (28–30). In particular, we used nine dichotomous variables (yes/no) that evaluated possession of household assets. The asset index was created using a polychoric correlation matrix through the application of principal component analysis (PCA). The first component explained 44% of the variation in the data. The index generated by PCA is continuous, with higher values denoting higher household SES.

Statistical Analysis

Variables were described using means (standard deviations) or proportions, as appropriate. In bivariate analysis, the following statistical procedures were used according to the characteristics of each variable: Chi-squared test for categorical data and Mann-Whitney test for continuous data. Exploratory analyses, including graphs (histograms and scatter plots), were also used to determine the probability distributions of the outcome variable. At this stage, we observed a considerable percentage of OA that did not show out-of-pocket expenses (30%), and the

TABLE 1 | Health and sociodemographic characteristics of older adults according to the status of ADL and IADL dependence[a].

	ADL[b] dependence		*p*-value	IADL[c] dependence		*p*-value
	No ***n*** **= 672 (91.4%)**	**Yes** ***n*** **= 63 (8.6%)**		**No** ***n*** **= 625 (85.0%)**	**Yes** ***n*** **= 110 (15.0%)**	
Outcomes						
Probability of incurring OOP[d] healthcare expenditures	0.63	0.84	<0.01	0.62	0.75	<0.01
Mean annual OOP healthcare expenditures	7,532 (27,135)	29,272 (61,925)	<0.01	7,847 (28,192)	18,197 (48,187)	<0.01
Covariates						
Sex (female = 1)	55.8	79.4	<0.01	55.3	71.9	<0.01
Age	70.3 (7.7)	79.5 (10.4)	<0.01	69.7 (7.5)	79.0 (9.2)	<0.01
Marital status (married/civil union = 1)	58.5	30.2	<0.01	58.8	40.0	<0.01
Years of formal schooling	4.3 (4.4)	2.8 (3.2)	<0.01	4.4 (4.5)	2.6 (2.9)	<0.01
Health coverage (yes = 1)	89.0	85.7	0.43	88.3	90.9	0.43
Number of chronic diseases	1.2 (1.3)	2.1 (1.6)	<0.01	1.2 (1.3)	1.8 (1.6)	<0.01
Retirement pension (yes = 1)	34.2	39.7	0.38	32.3	48.2	<0.01
Labor status (current worker = 1)	33.5	4.8	<0.01	36.2	1.8	<0.01
Socioeconomic status (asset index)	0.1 (2.0)	0.3 (1.9)	0.52	0.1 (2.0)	0.4 (1.9)	0.08
Dwelling area (urban = 1)	75.4	82.5	0.21	75.4	80.0	0.29
Number of visits to physician in the last 6 months	1.7 (2.8)	2.8 (3.2)	<0.01	1.7 (2.8)	2.5 (2.9)	<0.01
Number of hospital overnight stays in the last 12 months	0.2 (1.8)	3.0 (12.2)	<0.01	0.2 (1.8)	1.8 (9.3)	<0.01

[a] *Cells are percentages, means (SD), or proportions.*
[b] *ADL, basic activities of daily life.*
[c] *IADL, instrumental activities of daily life.*
[d] *OOP, Out-of-pocket.*

distribution of expenditure showed a right-skewed distribution, so in the multivariate analysis we used a two-part regression model (14, 31).

In the Two-Part model, the outcome variable is analyzed in two phases. In the first part, a regression for dichotomous variables (logit or probit) is used to estimate the probability of incurring OOP health expenditures. In our case, we coded the dependent variable (OOP health expenditures) as a binary indicator, where one equaled older adult that incurred OOP health expenditures and zero equaled those that did not. In the second part, to reduce the effect of skewness of healthcare costs, a linear regression model on the natural logarithm of this variable is applied to estimate the average expenditures among individuals that incurred health expenditures. In general, it is recommended the use of the natural logarithm of healthcare costs to reduce the effects of the skewed nature of this variable. Results are interpreted (β) as semi-elasticities (i.e., as the percentage increase observed in the response variable for one increment in the independent variable). Finally, total expenditures for each individual are estimated by multiplying the probability by the average results obtained through the first and second parts of the model, using Duan's smearing retransformation to obtain fitted values (32).

We further conducted several sensitivity analyses to check the robustness of our results. First, we examined the combined effect of ADL and IADL dependence on OOP health expenditures. The combined effect of ADL and IADL dependence was analyzed by creating a new dichotomous variable, where 1 reflected the simultaneous presence of ADL & IADL, and 0 the presence of neither. Second, instead of modeling mean of healthcare expenditures, we modeled the median of OOP healthcare expenditures using a quantile regression model (33, 34).

All regression models were adjusted for variables described in the Covariates section. Statistical analyses were performed using STATA version 15.1 software (StataCorp. 2015. College Station, TX.). Ninety-five percent confidence intervals and *p*-values were reported. Differences were considered statistically significant if $p < 0.05$.

RESULTS

The following sociodemographic and health characteristics were observed in our sample. Mean age of participants was 71.1 years ($SD = 8.4$ years). 57.8% were female, 56.0% married/cohabited, and 31% current workers. Mean of years of formal education was 4.2 ($SD = 4.4$). Regarding health characteristics, 63.4% reported at least one chronic condition, and 32.1% had multimorbidity, defined as the presence of two or more chronic diseases. Prevalence of ADL and IADL dependence was 8.6 and 15.0%, respectively.

Table 1 displays the study sample characteristics according to the presence of ADL and IADL dependence. Overall, dependent OA were mostly female ($p < 0.01$), older ($p < 0.01$), and single or widowed ($p < 0.01$). They worked less ($p < 0.01$) and had fewer years of schooling ($p < 0.01$). They had more visits to a physician ($p < 0.01$), more hospital overnight stays ($p < 0.01$), and a

TABLE 2 | Out-of-pocket health expenditures by specific cost items according to the status of ADL dependence.

	Probability of incurring out-of-pocket healthcare expenditures[a]			Annual mean out-of-pocket healthcare expenditures		
	ADL[b] dependence			ADL dependence[c]		
	No	Yes	*p*-value	No	Yes	*p*-value
DIRECT COSTS						
Medical						
Medical consultations	0.21	0.33	0.03	1,425 (7,210)	4,000 (9,252)	<0.01
Medical specialist consultations	0.09	0.14	0.15	303 (2,890)	676 (2,749)	0.13
Medicines (including vitamins)	0.36	0.59	<0.01	4,199 (16,897)	13,782 (31,999)	<0.01
Laboratory tests	0.08	0.11	0.32	413 (2,374)	457 (2,541)	0.36
Hospitalization	0.02	0.17	<0.01	305 (2,945)	1,738 (6,856)	<0.01
Non-medical						
Nursing services	0.01	0.08	<0.01	49 (626)	5,035 (30,626)	<0.01
Devices (visual, hearing, orthopedic) or prosthesis	0.13	0.19	0.15	325 (2,254)	124 (368)	0.17
Transportation to health units	0.22	0.41	<0.01	296 (1,383)	1,425 (4,063)	<0.01
Others (personal hygiene, healing material, traditional medicine)	0.18	0.36	<0.01	188 (1,375)	1,377 (3,267)	<0.01
INDIRECT COSTS						
Morbidity						
Loss labor productivity (older adult)	0.01	0.13	<0.01	22 (308)	429 (2,541)	<0.01
Loss labor productivity in the household (caregiver or relative)	0.01	0.17	<0.01	8 (84)	229 (827)	<0.01

[a]*Cells are proportions.*
[b]*ADL, basic activities of daily life.*
[c]*Means and standard deviations.*

greater number of chronic diseases ($p < 0.01$). Regarding OOP healthcare expenditures, dependent OA had a greater probability of incurring expenses than non-dependent OAs ($p < 0.01$) and also a higher annual mean expenditure ($p < 0.01$). This general profile was similar for ADL and IADL dependent OA. Finally, OA with ADL dependence had an unadjusted total annualized mean OOP healthcare expenditure of $29,272 (Mexican pesos), while the amount in OAs with IADL was $18,196.

The results of OOP healthcare expenditures for specific items are shown in **Tables 2**, **3**. For ADL dependence, expenditures from medications, nursing services, and medical consultations, mostly contributed to total OOP healthcare expenditures (**Table 2**). As for IADL dependence, medications and nursing services were the highest contributors (**Table 3**).

The results of the adjusted two-part regression models are presented in **Table 4**. Neither ADL dependence (OR = 1.86, CI95%: 0.85–4.11) nor IADL dependence (OR = 1.27, CI95%: 0.72–2.25) was found to be associated with the probability of incurring total annual OOP expenditures. We also did not observe a significant association for the combined presence of ADL and IADL dependence (OR = 1.73, CI95%: 0.78–3.81).

The presence of ADL dependence was associated with an 107% higher mean OOP health expenditure compared to non-dependent OA (β = 1.07, CI95%: 0.43–1.71). This was 97% for IADL dependence (β = 0.97, CI95%: 0.49–1.45). The combined effect of ADL and IADL dependence (132%) was greater (β = 1.32, CI95%: 0.74–1.90) than the isolated presence of ADL or IADL dependence.

With regard to the median of OOP healthcare expenditure, we found that ADL dependent individuals had a median annual expenditure $5,798 higher than non-dependent individuals (Mexican pesos), while the IADL dependent OA had an expenditure that was $1,844 higher than their non-dependent counterparts. This number was greater for the combined ADL and IADL dependence ($8,178 Mexican pesos) (**Table 4**).

Finally, **Figures 1**, **2** show the estimated OOP healthcare expenditures according to the presence of dependence in OA. **Figure 1** displays the data for mean annual expenditure, while **Figure 2** displays median expenditure. The average expenditure was 4.1, 3.3, and 2.8 times larger for the ADL and IADL, ADL-only, and IADL-only groups, in relation to the group without dependence. Meanwhile, the same data for median expenditure was 5.4, 4.1, and 1.9, respectively.

DISCUSSION

Our findings corroborate that there is a significant association between dependence in OA and OOP healthcare expenditures. Based on a sample of 735 community-dwelling older Mexican adults, we observed that the presence of ADL or IADL dependence as well as their combined presence was associated with a significant increase in the total annualized OOP healthcare expenditures.

Consistent with previous studies, we found a significant association between dependence in OA and healthcare costs. One study with European older adults age 65+ found that ADL

TABLE 3 | Out-of-pocket health expenditures by specific cost items according to the status of IADL dependence.

	Probability of incurring out-of-pocket healthcare expenditures[a]			Annual mean out-of-pocket healthcare expenditures		
	IADL[b] dependence			IADL dependence[c]		
	No	Yes	*p*-value	No	Yes	*p*-value
DIRECT COSTS						
Medical						
Medical consultations	0.21	0.29	0.06	1,517 (7,514)	2,375 (6,953)	<0.01
Medical specialist consultations	0.09	0.12	0.31	320 (2,995)	424 (2,106)	0.13
Medicines (including vitamins)	0.36	0.50	<0.01	4,464 (17,626)	8,177 (24,460)	<0.01
Laboratory tests	0.08	0.07	0.79	439 (2,457)	289 (1,947)	0.36
Hospitalization	0.03	0.11	<0.01	241 (2,167)	1,486 (7,281)	<0.01
Non-medical						
Nursing services	0.01	0.05	<0.01	40 (566)	2,956 (23,237)	<0.01
Devices (visual, hearing, orthopedic) or prosthesis	0.12	0.17	0.17	344 (2,336)	102 (315)	0.17
Transportation to health units	0.21	0.35	<0.01	258 (1,163)	1,162 (3,658)	<0.01
Others (personal hygiene, healing material, traditional medicine)	0.19	0.26	0.06	197 (1,424)	816 (2,554)	<0.01
INDIRECT COSTS						
Morbidity						
Loss labor productivity (older adult)	0.01	0.07	<0.01	24 (320)	245 (1,928)	<0.01
Loss labor productivity in the household (caregiver or relative)	0.01	0.14	<0.01	2 (38)	165 (654)	<0.01

[a] *Cells are proportions.*
[b] *IADL, instrumental activities of daily life.*
[c] *Means and standard deviations.*

TABLE 4 | Results of two-part and quantile regression models*.

	Two-Part regression model						Quantile regression		
	Probability of incurring out-of-pocket healthcare expenditures			Annual mean out-of-pocket healthcare expenditures			Annual median out-of-pocket healthcare expenditures		
	Logistic model			Linear model (log y)					
	OR[c]	CI[d] 95%		β[e]	CI 95%		Coefficient	CI 95%	
ADL[a] dependence	1.86	0.85	4.11	1.07	0.43	1.71	5789.6	3861.9	7717.4
IADL[b] dependence	1.27	0.72	2.25	0.97	0.49	1.45	1844.4	267.4	3421.3
ADL and IADL combined	1.73	0.78	3.81	1.32	0.74	1.90	8178.0	6252.8	10103.2

All models were adjusted for covariates showed in **Table 1.*
[a] *ADL, basic activities of daily life.*
[b] *IADL, instrumental activities of daily life.*
[c] *OR, odds ratio.*
[d] *CI, confidence interval.*
[e] β, *Beta Coefficient.*

and IADL dependence were associated with higher societal costs (including primary, secondary, social, home, and informal care). Although, this study measured ADL and IADL dependence on a continuous scale and was focused on societal costs rather than OOP expenditures (17). Even so, we similarly found that dependent OA tend to have higher healthcare cost than their independent counterparts. Another study among US adults found that ADL and IADL difficulties were associated with total annual cost of care (TACC). In this study, however, ordinal variables were used to measure ADL and IADL difficulties (0, 1–2, and 3 or more difficulties), and results showed that having three or more difficulties was associated with a higher TACC (18). In our study, we observed significant associations from the presence of a single difficulty. Two possible explanations could be advanced for this difference. First, we just include OA while they included adults age 18 or more, so our study sample could have worse health and functional conditions that would make it possible to observe significant associations with minor levels of ADL or IADL difficulties. Second, our definition of dependence includes not just difficulties in ADL or IADL, but also the

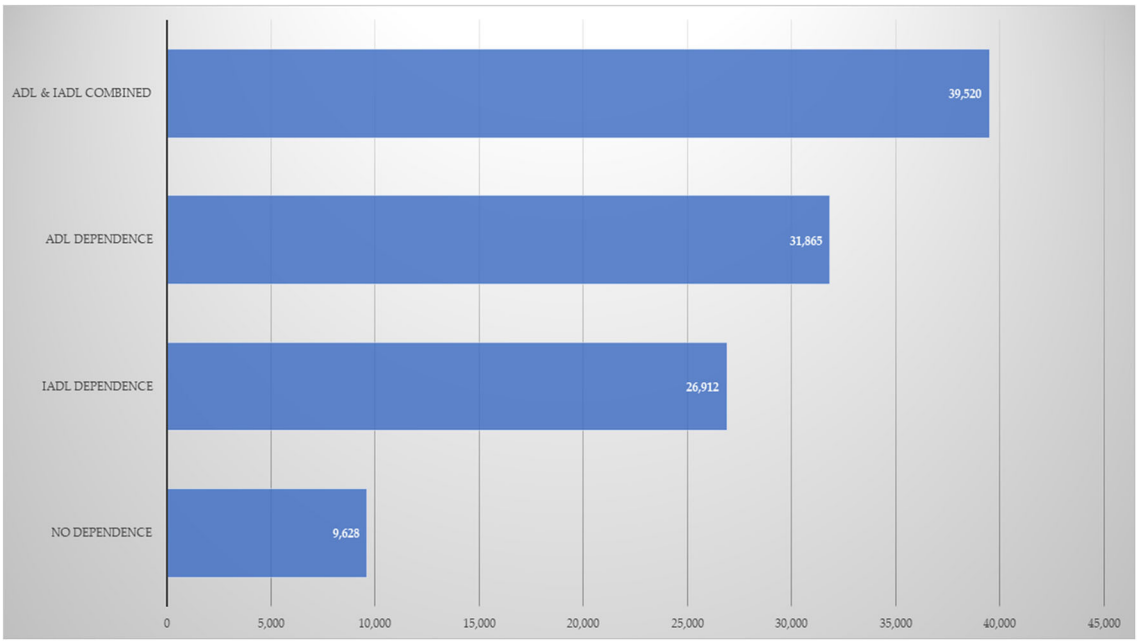

FIGURE 1 | Annual mean OOP healthcare expenditures (Mexican pesos). ADL, basic activities of daily life; IADL, instrumental activities of daily life.

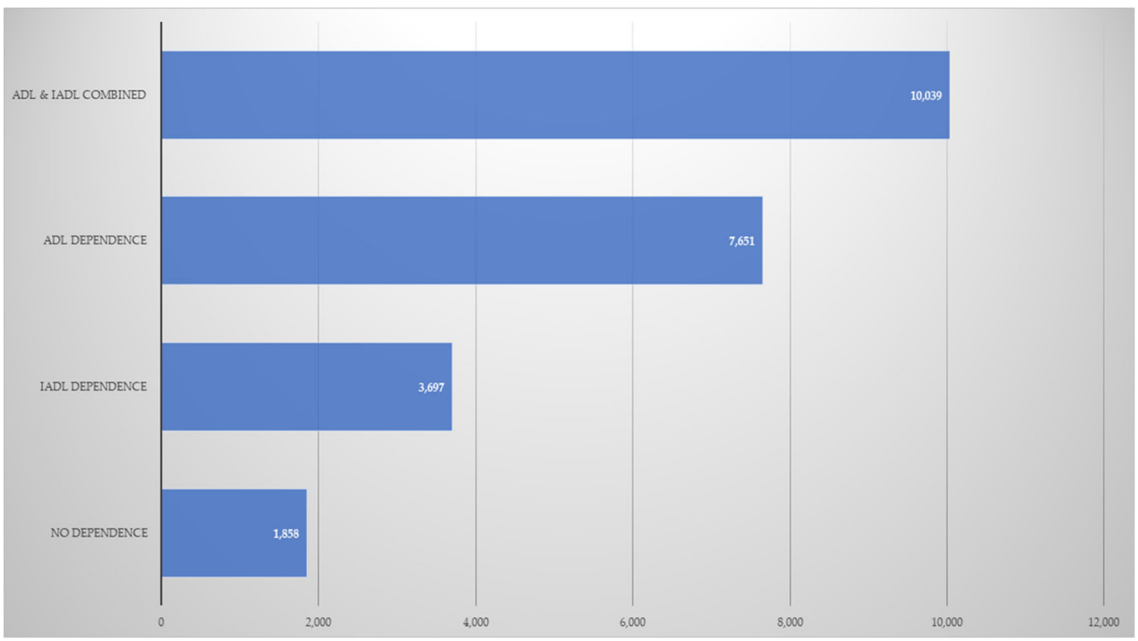

FIGURE 2 | Annual median OOP healthcare expenditures (Mexican pesos). ADL, basic activities of daily life; IADL, instrumental activities of daily life.

need for someone to help in the execution of these activities. Finally, a study conducted with older US adults, including beneficiaries of Medicare and participants of the Health and Retirement Study, reported that compared to those with no ADL impairment, the most severely impaired (two or more ADL difficulties) had a 33% higher cost (19). It is interesting to note that the sample considered for this study were OA who were admitted to a hospital at least once in a previous period of 10 years, while our sample was comprised of community-dwelling individuals who were not hospitalized or institutionalized.

Despite this difference, our results are consistent regarding the association between ADL dependence and OOP healthcare costs.

Despite the similarity in the described results, we should note that none of the studies -to the best of our knowledge- on the economic impact of dependency have used the two-part model approach. This fact has two important implications. On the one hand, the results are not strictly comparable, given that those studies conceive of healthcare spending as a single-stage process (i.e., the estimation of the total amount disbursed). Meanwhile, the two-part model recognizes the potential presence of two phases: (a) to incur or not in healthcare expenditures (i.e., the probability of incurring in spending), and (b) given the incidence of healthcare expenses, what was the amount disbursed? (i.e., the estimation of the average expenses).

On the other hand, we found that neither ADL nor IADL was associated with the probability of incurring OOP healthcare expenditures (even the two conditions combined). Although a similar result has not been reported in the literature, one study found that the severity of disability in older adults, assessed through the WHO Disability Assessment Schedule -WHODAS 2.0, was associated with a higher probability of healthcare expenses (14). Given that disability reported in that study included six domains (cognition, mobility, self-care, getting along, life activities, and social participation) that encompassing more characteristics than a single component of physical limitations, then the isolated presence of physical dependency could not be enough to increase the probability of having healthcare expenses. However, future studies are needed to confirm or dismiss this hypothesis.

The results of our study have several implications. First, the high prevalence of dependence among OA calls for concerted efforts of healthcare professionals, clinical researchers, and policy-makers to design effective interventions that prevent or ameliorate the adverse effects of dependence in advanced ages. For example, in Mexico the creation of a National Care System (*Sistema Nacional de Cuidados*, SNC by its Spanish acronym) is currently being considered. The objective would be to provide public services that are accessible, pertinent, of quality, and sufficient to guarantee the right of all people to be cared for, and also the rights of caregivers (35). It is expected to be financed with public funds, but also through the families' corresponsability. In particular, the SNC proposes that a catalog of care services be generated that includes financial benefits, home care assistance and care support centers. It would also include support for unpaid carers through a cash payment (for hiring a caregiver). Second, the health systems should be prepared for the increased demand on the use of health services by dependent OA, given that the OOP healthcare expenditures of these individuals will grow exponentially in the next few years. Third, gerontological research on the functional status of the older adults should highlight the joint assessment of ADL and IADL dependence for the estimation of healthcare expenditures, because their economic impact might be more significant than either on its own.

Our study has some strengths. To the best of our knowledge, our study is the first designed to deliberately estimate the economic impact of ADL and IADL dependence. It is also the first attempt to analyze the combined effects of ADL and IADL dependence on OOP healthcare expenditures. Nevertheless, some limitations must be considered also. First, recall and survivor bias can be limitations for epidemiological studies with older adult participants. It could be, for example, that older adults with chronic conditions tend to overestimate their healthcare expenditures in comparison with healthiest older adults. Second, healthcare costs variables are self-reported. This may have led to overestimation or underestimation of true OOP healthcare expenditures. In spite of this, consistent associations between dependence and healthcare costs have been reported previously in the literature (16, 19). Third, the results from the current study came from a cross-sectional study, and thus a causal pathway between dependence and OOP healthcare expenditures cannot be determined. And fourth, our measurement of dependency has been expressed dichotomously, which implies that severity levels of dependency are not properly captured, which could restrict the generalization of our results to even more vulnerable populations, like OA with a greater number of limitations in ADL or IADL.

CONCLUSION

Our study shows that ADL and IADL dependence are associated with total annualized OOP healthcare expenditures. This association is even higher when both conditions are present together. These findings tried to highlight the economic implications of dependence on individuals, their families, and the health system. Finally, given that the current evidence is insufficient to conclude which strategies to prevent dependence in OA are more effective, future studies should be conducted to estimate the costs and effectiveness of different interventions to address dependence in OA.

DATA AVAILABILITY STATEMENT

The datasets analyzed during the current study are freely available in the figshare repository [doi: 10.6084/m9.figshare.9978599].

ETHICS STATEMENT

The ethics and Research Committees of the National Institute of Public Health in Mexico approved the study economic impact of physical dependence in older adults and the burden of informal care (No. 1203-2018). All participants were provided with a detailed explanation of study procedures and signed an informed consent letter.

AUTHOR CONTRIBUTIONS

AS-R, BM-E, and JM-H conceived and designed the study. AS-R and JM-H carried out the analysis. AS-R, IT, and JM-H drafted the manuscript. All authors reviewed, edited, contributed to rewriting of the manuscript, and granted final approval to the version submitted for publication.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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BRIEF RESEARCH REPORT
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An Exploratory Study of the Relative Effects of Various Protective Factors on Depressive Symptoms Among Older People

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Objective: The present study investigated the relative importance of various factors found to be negatively associated with depressive symptoms in older adults and assessed the potential moderating effect of sociodemographic characteristics for each factor.

Method: Depressive symptoms were measured with the Center of Epidemiological Studies Depression Scale. Psychological, social, and physical health measures relating to the following factors were also administered: personal growth, purpose in life, self-esteem, self-efficacy, social support, self-rated health, life satisfaction, and physical activity. Multivariate linear regression analysis was used to investigate the most important factors associated with depressive symptoms, and moderation analyses were employed to identify any moderating effects of sociodemographic factors.

Results: Life satisfaction, self-esteem, and purpose in life were found to be negatively associated with depressive symptoms. Only one moderating effect was observed—the negative relationship between life satisfaction and depressive symptoms was significantly stronger among the younger respondents.

Conclusion: These findings suggest that strategies for the prevention or amelioration of depressive symptoms across subgroups of the senior population could be optimized by focusing on enhancing life satisfaction, self-esteem, and purpose in life.

Keywords: older adults, aging–old age–seniors, protective factors, comprehensive model, depressive symptoms

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INTRODUCTION

Depression is a leading cause of burden of disease worldwide (1). With the proportion of people aged 60+ years worldwide projected to increase from 13% in 2017 to ∼21% in 2050 (2), the prevention and amelioration of depressive symptoms among older adults is recognized as a public health priority to ensure increasing life expectancy is accompanied by positive psychological well-being (3). Depressive symptoms can be especially debilitating for older adults because they (i) are particularly intransigent among members of this population

segment (4); (ii) complicate the treatment of chronic diseases (5), which are disproportionately prevalent among older adults (6); and (iii) often go undetected due to uncertainty about what constitutes depressive symptoms in this cohort (7, 8). In addition, older adults tend to have more limited social networks and suboptimal coping strategies compared to younger cohorts, which can make them more vulnerable to depressive symptoms (9–11). The development of effective strategies to prevent and ameliorate depressive symptoms is critical to optimize older people's well-being and reduce health system costs (5, 12).

Identifying factors that can protect against later life depressive symptoms is important for informing the development of appropriate prevention and amelioration strategies. Previous research suggests that relevant modifiable factors that could be the focus of such strategies include social support, self-rated health, and physical activity (13–16). There is strong evidence for the protective effects of each of these factors, individually and in various combinations, across both cross-sectional and longitudinal studies (17–26). Overall, research investigating the trajectory of depressive symptoms in older people has found higher levels of social support, self-rated health, and physical activity to be associated with (i) fewer depressive symptoms at baseline and (ii) a lower likelihood of depressive symptoms emerging over time (24, 25). In addition to these well-established protective factors, there is growing evidence that life satisfaction, purpose in life, personal growth, self-efficacy, and self-esteem are protective against depressive symptoms (15, 26–34).

While previous work supports the importance of each of these protective factors, to date there does not appear to be research incorporating them all to provide an understanding of their relative effects to enable appropriate prioritization in intervention design. To address this deficit, the present study adopted an exploratory approach to investigate the relative importance of modifiable factors that have been found to be protective against depressive symptoms (as outlined above). A second aim was to investigate whether sociodemographic characteristics (gender, age, living arrangement, and educational attainment) moderate the relationships between these protective factors and depressive symptoms to assist in identifying specific sub-segments of older adults who are likely to benefit most from interventions. The results provide insights into which factors are likely to be important to consider in the development of population-level depressive symptom prevention and amelioration strategies for older people, and also suggest key variables to incorporate in future longitudinal research designed to further extend this field of research.

METHOD

Design, Recruitment, and Procedure

The data used in this cross-sectional study were collected between 2014 and 2016 as part of a larger project exploring healthy aging among older adults (35). Ethical approval was received from Curtin University's Human Research Ethics Committee. Eligibility criteria were being aged 60 years or older, living in a community setting, and being fully retired. Participants were recruited via a range of methods including notices in community newspapers, radio announcements, and flyers placed at seniors' events and retirement villages across the metropolitan area of Perth, Western Australia.

In total, 801 adults met the above eligibility criteria and provided written informed consent. Participation involved completing a self-administered survey that included psychological, social, and physical health measures validated for use in older adults. These measures are described in detail below. Unless otherwise stated, the items forming each of the scales included in the survey were summed for analysis purposes.

TABLE 1 | Sample characteristics.

Characteristics (%)	Sample (*N* = 801)	Australian 60+ population[a] (*N* = 4,976,160)	*P*
Gender			0.317
Female	61	53	
Male	39	47	
Age			0.085
60–69	41	50	
70–79	46	31	
80+	13	19	
Education			0.120
Non-tertiary	43	55	
Tertiary	57	45	
Living arrangement			0.040
Not living alone	65	79	
Living alone	35	21	

Education = highest level of education attained.
[a]Percentages based on data for all women and men aged 60 years and older from the 2016 Australian Census (36).

Sample Characteristics

The final sample consisted of older adults ranging in age from 60 to 95 years (M = 71.93 years, SD = 6.68), 61% of whom were female. Characteristics of the present sample alongside those of the Australian older adult population are presented in **Table 1**. Pearson chi-square tests indicated the sample was representative in terms of gender, age, and education but not living arrangement: the present sample had a significantly higher proportion of older adults living alone compared to the Australian older adult population.

Outcome Variable

Depressive symptoms were assessed using the 20-item Center for Epidemiological Studies Depression Scale [CES-D: (37)]. Participants responded to each item (e.g., "I felt that everything I did was an effort") on a 4-point scale that ranged from 0 (*rarely or none of the time*) to 3 (*most or all of the time*). Cronbach's alpha in the present study was 0.87, indicating good reliability.

Independent Variables

The 14-item Personal Growth and Purpose in Life subscales of Ryff's (38) Psychological Well-Being Scale were used to measure personal growth and purpose in life, respectively. Responses to

items (e.g., "I have the sense that I have developed a lot as a person over time"; "I have a sense of direction and purpose in life") were made on a scale of 1 (*strongly disagree*) to 5 (*strongly agree*). Cronbach's alpha in the present study indicated good reliability for scores on both the Personal Growth ($\alpha = 0.86$) and Purpose in Life ($\alpha = 0.88$) subscales.

Self-esteem was measured using the 10-item Rosenberg Self-Esteem Scale (39). Respondents answered each item (e.g., "I feel that I'm a person of worth, at least on an equal plane with others") on a 4-point scale that ranged from 0 (*strongly disagree*) to 3 (*strongly agree*). Cronbach's alpha for scores on this scale was 0.88, indicating good reliability. The 24-item Social Provision Scale (40) was used to assess social support. Each item (e.g., "There is someone I could talk to about important decisions in my life") was measured on a 4-point scale that ranged from 1 (*strongly disagree*) to 4 (*strongly agree*). The scores on this scale were found to have excellent reliability ($\alpha = 0.92$).

Self-efficacy was assessed using the 10-item General Self-Efficacy Scale (41). Participants responded to each item (e.g., "I can solve most problems if I invest the necessary effort") on a 4-point scale that ranged from 1 (*not at all true*) to 4 (*exactly true*). Cronbach's alpha was 0.90, indicating excellent reliability. Life satisfaction was assessed by asking participants to rate how satisfied they are with their life on a scale of 1 (*very satisfied*) to 5 (*very dissatisfied*) [adapted from the World Values Survey: (42)]. For analysis purposes, this variable was reverse scored.

Level of physical activity was measured by asking participants: *How many hours of moderate to vigorous activity (that is, physical activity that makes you breathe harder or puff and pant) would you do in an average week?* The definition provided for moderate to vigorous activity was based on the Australian Department of Health's Physical Activity and Sedentary Behavior Guidelines (43). Response options were: 0 h, <1 h, between 1–2 h, between 2–3 h, between 3–4 h, between 4–5 h, and 5 or more h.

Consistent with previous research (44), self-rated health was assessed by asking participants to describe their physical health on a scale from 1 (*very good*) to 5 (*very bad*). For analysis purposes, this variable was reverse scored.

Sociodemographic variables included age (treated as continuous), gender (1 = male, 2 = female; treated as dichotomous), living arrangement (1 = lives alone, 2 = does not live alone; treated as dichotomous), and highest level of education attained (no formal school/primary school, high school, technical/trade certificate, undergraduate, postgraduate; treated as continuous).

Statistical Analysis

Descriptive statistics for each modifiable protective factor are presented in **Table 2**. Univariate linear regression analyses were conducted to assess the relationships between each of the independent variables and the outcome variable of depressive symptoms (treated as continuous). Independent variables found to be significantly associated with depressive symptoms were then simultaneously entered into a linear multivariate regression model using SPSS 26. The Variance Inflation Factor (VIF) was used to assess for multicollinearity.

Moderation analyses were conducted using the PROCESS macro in SPSS to determine if the sociodemographic variables of gender, age, level of education, or living alone moderated the relationship between each of the significant independent variables and the outcome variable of depressive symptoms (45). Each of the independent variables found to be significant in univariate analyses and each of the sociodemographic variables were entered in analyses separately. Bootstrapping was performed ($n = 5{,}000$ samples), and a Bonferroni-adjusted alpha level of <0.005 was used to control for the family-wise error rate. Missing data were treated listwise.

TABLE 2 | Descriptive statistics for tested protective factors (IVs) and depressive symptoms.

IVs	M (SD)	Sample range	Scale range	Skewness	Kurtosis
Life satisfaction	4.07 (0.82)	1–5	1–5	−0.99	1.19
Self-esteem	23.48 (4.96)	1–30	0–30	−0.68	0.43
Purpose in life	66.57 (11.72)	18–84	14–84	−0.76	0.43
Social support	79.00 (10.41)	33–96	24–96	−0.58	0.49
Self-rated health	4.00 (0.77)	1–5	1–5	−0.99	1.20
Self-efficacy	32.19 (4.38)	12–40	10–40	−0.37	0.77
Physical activity	3.77 (1.82)	1–7	1–7	0.39	−0.94
Personal growth	69.48 (10.06)	29–84	14–84	−0.73	0.27
Depressive symptoms	9.02 (8.14)	0–54	0–60	1.68	3.59

IVs = independent variables; M = mean; SD = standard deviation.

TABLE 3 | Unstandardized parameter estimates, standardized parameter estimates, and standard errors for the multivariate model (in descending order of part r^2).

IVs	B	*SE*	*β*	*p*	95% CI for B	Part r^2
Life satisfaction	**−2.76**	**0.33**	**−0.28**	**<0.001**	**−3.40, −2.12**	**−0.21**
Self-esteem	**−0.42**	**0.06**	**−0.26**	**<0.001**	**−0.54, −0.30**	**−0.17**
Purpose in life	**−0.13**	**0.03**	**−0.19**	**<0.001**	**−0.19, −0.07**	**−0.11**
Social support	−0.07	0.03	−0.08	0.012	−0.12, −0.02	−0.06
Self-rated health	−0.77	0.30	−0.07	0.011	−1.37, −0.18	−0.06
Self-efficacy	−0.13	0.06	−0.07	0.018	−0.25, −0.02	−0.06
Living alone	−0.82	0.45	−0.05	0.066	−1.70, 0.06	−0.05
Physical activity	0.11	0.12	0.03	0.338	−0.12, 0.35	0.02
Personal growth	0.01	0.03	0.01	0.758	−0.05, 0.06	0.01
Education	−0.00	0.19	0.00	0.997	−0.38, 0.38	0.00

IVs = independent variables; B = unstandardized estimates; SE = standard error of B; β = standardized estimate; p = significance value; CI = confidence interval; Part r^2 = proportion of unique variance accounted for. Results significant at p <0.005 are presented in bold.

RESULTS

Regression Analyses

Univariate regression analyses showed that life satisfaction, purpose in life, personal growth, self-esteem, social support,

TABLE 4 | Significant moderating effect of age between life satisfaction and depressive symptoms.

Age	B	*SE*	*p*	95% CI for B
65.25 (−1SD)	−6.82	0.35	<0.001	−5.98, −4.35
71.78 (Mean)	−5.99	0.28	<0.001	−6.54, −5.45
78.30 (+1SD)	−5.16	0.41	<0.001	−5.98, −4.35

B = unstandardized estimates; SE = standard error of B; p = significance value; CI for B = confidence interval. Bonferroni-adjusted alpha level of <0.005.

self-efficacy, physical activity, self-rated health, educational attainment, and living arrangement were all negatively associated with depressive symptoms (see **Supplementary Table 1** for results of univariate regressions). A multivariate regression analysis combining these variables into a single model was used to explore the relative importance of these factors. VIF was <10 indicating that multicollinearity was not an issue. The model explained 55.6% of the variance in depressive symptoms ($F_{(10,734)} = 91.93$, $p < 0.001$). The variables in the model that remained significantly and negatively associated with depressive symptoms at the Bonferroni-adjusted alpha level of <0.005 in descending order of effect were: life satisfaction, self-esteem, and purpose in life (see **Table 3**).

Moderating Effects

At the Bonferroni-adjusted alpha level of <0.005, a significant moderating effect of age was observed for life satisfaction (B = 0.13, SE = 0.04, $p < 0.002$, 95% CI for B [0.05, 0.21]). See **Supplementary Table 2** for results of moderation analyses. *Post-hoc* investigation of this effect showed that life satisfaction was negatively associated with depressive symptoms for all age groups, but the strength of the association was stronger for those participants below the average age of this sample compared to those of mean age or older (see **Table 4** and **Supplementary Figure 1** for significant results). Age did not moderate the relationships between any of the other independent variables and depressive symptoms, nor were there significant moderating effects observed for gender, living arrangement, or educational attainment (see **Supplementary Table 2**).

DISCUSSION

To better understand the nature of the relationships between factors that are particularly important in protecting against depressive symptoms among older adults, the present study combined a broad range of factors that have been identified in previous research as being potentially relevant. To assess whether interventions should be targeted at specific subgroups of the wider older adult population, a second aim of this study was to investigate whether sociodemographic characteristics moderated any of the relationships between each protective factor and depressive symptoms.

The tested model explained a large proportion (55.6%) of the variance in depressive symptoms. Life satisfaction, self-esteem, and purpose in life were found to have the strongest (negative) association with depressive symptoms, which is consistent with previous longitudinal research (26, 30–33). However, this past work examined each of these variables in isolation or in models including a limited number of factors. The results of the present study indicate that even when considering a larger number of potential variables, life satisfaction, self-esteem, and purpose in life may be especially important in preventing and ameliorating depressive symptoms among older people.

The results of the present study in relation to physical activity are in contrast with the conclusions of a recent systematic review that found a negative relationship between extent of participation in physical activity and the experience of depressive symptoms among older people (16). The non-significant relationship found here may reflect the range of other psychological variables included in the study and their relative importance in protecting against depressive symptoms. Measurement limitations may also have played a role, such as the reliance on self-report (46, 47) and the assessment of only moderate to vigorous activity, which may not adequately capture all forms of protective activity relevant to older people (18, 21–23).

In terms of the moderation analyses used to assess whether interventions should target particular groups of older adults, just one moderating effect (age) was found, whereby a stronger relationship was found between life satisfaction and depressive symptoms among those participants below the average age of this sample, thus suggesting that interventions to improve life satisfaction could be particularly beneficial for those who are in this younger category (and likely to be newly retired). There is little prior work with which to compare these moderation outcomes. Some studies have examined the moderating effects of age, gender, education level, and living arrangement on the relationship between social support and depressive symptoms (48–51). This work has produced inconsistent results, which in combination with the general lack of effects found in the present study suggests that there may be little need to tailor intervention efforts to demographic subgroups within the broader cohort of older people.

Implications

The results from this study highlight the importance of life satisfaction, self-esteem, and purpose in life as focus areas for interventions aimed at preventing and ameliorating depressive symptoms among older people. While self-esteem exhibits trait-like stability (52), and is thus better suited to individual therapeutic intervention, life satisfaction and purpose in life have the potential to be modifiable through population-level interventions. As such, interventions that focus on ways of enhancing life satisfaction and purpose in life are likely to hold most potential for scalable prevention and amelioration strategies. Previous research suggests that encouraging people to participate in meaningful tasks such as hobbies, leisure activities, and/or volunteering can increase their life satisfaction and purpose in life (53–56). These activities have been suggested to provide older adults with opportunities that promote purpose in life and life satisfaction from (i) the relationships formed, (ii) the pursuit of goals, (iii) maintenance of independence, and (iv) engagement with the community (56, 57). These types of activities have also been found to be associated with social

support, self-efficacy, and self-rated health (58–60). Further, participation in meaningful tasks appears to be beneficial in helping individuals adjust to age-related losses such as retirement (i.e., loss of work role) and bereavement (53, 55, 60). Encouraging older adults to engage in meaningful activities and facilitating relevant opportunities for them to do so may thus constitute means of preventing and ameliorating depressive symptoms in later life.

Limitations, Future Directions, and Strengths

The main limitation of the present study was its cross-sectional design. Further research is needed to test the results longitudinally to assess whether the identified relationships hold over time. Another potential limitation was the use of convenience sampling, although the resulting sample was largely similar in profile to the population of older Australians, with the exception of living arrangement (see **Table 1**). Future studies should seek to access representative samples to test whether these results are generalizable. Similar research could also be conducted in other countries to assess the extent to which the identified relationships are relevant to other cultures. Given the inclusion of a broad range of psychological constructs in this study, a further potential limitation was the risk of social desirability bias in responses. To minimize this risk, an "arms-length" data collection method was used in the form of self-administered surveys. This approach has been found to result in more truthful responses to sensitive questions compared to when an interviewer is present (61).

The primary strength of this study was the large number of potential protective factors incorporated into a model that was tested on a substantial sample of community-dwelling older people. However, despite the wide range of factors included in this study, some potentially relevant variables were not assessed and could be incorporated into future research. In particular, including a measure of objective health could provide additional important data and overcome the limitations associated with relying solely on self-rated health as an indicator of physical well-being. Further, recent research suggests that sleep and diet quality may influence older people's experience of depressive symptoms (16), making these potentially important variables to include in future studies.

CONCLUSION

This study assessed the relative importance of a large number of factors that have been established in prior work as being protective against depressive symptoms in older adults. Life satisfaction and purpose in life were found to be the most influential factors, and could therefore be the focus of prevention and amelioration strategies targeting depressive symptoms in later life. Previous research has shown that engaging in activities perceived to be meaningful can increase older adults' life satisfaction and purpose in life. As such, it is likely that programs that focus on enhancing these protective factors could decrease the risk of depressive symptoms and improve overall well-being among older adults.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because ethics clearance was received on the basis that information would be confidential. Requests to access the datasets should be directed to spettigrew@georgeinstitute.org.au.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Curtin University Human Research Ethics Committee. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

CW conducted the analyses and took primary responsibility for preparing the manuscript. MJ, SP, and CW collected the data. SP and MJ assisted with manuscript preparation. All authors contributed to study conceptualization, read and edited drafts of the manuscript, and approved the final manuscript. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

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Multi-Morbidity in the Older Person: An Examination of Polypharmacy and Socioeconomic Status

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There has been increased focus on clinically managing multi-morbidity in the older population, but it can be challenging to find appropriate paradigm that addresses the socio-economic burden and risk for polypharmacy. The Commission on Social Determinants of Health (CSDH) has examined the need for institutional change and the parallel need to address the social causes of poor health. This study explored three potential interventions namely, meaningful information from electronic health records (EHR), social prescribing, and redistributive welfare policies from a person-centered perspective using the CARE (connecting, assessing, responding, and empowering) approach. Economic instruments that immediately redistribute state welfare and reduce income disparity such as direct taxation and conditional cash transfers could be adopted to enable older people with long-term conditions have access to healthcare services. Decreased socioeconomic inequality and unorthodox prescriptive interventions that reduce polypharmacy could mitigate barriers to effectively manage the complexities of multi-morbidity.

Keywords: polypharmacy, multi-morbidity, socioeconomic status, older adult, person-centred care, care approach

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INTRODUCTION

The term multi-morbidity describes the presence of more than two long-term conditions within an individual (1, 2). Although the term is used inconsistently and interchangeably with co-morbidity, it is different from co-morbidity, which is the concurrent presence of two long-term conditions that may occur before or after the onset of a disease of interest (3). Multi-morbidity is a complicated and socially patterned phenomenon associated with socio-economic deprivation (1), because people with multi-morbidity usually face social, mental, and physical health conditions that require care from multiple services, and are often in need of support for additional unplanned emergency care, which makes coordinating their care challenging (2, 4). While some people with complex conditions might require a tailored approach such as implementing an individualized management plan, reviewing medicines, establishing treatment burden, and other recommendations in the NICE guidelines, this may not be beneficial for others with related and well-controlled long-term conditions (4). A lack of understanding of the complexities of multi-morbidity, which is often impacted by social factors that affect treatment and improved patient experience, complicates healthcare interventions for people with the condition (5, 6).

It is estimated that one in three adults globally has multiple morbid conditions (7). In Scotland for example, it was reported that older people (>65+ years) are living with three or more long-term conditions, and predictions indicate that in 20 years there will be an increase of ∼50%, which will

invariably lead to increased demand for social and health care services (8). This implies that more funding for social and health care services will be needed to respond to trends in the population demographic profile due to an increase in older populations and socioeconomic inequality (8, 9).

Socio-economic inequality is a challenge that complicates the management of multi-morbidity among older people due to the high cost of health care, and the disparity in income distribution for less affluent older people in both developed and developing countries (10). In the US, for example, the poverty rate among older people aged 65 and over is 9.7% (11), and about 7 million older adults are living below the national poverty line (10). Economically, poor older populations experience unequal access to health care due to their social-economic position. Apart from the socio-economic problems faced by less affluent older people with multi-morbidity, healthcare providers spend huge sums of money annually managing patients with multi-morbidity (12) compared to those without a long-term condition (13). For example, in Singapore, the annual economic cost of managing an additional long-term condition is increased by SGD$3,177 and SGD$2,265 for social and health care respectively (14). This continuous spending on patients with multi-morbidity is unsustainable (15); and there is a need for a more holistic approach to the complexities of multi-morbidity (16). Scientific attention has been drawn to the fact that, apart from the differences in health conditions between the affluent and the less affluent in society, the social determinants of health (sensitivity of one's health to the social environment) is an important area for understanding the complexities of multi-morbidities (16).

According to the WHO (16), socioeconomic factors are a determinant of good health throughout life. Older people who are economically poor and isolated are more likely to have long-term diseases and higher levels of disability, especially when they do not receive social care that meet their needs (17). This is especially true because socioeconomic inequality could lead to social isolation (18) and as social beings that live in a society, we need friends, social connections, and meaningful work, to feel appreciated and valued. Without socioeconomic protection, older individuals become susceptible to depression and other physical and mental health conditions (16) and the severity of these conditions are also connected to social status (19).

The challenges around clinical management models, socio-economic status, and the healthcare burden arising from multi-morbidity and increased risk of adverse drug reactions (ADR) are continually emerging topics of discussion among healthcare providers and policymakers (5). The onset of multi-morbidity is present in about 98% of older population (20), who often need treatment with multiple medications specific to the disease, predisposing them to the risk of polypharmacy, which is the use of medications not clinically indicated. This further increases the complexity of managing multi-morbidity for both physicians and patients (1, 21, 22).

This paper studies the complexity of multi-morbidity among older people (≥65 years) in relation to socio-economic status and polypharmacy. It examines the influence of socio-economic inequalities, drawing from the Commission on Social Determinants of Health (CSDH), a global network brought together by the WHO that aims to address the social causes of poor health and health inequity by inspiring policy and institutional change (23). The CSDH framework shows how socio-economic and political mechanisms such as income, housing, education, and employment gives rise to economically stratified populations, which in turn, shapes health determinant status and differences in vulnerability to morbid conditions (24, 25). These factors play a role in shaping the lives of older people and can determine the extent to which the complexities of multi-morbidity are managed (25). The study proposes implementing redistributive welfare policies or social program that reallocate wealth to citizens in order to reduce socioeconomic inequalities. The use of information from electronic health records and social prescribing to prevent unnecessary drug prescription were two other suggested interventions discussed using the CARE approach (26, 27). The CARE approach is an important framework for person-centered and empathic encounters in healthcare relationships. It is used to understand a patient's situation, perspective, and underlying meanings, and to communicate this accurately in a flexible and helpful way (27). It involves actively engaging with a patient to open communication lines (connecting), listening for attached meanings (accessing), accurately communicating this understanding (responding), and planning measures in partnership with them (empowering) (27). The flexibility offered by this approach allows for different guiding principles to be applied to different circumstances.

This paper will be organized first by highlighting the complexities of multi-morbidity in relation to polypharmacy and socio-economic status. Next, person-centered interventions namely, social-prescribing, electronic health records, and models for effective communication between patients and healthcare providers will be presented using the CARE approach. The study will discuss ways society can redistribute welfare so that income disparity is reduced, and will conclude with a summary of how older people may benefit from the interventions.

THE COMPLEXITIES OF MULTI-MORBIDITY IN THE OLDER PERSON

Most people above 65 years of age live with multi-morbid conditions (28), and no established index exists for measuring the complexity of multi-morbidity based on socio-economic indicators (29). Some studies have attempted to develop instruments to measure the condition (30) by reviewing measures used in primary and community care settings. As Huntley et al. (31) reiterated, the lack of standardized indicators for accessing and measuring multi-morbidity are due to its complex nature.

Multi-morbidity among older people is associated with the risk of ADR arising from multiple drug combinations which are unnecessary and preventable, and from drug-disease interactions (32, 33). Budnitz et al. (34) reported that ADR was common in one-third of emergency visits by older adults. This correlates with a previous report by Goldberg et al. (35) who stated

that patients who took two drugs at the same time were found to have a 13% risk of ADR, while those who took four, seven, or more medications simultaneously were 38% and 82% at risk, respectively. Polypharmacy may arise from self-prescription due to lack of affordable healthcare, and from multiple treatments for poorly managed pain in older adults with long-term conditions such as musculoskeletal diseases, cancer, insomnia, and depression (36, 37). One study reported that 60–75% of older people aged 65 years have persistent pain, and 80% of this population experience pain resulting from osteoarthritis, while ∼25–50% of older people experience significant levels of pain from cancer (28, 38, 39). Moreover, these older patients are usually on high doses of pain medication and frequently seek multidisciplinary pain management services that could leave them being administered multiple drugs in a bid to manage chronic pain, thus increasing the risk of polypharmacy (40).

In addition to chronic pain caused by multiple diseases, sustained lower levels of social interaction have been suggested to contribute to depression, impaired function, and pain in older people because of a lack of social support which is known to have a buffering effect on pain. It is therefore important to also understand multi-morbidity within a social context (41). Increased interaction and togetherness between an older person and family or neighbors, rather than with formal services is suggested to be an important aspect of pain management that potentially lowers the risk of polypharmacy (42). This is because the social connections one has can provide emotional support that helps reduce psychological distress experienced as a result of failing health and insufficient income.

The prevalence of multi-morbidity has been associated with inequality in income across population groups, leading to a situation where affluent groups have the socio-economic and political mechanisms to afford medical care, making their care coordination less complex compared to less affluent groups, stratified according to income, education, occupation, gender, and race (43). These health determining social factors are associated with the presence of multiple long-term conditions (44) and governed by fundamental structural mechanisms such as the presence or absence of good governance, redistributive state welfare policies or social welfare programs, and educational attainment, all of which shape social hierarchies and are some of the root causes of health inequities and exclusion that make access to health care services difficult for people with lower socioeconomic status (44, 45).

Socioeconomic inequalities are not necessarily solely related to health care systems. Although health inequalities may very well amplify social inequalities, Mackenbach (46) stated that the relationship between health inequalities and socioeconomic inequality is probably more than a consequence of social inequality, as health inequalities have persisted and widened even in welfare states with generous arrangements. While Kohler (45) highlighted a positive correlation between higher GDP and lower socio-economic inequality, more studies are still required to establish this relationship. The non-elimination of the inability to access welfare resources and homogeneity of lower socio-economic groups in association with ill-health were two of the three circumstances suggested as plausible reasons that health inequalities have persisted in states with generous welfare arrangements (47). Another report discussed how a global within-country increase in unequal income over the past three decades was due to a decline in redistributive policies (45). While income-generating assets are important in determining income inequality, the non-effective implementation of welfare redistribution leads to a suboptimal outcome (47). This clarifies the intertwined and distinct relationship between socioeconomic inequalities, health inequalities, a welfare state, and access to health care systems.

A complexity survey by primary care physicians in Scotland rated socioeconomic and behavioral factors, rather than medical diagnosis as the major driving factors of complexity for patients (48). In addition, a study by Barnett et al. (43) using clinical data from registered patients in 314 medical practices in Scotland, revealed that less affluent people living in deprived areas were more likely to be diagnosed with long-term obstructive pulmonary disease, depression, and pain disorders. This implies that multi-morbidity in older individuals is potentially worsened by one's socio-economic potential to afford treatment for current co-morbid conditions. Moreover, the expensive cost of treatment from unplanned care and medication can force people with lower socioeconomic status further into poverty (5).

Taking care of people with multi-morbid condition cost billions of dollars annually. A study estimating the economic cost of multimorbidity among older people in Singapore found that about SGD$15,148 was the total annual societal cost required to take care of an older person with multiple long-term condition as opposed to SGD$5,610 for an older person with one long-term condition and SGD$2,265 for those with no long-term condition (14). The overall population cost was estimated at SGD$4.37 billion and was driven by the cost for social care rather than healthcare costs (14). This finding implies a linear relationship between the number of long-term conditions and increased health care expenditure. It is supported by Lehnert et al. (49) and also by Asmus-Szepesi et al. (50) who have reported a mean formal and informal healthcare costs of €30k euro per older person per year in the Netherlands. The calculated informal healthcare costs between hospital discharge and a year follow-up was €9,5k (50), showing that the cost of unpaid caregiving is substantial. The same can be seen in the United States where the estimated cost of unpaid caregiving for people with dementia is between $159–215 billion (51, 52).

HOW SOCIETY CAN REDISTRIBUTE WELFARE SO THAT INCOME DISPARITIES ARE REDUCED

Redistributive policies are a vital tool for decreasing socioeconomic inequity, however, this cannot be achieved under a model that ultimately uses private investment-led economic growth as a criterion of progress, but instead, one that acknowledges the firm placement of the economy in society to maximize human well-being (53, 54). Measures to reduce socio-economic inequalities should incorporate asset/wealth inequality and not only economic metrics to optimize inequality

reduction; this involves the equitable distribution of assets between the public and private sectors (45). Addressing equitable redistribution of wealth, affordable social care and health care among older individuals will help mitigate the complexity inherent in managing multi-morbidity in the older population (23).

Although there is no easy solution to effectively reduce income disparities, shifting resources from the affluent to those at the bottom of the income scale through taxation is one way to give older people with long-term conditions access to health care, and the most direct and immediate way to reduce inequality and social tensions (55). Apart from progressive taxation, increasing opportunities for growth and cash transfers are other instruments that can be implemented to keep inequality in check (55). Cash transfer programs that give older adults with multi-morbidity access to healthcare on the condition that they adhere to medical treatment and maintain contact with healthcare services are practical approaches to sustaining welfare redistribution. Examples of conditional cash transfers include those that require regular school attendance for children in developing economies and other cash transfer initiatives such as Mexico's *Prospera* and Brazil's *Bolsa Família*, which have been successful (55). Conditional cash transfers in the form of micro-credits, transportation, education, and training for carers are measures that can directly impact on the quality of life for the older person, assisting them in coping with adverse shocks pertaining to their circumstance. While income taxation and redistribution is a direct way to reduce inequality, it is, however, a short term measure with less future growth; indirect taxation on the other hand may not close the inequality gap in the short term but could lead to future growth unlike subsidies on consumption which do not effectively redistribute wealth, because the affluent also enjoy these measures (55, 56).

INTERVENTION FOR POLYPHARMACY USING A PERSON-CENTERED APPROACH

Multi-morbid disease management templates that take into account factors such as polypharmacy and social exclusion are a way to connect with, access, respond, and empower older people, using the CARE approach to communicate and develop policies that provide direction for patient pathways and guidelines in the management of multi-morbid conditions (57). Encounters that promote social prescribing have been touted as an alternative that could reduce polypharmacy, and manage the complexity of multi-morbidity because it is a way of referring frail older adults to healthcare services or to community support groups for practical social support (33). This approach provides a range of unorthodox prescriptive interventions that can be implemented alongside primary care to optimize functioning and reduce unnecessary prescription of medications by involving older persons in participatory activities such as volunteering, music, and exercise to foster togetherness within their social circles.

The use of electronic health records (EHR) is another person-centered approach to reduce the risk associated with polypharmacy. The Electronic Frailty Index (eFI) can be used to foretell adverse events for older patients (58) because it can facilitate a regular comprehensive review of prescriptions from multiple service providers. An accessible electronic medical database would assist physicians in prescribing new drugs, reviewing medication efficacy, and to deprescribe when co-morbid conditions improve (32, 33). This method can potentially prevent avoidable ADR that may result from polypharmacy via drug-drug interactions. Another important aspect of the electronic medical record system is that it contains the results of the administrative and clinical encounters of a patient, therefore EHR interoperability with other provider systems will help prevent extended hospitalization and delayed referrals for older persons due to the compilation of medical history (59). Easy referrals and lack of extended hospitalization reduce the risk of polypharmacy because a reduction in time spent in hospital care reduces further drug prescriptions (60).

Research has shown that patients prioritize empathy and the human aspects of care in clinical and disease management (57). Developing patient pathways from a more patient-centered approach rather than using a disease-specific model in multi-morbid disease management for older patients have been suggested as a way of looking to the future (61). One way to do this is to strengthen effective communication channels between healthcare professionals and older patients to provide opportunities for the patient to express their views and to participate willingly in the medical decision-making process (57). A practical approach to establishing rapport is the self-awareness of healthcare practitioners in how they approach the patient at the bedside, the non-verbal way they introduce themselves, their opening words and sentences as opposed to maintaining less eye contact, talking loudly, raising an eyebrow which are non-verbal communications that may come across as critical (27). Listening more to the patient, summarizing key points of the patient's explanation, revising decisions about the next actions, telling the patient what they are typing in the computer, talking less, signaling with occasional grunts, and helping the patient gain control in situations that require lifestyle changes rather than additional prescription are ways of connecting, accessing and responding to effectively communicate in a helpful and non-patronizing way (27).

The need for effective communication between healthcare providers and older people with multimorbidity is vital for achieving person-centered care and lowering the treatment burden. A report by the NHS (62) outlined that about 70–80% of the population in Scotland with long term conditions are on self-care management due to a lack of effective communication, because nurses in community practice consistently overestimate or underestimate the degree of pain in older adults, and are more likely to perceive them as exaggerating (63). Effective communication between healthcare professionals and the older person with multimorbidity is crucial to gain an understanding of the patient's situation and enable proper diagnosis and administration of treatment.

CONCLUSION

Multi-morbidity in older people requires a systematic understanding of its varied complexities in order to inform strategies that equip healthcare practitioners with the right skill-sets to understand the condition and to develop a standardized assessment and treatment tool for providing care for patients with long term conditions. Communication from a person-centered perspective is key to encourage patient interaction and collaboration, and to give clinicians more information that will help them make informed medical decisions to optimize an all-round benefit for the older person with multi-morbidity.

Reducing social and health inequities and redistributing state wealth via direct taxation and conditional cash transfers are important ways countries can quickly mitigate barriers to effectively manage the complexities of multi-morbidity. In addition, the use of electronic health records and the electronic frailty index (EFI) are digital formats that may assist in reducing complications arising from delayed referrals, extended hospitalization, and for providing information on polypharmacy and additional long-term conditions not clearly known. Since polypharmacy is a risk factor for poor health outcomes and mortality, social prescribing can be used as a person-centered alternative intervention to reduce the need for additional drug prescriptions, foster social connectedness, and reduce social exclusion among older people with multi-morbidity.

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Health Literacy Mediates the Association Between Socioeconomic Status and Productive Aging Among Elderly Chinese Adults in a Newly Urbanized Community

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Productive aging, or older adults engaging in paid or unpaid activities that produce socially valued goods or services, has been suggested to have the beneficial impact on older adults' health and well-being. We performed a cross-sectional study to examine the influence of health literacy on the relationship between socioeconomic status (SES) and productive aging among older Chinese adults in a newly urbanized community. Data was collected from 995 older adults from a newly urbanized community between June and August 2013 in Chengdu, China. We used structural equation modeling (SEM) to test the hypothesized relationship among SES, health literacy and productive aging. Results showed that education attainment and income had a direct positive effect on health literacy ($\beta = 0.47$and $\beta = 0.15$, respectively). Education had a partial indirect effect on productive aging through health literacy ($\beta = 0.27$). And health literacy was an important factor in improving the productive aging of the elderly. Interventions targeting health education and health promotion should be taken to improve health literacy of older adults under the background of urbanization, especially for those with lower SES.

Keywords: health literacy, socioeconomic status, productive aging, mediation, newly urbanized community

INTRODUCTION

China's older adult population is expected to increase rapidly in the next few decades, with the projected tripling of the proportion of adults aged 65 or over in the next 30 years comparing to a doubling of the same proportion in the U.S. (1). Despite improvements in living conditions and health services, older age is often associated with the decline in physical and cognitive health, as well as financial resources. There is growing concern that China's current health care and social security system will not be able to adequately meet the needs of these older residents (2). Surveys suggest that maintaining good health and having enough resources to cover health care costs are two most important concerns among older adults in China (3).

Because the great majority of older adults live in the community, encouraging older adults to participate in social activities has become a feasible way to help them stay healthy and active (56). Productive aging has been defined as any activities undertaken by an older adult, which produces socially valued goods or services, whether paid for or not (4). In general, it included employment, providing assistance to families, volunteering, and other forms of social participation (5). Researches generally showed that more participation in productive aging were associated with better health outcomes such as lower level of mortality (6), enhanced self-esteem, and improved life satisfaction (7). At the same time, productive aging would reduce the pressure of health care needs or even societal pension burden among the same population (5). However, previous studies on productive aging mainly focused on volunteering and its effect on health, resulting in a lack of understanding of other productive activities. And few studies explored the factors that affect older adults' productive aging. Moreover, these studies were conducted mostly in developed countries with well-health care systems, little is known about productive aging in China, a developing country with a vastly different cultural and social background (56).

Health literacy is an important factor that influences behavior of older adults (8). Health literacy can be defined as the degree to which individuals are able to acquire, process and understand the basic health information and services required to make appropriate health decisions (9). Also, health literacy refers to a broad range of social resources people need to access, understand, communicate, and utilize to make decisions about health (10). Older adults are a vulnerable group with regard to health literacy (8). In China, only 3.81% of people aged 65–69 had adequate health literacy in 2009 (11). A study in America demonstrated that low health literacy was a contributor to poor health outcomes and worse self-monitoring among older adults with asthma (12). Another study showed that individuals with diabetes who had low health literacy had higher odds of having unhealthy dietary habit. Although many studies on health literacy of the elderly have examined the association between health literacy and health behaviors, such as chronic disease self-management (13, 14), no study has explored the association between health literacy and productive aging among Chinese older adults.

Socioeconomic indicators such as education, income, and occupation have been found to be associated with health literacy and health behaviors (15–17). People with lower socioeconomic status (SES) are more likely to have low health literacy (18) and are less likely to engage in healthy behaviors. Furuya et al. found respondents with lower education were likely to have poorer health literacy (19). Also, Tang et al. suggested that older adults with higher SES were more actively involved in productive aging, especially regarding work and volunteering (20). It remains unclear about whether and how SES influence productive aging and the role of health literacy among Chinese older adults, as there are some qualitative evidence suggesting that Chinese older adults may have different interpretations of productive aging as compared to their western counterparts. We postulated that SES may largely determine the number of social resources that a person have access to (21), which may further influence health literacy and engagement in productive aging.

The study of the relationship between SES, health literacy and productive aging may be especially important under China's rapid urbanization process, resulting in major shifts in the population, its lifestyle and time use, from agriculture to non-agriculture. In 2011, the proportion of the urban population (51.3%) exceeded that of the rural population for the first time in history (22). The urbanization process displaced many formerly non-urban residents and created many new urbanized communities. The resulting changes in population age composition is further exacerbated by increased mobility of young people especially from the rural areas to cities and broke the traditional model of family support. Consequently, the burden of old-age care had been shifted from family to the state or other social organizations (23). The impact of urbanization on health is two-fold. On the one hand, changes in living environment and lifestyle are all related to the rapid growth of urbanization (24). Many factors, such as deteriorating air quality, increased high-calorie intake, and reduced social interaction with neighbors, affect the health of the elderly. On the other hand, people tend to have better access to quality health services and other community resources, including health information (25). Thus, health literacy may change as health information becomes more accessible (11).

Most previous researches focused on the traditional urban elderly or the rural elderly, while there are few studies researched on productive aging among the new urbanization residents. This study examined the effects of SES and health literacy on productive aging among elderly in a newly urbanized community in China and had important implications for health promotion in older adults.

Drawn from the extant literature and empirical support, we tried to establish the relationships among SES, health literacy and productive aging. We hypothesized that health literacy would mediate the effect of socioeconomic on productive aging. The theoretical hypotheses and the mediator model were shown in **Table 1** and **Figure 1**. We assumed that health literacy directly affected productive aging. Education and income affected productive aging both directly and indirectly. This study would further explore the intermediary effect of health literacy on the relationship between education, income and productive aging.

METHODS

Participants

The cross-sectional study was conducted between June and August 2013. The face-to-face questionnaire survey was conducted in a newly urbanized district in the suburbs of Chengdu, Sichuan Province. The sample inclusion criteria were that the participants were 65 years old and above and had resided continuously in the community for more than 6 months.

We calculated the sample size using the following formula: $n = \left(\frac{Z_{\alpha/2}}{\delta}\right) \wedge 2 \times \pi \times (1 - \pi)$ (26), =9.94% (which was the overall health literacy rate of urban residents in the first Chinese Residents' Health Literacy Survey in 2009) (27) = 2%, $\pi = 0.05$, =1.96. Based on this formula, the sample size was calculated as

TABLE 1 | The theoretical hypotheses.

Hypotheses
1. Education has a positive effect on income.
2. Education has a positive effect on health literacy.
3. Income has a positive effect on health literacy.
4. Health literacy has a positive effect on productive aging.
5. Education has a direct positive effect on productive aging.
6. Income has a direct positive effect on productive aging.
7. Education has an indirect positive effect on productive aging through the mediating effect of health literacy.
8. Income has an indirect positive effect on productive aging through the mediating effect of health literacy.
9. Education has an indirect positive effect on health literacy through the mediating effect of income.

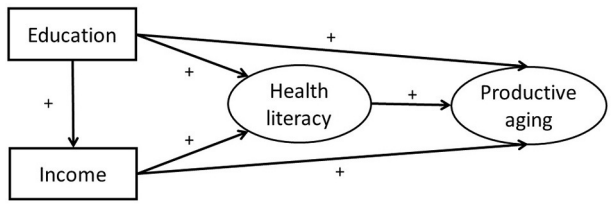

FIGURE 1 | The theoretical model and hypotheses.

818. Considering possible dropout, we increased the sample size by 20%, which resulted in a final sample size of 1,000.

Participants were recruited through simple random sampling methods. The SAS 9.3 proc plan program was used to randomly select respondents from a database of elderly adults established by the Community Health Service Centers. A total of 1,000 older residents were surveyed face-to-face by trained investigators; of these, we obtained and analyzed 995 (99.5%) valid responses. The study protocol was approved by the Institutional Review Board of West China School of Public Health, Sichuan University. Informed consent was obtained from each participant following a detail explanation about the purpose of the study.

Measures

The questionnaire included four parts, (a) socioeconomic status, (b) other demographic characteristics, (c) health literacy, (d) productive aging.

In this study, we used education and personal monthly income to measure SES of participants. Education was defined as four different levels (1 = no formal education, 2 = primary school, 3 = junior school, 4 = high school and above). Personal monthly income was categorized into four levels, ranging from <1,000¥ to more than 3,000¥ by an increment of 1,000¥.

Other demographic information mainly includes gender, age, marital status and living arrangements. Age was categorized as 65∼, 70∼, 75∼ and 80∼ years. Marital status was measured as single, married, divorced, and widowed. Living arrangements included four types: living with spouse, living with children, living with spouse and children and living alone.

We adapted the Chinese Residents' Health Literacy Questionnaire to measure literacy. This questionnaire was originally designed by the National Health and Family Planning Commission of the People's Republic of China (28). We adapted the questionnaire by selecting items closely related to the health literacy of the elderly and adding items about health knowledge of the prevention of common chronic disease per expert opinions. The revised questionnaire of health literacy (see **Appendix 1**) had 29 items, divided into three domains, including knowledge and belief (n = 19), behavior (n = 8) and skills (n = 2). Each item was given a score of 1 point if a correct response was provided. The total score ranges from 0 to 29, with the higher score indicating a higher level of health literacy. Participates receiving a score of 23 [which was 80% of the full marks of 29 (29)] or higher were categorized as having adequate health literacy. This scale has been shown to have good psychometric property (Cronbach' alpha 0.886) (55).

Productive aging describes productive activities taken by the elderly. In our study, five productive activities were examined: employment, doing household chores, caregiving, volunteering and learning. For employment, we asked participants whether they maintained work after retirement (0 = no, 1 = yes), including both full-time and part-time work. For the other four items, participants were asked to indicate the frequency of each activity (see **Appendix 1**). This four items response ranged from 0 = never to 3 = frequently. The total score ranged from 0 to13, with a higher score indicating a higher level of productive aging. This scale has a Cronbach's α coefficient of 0.731.

Statistical Analysis Method

Descriptive statistics were used to examine the distribution of each variable. Pearson coefficient was used to analyze the correlation of major constructs of the theoretical model. IBM SPSS 20.0 software was used for descriptive statistical analysis and correlation analysis. Structural equation model (SEM) was used to further test the hypothesized relationship between the four dimensions, education, income, health literacy and productive aging. IBM SPSS AMOS 24.0 software was used for establishing structural equation model. A P-value < 0.05 was defined as statistically significant. The structural equation model used bootstrap maximum likelihood estimation. Model fit was assessed through several commonly reported fit statistics, such as RMSEA (root mean square error of approximation) <0.08, NFI (normal fit index), CFI (comparative fix index), IFI (incremental fit index) of 0.90 or above, PCFI (parsimony comparative fix index), PNFI (parsimony normed fit index) of 0.50 or above (7).

RESULTS

Characteristics of the Participants

This descriptive information of 995 participants was provided in **Table 2**. The average age of respondents was 71.8 years (SD = 13.9) and approximately half were women (52.6%). A majority of the participants reported receiving a primary school (45.5%) or no formal education (31.1%). Approximately three-fourths

TABLE 2 | The characteristics of the participants (n =995).

	Frequency (n) or Mean	Percentage (%) or SD*
Gender		
Male	472	47.4
Female	523	52.6
Age(years)		
65∼	431	43.3
70∼	282	28.3
75∼	180	18.1
80+	102	10.3
Married status		
Single	2	0.2
Married	750	75.4
Divorced	7	0.7
Widowed	236	23.7
Living situation		
With spouse	284	28.5
With children	229	23.0
With spouse and children	435	43.7
Live alone	47	4.7
Education		
No formal education	309	31.1
Primary school	453	45.5
Junior school	143	14.4
High school and above	90	9.0
Personal monthly income (RMB)		
<1,000	62	6.2
1,000∼1,999	736	74.0
2,000∼2,999	142	14.3
3,000+	55	5.5
Total score of health literacy	12.6	6.0
Knowledge and belief literacy	7.4	4.6
Behavior literacy	4.0	1.6
Skill literacy	1.2	0.6
Total score of the productive aging	6.0	2.7

SD, standard deviation.

were married (75.4%). Less than half of the elderly reported living with spouse and children (43.7%) and the vast majority of the residents earned <2,000 RMB a month (80.2%). The mean score of health literacy for the elderly was 12.6 (SD = 6.0). Only 8.5% of the participants were above 23, the threshold of adequate health literacy. The mean score of knowledge and belief literacy, behavior literacy and skill literacy were 7.4 (SD = 4.6), 4.0 (SD = 1.6) and 1.2 (SD = 0.6), respectively. Additionally, the average score of productive aging for the elderly in this survey was 6.0 (SD = 2.7). And 2.0% of samples answered No to all questions. You may insert up to 5 heading levels into your manuscript as can be seen in "Styles" tab of this template. These formatting styles are meant as a guide, as long as the heading levels are clear, Frontiers style will be applied during typesetting.

Productive Aging Status of the Participants

Table 3 shows productive status of the elderly. Only 4.2% of older adults reported participating in work. The elderly who often did household chores and cared for their families accounted for 59.0% and 46.0%, respectively. A small proportion of the participants frequently participated in volunteer and learning activities, taking up 3.8 and 17.1%, respectively.

Correlation Among SES, Health Literacy and Productive Aging

As presented in **Table 4**, the correlations between pairs of education, personal monthly income, health literacy and productive aging were statistically significant ($P < 0.01$). Productive aging was positively correlated with health literacy, education and personal monthly income. Participants who had higher health literacy scores had higher education and income level. Moreover, education was positively correlated with personal monthly income.

The Mediating Effect of Health Literacy on the Association Between SES and Productive Aging

This study established a structural equation model, shown in **Figure 1**, to examine how productive aging would be influenced by income, education and health literacy. The model fit indices of the hypothesized model were RMSEA = 0.108, NFI = 0.820, CFI = 0.831, IFI = 0.832. Those fit indices of the hypothetical model failed to meet the fitness criteria. Also, income had no significant direct effect on productive aging ($\beta = 0.00$, $P = 0.914$). Thus, this model needed to be modified. After adjusting, the final output model was shown in **Figure 2**, which presented the standardization path coefficient. With addition of other socio-demographics (gender, age, married status and living situation) as covariates, the arrow direction among the core variables in the model remained unchanged, in addition, the corresponding coefficients did not change significantly. Therefore, the socio-demographics were not confounding factors. Specifically, the absolute fit index, the incremental fix index and the parsimonious fit index of final model all met the fitness criteria (RMSEA = 0.058, NFI = 0.937, CFI = 0.951, IFI = 0.951, PCFI = 0.655, PNFI = 0.646).

Bias-corrected bootstrap with 2,000 replications using maximum likelihood estimation was employed for each path. The results of the estimation are shown in **Table 5**. If the 95% confidence interval (95% CI) of the estimation of the path coefficient does not include 0, it means that the direct, indirect, or total effect are statistically significant. Education had a positive effect on income ($\beta = 0.39$, $P < 0.001$). Education exerted a positive influence on health literacy ($\beta = 0.47$, $P < 0.001$). Income exercised a positive impact on health literacy ($\beta = 0.15$, $P < 0.001$). Health literacy had a direct positive effect on productive aging ($\beta = 0.51$, $P < 0.001$). Education had a direct positive effect on productive aging ($\beta = 0.29$, $P < 0.001$). Education influenced health literacy mostly directly. The proportion through the impact of income was very small. Finally, the final results supported all hypotheses except hypothesis 6.

TABLE 3 | Productive aging status of the participants.

	Paid work		Doing household chores		Caregiving		Volunteering		Learning	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
No	953	95.8								
Yes	42	4.2								
Never			97	9.7	222	22.3	764	76.8	167	16.8
Rarely			115	11.6	114	11.5	53	5.3	532	53.5
Occasionally			196	19.7	201	20.2	140	14.1	126	12.7
Frequently			587	59.0	458	46.0	38	3.8	170	17.1

TABLE 4 | Correlation among SES, health literacy and productive aging.

		1	2	3	4
1	Education	1			
2	Personal monthly income	0.395**	1		
3	Health literacy	0.476**	0.301**	1	
4	Productive aging	0.357**	0.184**	0.413**	1

***P<0.01, two-tailed.*

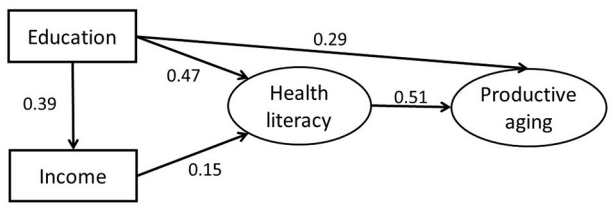

FIGURE 2 | The final model and standardized model path coefficient.

TABLE 5 | Significance test of the mediating test.

Model pathways	Estimated	95% CI
Total effects		
Income ← Education	0.395	0.332–0.454
Health literacy ← Education	0.533	0.472–0.595
Health literacy ← Income	0.152	0.086–0.217
Productive aging ← Health literacy	0.508	0.407–0.626
Productive aging ← Education	0.560	0.484–0.632
Productive aging ← Income	0.077	0.044–0.116
Direct effects		
Income ← Education	0.394	0.332–0.454
Health literacy ← Education	0.474	0.405–0.543
Health literacy ← Income	0.152	0.086–0.217
Productive aging ← Health literacy	0.508	0.407–0.626
Productive aging ← Education	0.289	0.186–0.383
Indirect effects		
Productive aging ← Education	0.271	0.209–0.349
Productive aging ← Income	0.077	0.044–0.116
Health literacy ← Education	0.060	0.034–0.089

TABLE 6 | Significance test of every mediating pathway.

Model pathways	95% CI
Health literacy ← Income ← Education	0.134–0.403
Productive aging ← Health literacy ← Education	0.004–0.013
Productive aging ← Health literacy ← Income	0.002–0.007

Table 6 displays the significance test of three mediating pathways of final model. The results showed the 95% CI of the estimates of the three-mediation path did not include 0, indicating that mediating effects of health literacy on the influences of education and income on productive aging were both statistically significant (30). With respect to the influence of education on productive aging, we found that the total effect, direct effect and indirect effect of this path were all statistically significant, suggesting that education influenced productive aging both independently and partially through health literacy. However, the effects of income on productive aging was completely mediated through health literacy. We also found that education influenced health literacy partially through the effects of income.

DISCUSSION

This study is dedicated to explore how SES (education, income) and health literacy influence productive aging among older Chinese adults in a newly urbanized community for the first time, thereby providing theoretical support for promoting health of the elderly.

The research showed that the mean score of productive aging for the elderly in this survey was only 6.0 (SD = 2.7). It suggests that the level of productive aging was generally low, especially with respect to the engagement in work, volunteer and leaning activities. The productive aging of elderly residents was mainly focused on family contribution, such as doing household chores (59.0%) and caregiving (46.0%). A similar situation of productive aging has been reported by Li et al. that older Chinese adults had a low participation rate in paid employment but high participation in assisting family. In newly urbanized communities, most elderly lost their land and can no longer do farm work. They may spend more time doing housework and caring for grandchildren, which is a common phenomenon in

China, a family-oriented, collectivist country (31, 32). At the same time, the relevant policies and infrastructure are still not perfect in the newly urbanized communities, as well as jobs and volunteer service organizations are scarce for the elderly (33). Accordingly, older adults rarely have the opportunity to continue working or volunteering, let alone studying. Older adults who engaged in more hours of volunteering or lifelong learning reported higher levels of well-being (34, 35). Therefore, the government should encourage the elderly to participate in social activities and make lifelong learning by creating an environment supporting productive aging.

In addition, the mean score of health literacy for the elderly was 12.6 (SD = 6.0). Only 8.5% of the participants had adequate health literacy. It meant that health literacy of the participants was rather low, lower than the results of urban residents reported by the first *Chinese Residents' Health Literacy Survey* in 2009 (9.9%) (27). This reflected the lack of health related knowledge, behavior and skill among the elderly in the new urbanized community. 76.8% of participants had a primary school level of education or below in this study. Despite a lot of health information on the web, the majority of older adults cannot use the internet (36).

The model demonstrated that health literacy positively influenced productive aging. Considerable previous researches found that health literacy could affect the behaviors of the elderly (37–39). Those with higher health literacy may better adopt positive aging to promote their health (40). A prior study revealed health literacy increased utilization of preventive care among older adults in Taiwan (13). Peterson et al. verified that patients with higher health literacy reported less barriers to complete cancer screening (41). In the current research, we found that health literacy would directly positively influence productive aging. As a collection of various active behaviors in the life of the elderly, productive aging such as volunteering and working were generally related to good health outcomes (42, 43). The elderly with higher health literacy may have more health information and more likely to take productive aging to promote their physical and mental health in the urbanized community.

The model also showed higher SES positively influenced health literacy, which was basically consistent with previous studies (44, 45). On the one hand, high education level was closely related to better health literacy. It may be that education affects older adult's access to information and resources and also willingness to obtain information (46). People with low education maybe not understand and use medical information in their daily life. On the other hand, the higher the income, the better the health literacy. This was consistent with the results of a survey conducted by Su et al. in Korean older adults (47). It may be because older people with higher incomes have more social resources and social support to improve their health literacy. At the same time, education also affected health literacy through income. Therefore, SES was important influencing factors of health literacy.

Our study found that education had a positive direct effect on productive aging, which was similar with previous studies. Horowitz et al. revealed education was an important way to promote productive aging (48). Other studies found that older adults with a lower education level were less likely to participate in social activities (49, 50). Policies that aims to promote the productive participation of older adults in social activities should focus on groups with lower education levels (51).

The important finding of this study was that education and income influenced productive aging through health literacy. This indicates that health literacy mediates the relationship between socioeconomic status and productive aging among the elderly in the newly urbanized community. Considering that the SES of the elderly is difficult to change, health literacy is a key factor in improving the productive aging of the elderly in urbanized communities. The level of productive aging could be increased through the improvement of health literacy (52). We can take health education and health promotion strategies for the elderly, such as conducting live health lectures or improving the accessibility and readability of health information, to facilitate the understanding of health-related information, and hence improve health literacy (53, 54).

The main limitation of this study is that it is a cross-sectional survey, it does not validate the causal relationship between SES, health literacy and productive aging. Our results only provide information concerning the direct and indirect influencing factors of productive aging among these older adults in the context of urbanization.

CONCLUSIONS

In conclusion, this study reveals that SES and health literacy are significantly related to productive aging among older adults in the newly urbanized community. Education and income have direct positive effects on health literacy. Health literacy has a direct positive effect on productive aging. Education also has a direct positive impact on productive aging, while the direct positive impact of income on the productive aging has not been affirmed. Health literacy mediates the influence of SES on productive aging. Thence, interventions targeting health literacy should be prioritized for older adults to promote productive aging under the background of urbanization, especially for those with lower SES.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Institutional Review Board of West China School of Public Health, Sichuan University. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

TM and DL conceptualized the idea. DL, CJ, and MS collected the data. TM performed the statistical analyses and wrote the first draft of the manuscript. DL, HM, and ZY critically revised the manuscript. All the authors checked and approved the final manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2021.647230/full#supplementary-material

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Loneliness and Healthcare Use in Older Adults: Evidence From a Nationally Representative Cohort in Northern Ireland—A Cross-Sectional Replication Study

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Background: Few have explored associations between loneliness and healthcare use independent of health and health behaviors. Recent indication of gender effects also requires validation across health service and cultural settings. We investigated the associations among loneliness, health and healthcare use (HCU) in older adults including stratification to investigate whether associations differed by gender.

Methods: Secondary analysis of a nationally representative sample of 8,309 community-dwelling adults aged 50 and over from the Northern Ireland Cohort for the Longitudinal Study of Aging. Primary outcomes were: self-reported General Practice (GP) and emergency department (ED) visits in past year. Negative binomial and logistic regression analysis were used to investigate associations between loneliness and HCU, later adjusting for potential confounders (health and health behaviors).

Results: Loneliness was consistently positively associated with both GP and ED visits (with IRRs ranging from 1.10 to 1.49 for GP visits, 1.16 to 1.98 for ED visits and ORs ranging from 1.13 to 1.51 for reporting at least one ED visit). With addition of health and health behaviors, all associations between loneliness and HCU became non-significant, excepting a small independent association between UCLA score and GP visits [IRR 1.03 (95% CI 1.01–1.05)]. Stratification of models revealed no gender effects.

Conclusion: All but one association between loneliness and HCU became non-significant when health and health behaviors were included. The remaining association was small but implications remain for health service resources at population level. No gender effects were present in contrast to recent findings in the Republic of Ireland. Further studies on gender, loneliness and healthcare use needed.

Keywords: loneliness, healthcare use, emergency department, general practice, older adults, Primary care (MeSH)

INTRODUCTION

A number of papers have explored associations between loneliness and healthcare use (HCU) (1–11), with a subset of these controlling in some way for the potentially confounding role of health in these associations (2, 3, 5, 7, 10, 11) as well as health behaviors more recently (12). The evidence base however remains mixed with some support for the presence of significant positive associations between loneliness and HCU independent of health (mostly in relation to physician/ General Practise (GP) visits (2, 3, 5, 7, 10) but lack of associations with HCU also reported at times (3, 5, 7, 8) as well as a negative association in one study where older adults who were lonely in Singapore had significantly lower odds of physician visits (13). Our recent analysis of three waves of population level data in the Republic of Ireland, was the first to adjust for a more comprehensive picture of subjective and objective physical and mental health and to include health behaviors and, revealed an independent impact of loneliness on GP visits in older adults, which was specific to women when models were stratified by gender (12). This somewhat novel finding in relation to potential gender effects in association between loneliness and HCU as well as the still mixed evidence base on loneliness and HCU in general meant that replication of this analysis was required, especially in an alternative health service setting where healthcare access differs to the Republic of Ireland In Northern Ireland healthcare access to GPs and ED are free to all at the point of access while in the Republic of Ireland there is a mixed system of delivery with different criteria for free access, for example those over 70 are eligible for GP visit cards allowing GP visits free of charge. If one attends an emergency department without being referred by a GP however a standard fee may apply. This cross-sectional replication study will, following our previous analysis (12), be the second ever paper on loneliness and HCU, to our knowledge, to adjust for a comprehensive picture of subjective and objective physical and mental health and too also include health behaviors. This comprehensive analysis is, we feel, crucial in building evidence on the presence of true independent associations between loneliness and HCU in older adults.

We hypothesized that loneliness would again be associated with increased HCU in older adults, but that this would again be largely confounded by health (objective and subjective measures of physical and mental health including diagnoses, symptoms, and body measurements) and health behaviors (self-reported physical activity, smoking status, and alcohol consumption), with independent associations more likely for GP visits. The basis for this hypothesis was the established associations between loneliness and poorer mental and physical health (14) findings of our previous analysis (12) as well as the mixed evidence from previous studies with less comprehensive analyses for potential confounding included as above. Thus, while we expected most associations to be explained by health and health behaviors, we saw independent associations between loneliness and HCU where present as likely to be explained by either residual confounding; HCU as a form of social engagement/participation to address loneliness; or loneliness denoting seeking help for a mental/emotional health issue beyond those captured in NICOLA (depressive symptoms; and already diagnosed "psychiatric, nervous, or emotional problem") such as anxiety symptoms. Unfortunately, it will not of course be possible within this analysis to truly infer the basis or potential drivers for any independent associations that might persist. We also hypothesized that stratifying by gender might reveal stronger independent associations in women in line with recent findings in the Republic of Ireland (12) and the known effects of gender on HCU and help seeking (15–17). The considerable literature on help seeking often focuses on factors relating to stigma and avoidance (18–20), with masculine attitudes and beliefs also thought to play a determining role in avoiding or rejecting help (21). The current paper tested these hypotheses by assessing whether loneliness was associated with HCU in a nationally representative sample of community living adults in Northern Ireland aged 50 and over; testing whether these associations, if present, were confounded by health and health behaviors; and finally investigating whether these associations and their potential confounders differed when we stratified by gender.

METHODS

Secondary Analysis of NICOLA Data

The sample comprised participants from the Northern Ireland Cohort for the Longitudinal Study of Aging (https://nicola.qub.ac.uk/) which provides a nationally representative sample of community dwelling adults aged 50 and over living in Northern Ireland (N = 8,309). The current analysis is based on those aged 50 and over at Wave 1 with data collected between February 2014 and March 2016. NICOLA participants undertook a comprehensive computer-assisted home interview (CAPI) and were also invited to complete and return a self-completion questionnaire (SCQ) as well as a health assessment. An overall CAPI response rate of 63% was achieved with 59% also returning an SCQ and 44% completing a health assessment. Further detail on the sampling strategy employed in the NICOLA study can be found in a previously published report (22). Ethical approval for the study was obtained from the School of Medicine, Dentistry and Biomedical Sciences Ethics Committee, Queen's University Belfast. Access to NICOLA data is available on application through https://www.qub.ac.uk/sites/NICOLA/InformationforResearchers.

Exposure Variables

UCLA Score

Loneliness was assessed in the self-completion questionnaire using the 5-item UCLA scale which is a revised version of the 20-item University of California-Los Angeles Loneliness scale ((23)). Each item is measured on a 3-point Likert scale (0–2) reflecting frequency of occurrence: "Hardly ever or never;" "Some of the time;" "Often." Possible scores range from 0 to 10 with higher scores indicating greater loneliness.

UCLA Threshold

To allow comparability, a loneliness threshold variable was created in line with previous papers establishing the impact of loneliness on HCU (7, 13) whereby any participant responding

"often" or "some of the time" to any of the first three items was defined as lonely.

Direct Item

Finally, responses of "some of the time" or "often" to UCLA item 5 which asks directly about how often respondents "feel lonely" were also modeled for associations with HCU in line with the previous cross-sectional analysis of TILDA (12) being replicated, as well as other previous analyses of loneliness and HCU which were solely based on single item measures which sought to directly assess loneliness (3, 5, 8, 10).

Outcomes

Primary outcomes were: GP and ED visits as self-reported during computer-assisted face-to-face personal interview. A binary categorical outcome variable was also generated to capture reports of at least one ED visit in the previous 12 months given the low numbers overall and in line with the cross-sectional component of the study we were replicating (analysing the Irish Longitudinal Study of Aging) (12).

Potential Confounders

All variables providing a profile of heath and health behaviors collected in the NICOLA study and showing significant associations with loneliness (as per **Table 1**) were included in our regression analyses in order to adjust for health and health behaviors as comprehensively as possible. This was in line with the cross-sectional component of the study we were replicating (analysing the Irish Longitudinal Study of Aging) (12). These were: presence of a self-reported doctor-diagnosed chronic condition (81%); reporting "troubled often with pain" (47%) or a fall in the last year (22%); BMI (mean 29.0, SD 5.22); waist circumference (mean 95.8 cm, SD 14.1); and depressive symptoms [CES-D (20-item)] (14% severe). Health behaviors included were smoking status [current (17%)/former (35%)]; self-rated alcohol consumption [drink a lot/heavily (4%); drink a moderate amount (25%)]; and physical activity with the sample split into four groups based on the number of days they reported they were moderately active in the last week (11% active 5 or more days; 8% active 3–4 days; 14% active 1–2 days; 67% active no days).

Doctor diagnosed chronic conditions included in NICOLA were: cancer; chronic lung disease; cardiovascular disease (angina; high cholesterol; hypertension; diabetes; myocardial infarction or coronary thrombosis; congestive heart failure; a stroke; or TIA); asthma; arthritis; osteoporosis; Parkinson's disease; "any emotional, nervous, or psychiatric problems;" alcohol or substance abuse; Alzheimer's disease; Dementia; serious memory impairment; stomach ulcers; cirrhosis/serious liver damage; and varicose ulcers. For the purposes of this analysis the presence of at least one chronic condition was defined as answering "Yes" when asked if they were "ever told by a doctor that" they had any of the above. Those who refused to answer or reported they did not know were treated as missing.

Statistical Analyses

Key variables and demographic characteristics of the sample were compared according to threshold and direct item loneliness using *t*-test and chi-square statistics as appropriate. As above, loneliness was modeled as (1) UCLA score; (2) UCLA threshold variable based on UCLA items 1–3; and (3) Direct item i.e., UCLA item 5 which asks directly about feeling lonely.

Multivariate negative binomial and logistic regression models were used to investigate associations between loneliness and GP visits (count) and between loneliness and ED visits (count; and any vs. none). In line with our previous analysis of HCU in another cohort (12), all models were adjusted for age, sex, education, and marital status and multilevel to account for non-independence at the household level. Potential confounders (health and health behaviors) were then simultaneously added to all models to investigate whether any independent associations between loneliness and HCU would remain. Negative binomial regression was employed for count data as an alternative to Poisson as it is useful for count data with overdispersion (i.e., sample variance is higher than the sample mean). Due to missing data the final analytic samples ranged from 2,523 to 2,466. Finally, all models were also stratified by gender to observe differences in associations according to gender.

RESULTS

Overall, the mean UCLA score for the 5-item scale was 2.09 (SD 2.16, Median 2) ($N = 4{,}685$). Among the 4,717 for whom UCLA items 1–3 were available, 41% ($n = 1{,}916$) were defined as lonely i.e., answered "sometimes" or "often" to at least one of these 3 items. In the case of UCLA item 5 meanwhile, or direct item loneliness, 33% ($N = 1{,}605/4{,}818$) reported they felt lonely "some of the time" (28%) or "often" (5%).

Mean self-reported GP visits in the last 12 months was 3.54 (SD 4.73, Median 2) ($N = 8{,}060$). Mean self-reported ED visits in the last 12 months was 0.32 (SD 1.03, Median 0) ($N = 8{,}143$). Overall 20.6% reported at least one ED visit.

Table 1 illustrates the main characteristics of the sample based on threshold loneliness. Meeting the "lonely" threshold was significantly related to gender, age group, marital status, GP, and ED visits as well as all health and health behavior variables. No association was found for education but since education level was related to HCU it was therefore retained in all models.

Loneliness as per UCLA item-5 was associated with all demographic, HCU health and health behavior variables.

Modeling associations between loneliness and HCU revealed that loneliness was significantly associated with both GP and ED visits across indicators of loneliness (**Table 2**) with IRRs ranging from 1.10 to 1.49 for number of GP visits, 1.16 to 1.98 for number of ED visits and ORs ranging from 1.13 to 1.51 in the case of reporting at least one ED visit. Following the addition of health and health behaviors to these models however, all associations between loneliness and HCU became non-significant, with one exception in the case of UCLA score and GP visits where a small independent association

TABLE 1 | Demographics, health and HCU characteristics of NICOLA cohort by Loneliness (Threshold variable based on items 1-3) ($N = 4,717$).

	Lonely ***n* = 1,916** **41%**		**Not lonely** ***n* = 2,801** **59%**		**t/Chi**	***P*-value**
Gender (*n* = 4,717)	***n***	**%**	***n***	**%**		
Male	822	38%	1,349	62%	12.7	<0.001**
Female	1,094	43%	1,452	57%		
Age group (*n* = 4,717)						
50–64	1,063	43%	1,411	57%	16.2	<0.001**
65–74	545	36%	948	64%		
75+	308	41%	442	59%		
Education (*n* = 4,712)						
Primary/none	371	40%	549	60%	0.43	0.808
Second level	845	41%	1,211	59%		
Diploma/certificate or higher	696	40%	1,040	60%		
Marital status (*n* = 4,717)						
Married/co-habiting	1,064	32%	2,254	68%	342.7	<0.001**
Single (never married)	192	57%	147	43%		
Separated/divorced	299	63%	176	37%		
Widowed	361	62%	224	38%		
Healthcare use						
GP visits past 12 months [M (SD)] ($n = 4,673$)	(3.91)	(4.72)	(2.89)	(3.83)	−8.14	<0.001**
ED visits past 12 months [M (SD)] ($n = 4,703$)	(0.37)	(1.17)	(0.23)	(0.82)	−4.75	<0.001**
ED visit (at least one) ($n = 895/4,717$)	423	47%	472	53%	20.2	<0.001**
Doctor diagnosed chronic condition ($n = 3,787/4,710$)	1,609	42%	2,178	58%	28.1	<0.001**
Pain ("often troubled with") ($n = 2,139/4,711$)	1,047	49%	1,092	51%	112.4	<0.001**
Fall(s) (in past year) ($n = 951/4,714$)	500	53%	451	47%	70.3	<0.001**
Waist cm [*M* (SD)] (*n* = 2,973)	(96.3)	(14.2)	(94.8)	(13.6)	−2.73	0.006*
BMI [*M* (SD)] (*n* = 2,983)	(29.2)	(5.36)	(28.6)	(4.69)	−2.89	0.004*
CES-D depressive symptoms (*n* = 2,520)						
Severe (16+)	240	75%	79	25%	346.2	<0.001**
Moderate (8–15)	298	54%	252	46%		
None/mild (7 or less)	431	26%	1,220	74%		
Alcohol consumption (*n* = 4,712)						
Hardly drink/do not drink	984	43%	1,300	57%	11.7	0.008*
Drink a little	350	38%	568	62%		
Drink a moderate amount	507	38%	825	62%		
Drink a lot/heavily	73	41%	105	60%		
Smoking (*n* = 4,714)						
Current	313	54%	264	46%	52.5	<0.001**
Former	689	40%	1,035	60%		
Never	913	38%	1,500	62%		
Days of moderate exercise in past week (*n* = 4,700)						
0 days	1,259	43%	1,698	57%	15.6	0.001*
1–2 days	271	36%	482	64%		
3–4 days	155	36%	278	64%		
5–7 days	223	40%	334	60%		

*<.05; **<.001.

remained following adjustment [IRR 1.03 (95% CI 1.01–1.05)].

The stratification of models by gender revealed no gender effects in relation to associations between loneliness and HCU in this cohort.

DISCUSSION

Loneliness was consistently positively associated with number of GP visits and number of ED visits in the past year, with IRRs ranging from 1.10 to 1.49 and 1.16 to 1.98, respectively. There

TABLE 2 | Associations between loneliness and HCU including adjustment for health and health behaviors.

						Adjusted for health and health behaviors			
	GP visits (count)	***N***	**IRR**	**95% CI**	***P*-value**	***n***	**Adjusted IRR**	**95% CI**	***P*-value**
1	UCLA score	4,637	1.10	(1.08–1.12)	<0.001**	2,466	1.03	(1.01–1.05)	0.013*
Men:		2,144	1.10	(1.07–1.13)	<0.001**	1,185	1.03	(0.99–1.06)	0.143
Women:		2,493	1.10	(1.07–1.13)	<0.001**	1,281	1.03	(1.00–1.05)	0.056
2	UCLA Threshold	4,669	1.35	(1.25–1.46)	<0.001**	2,479	1.04	(0.95–1.14)	0.404
Men:		2,160	1.31	(1.17–1.47)	<0.001**	1,193	0.97	(0.85–1.11)	0.649
Women:		2,509	1.39	(1.26–1.53)	<0.001**	1,286	1.10	(0.98–1.23)	0.091
3	Direct Item	4,767	1.49	(1.37–1.61)	<0.001**	2,510	1.05	(0.96–1.16)	0.294
Men:		2,210	1.57	(1.38–1.79)	<0.001**	1,211	1.03	(0.89–1.21)	0.665
Women:		2,557	1.44	(1.30–1.59)	<0.001**	1,299	1.06	(0.94–1.19)	0.352
	ED visits (count)	***N***	**IRR**	**95% CI**	***P*-value**	***n***	**Adjusted IRR**	**95% CI**	***P*-value**
1	UCLA score	4,669	1.16	(1.11–1.22)	<0.001**	2,476	1.03	(0.96–1.09)	0.411
Men:		2,152	1.15	(1.09–1.22)	<0.001**	1,192	0.99	(0.92–1.08)	0.922
Women:		2,517	1.18	(1.11–1.25)	<0.001**	1,284	1.07	(0.98–1.17)	0.130
2	UCLA Threshold	4,700	1.56	(1.29–1.89)	<0.001**	2,489	0.95	(0.75–1.21)	0.674
Men:		2,168	1.39	(1.08–1.78)	0.010*	1,200	0.86	(0.61–1.22)	0.405
Women:		2,532	1.75	(1.36–2.25)	<0.001**	1,289	1.12	(0.84–1.49)	0.444
3	Direct Item	4,802	1.98	(1.63–2.39)	<0.001**	2,520	1.23	(0.97–1.54)	0.083
Men:		2,219	2.01	(1.56–2.58)	<0.001**	1,218	1.21	(0.85–1.73)	0.289
Women:		2,583	1.93	(1.49–2.51)	<0.001**	1,302	1.23	(0.92–1.66)	0.168
	ED visit (1 or more)	***N***	**ORR**	**95% CI**	***P*-value**	***n***	**Adjusted ORR**	**95% CI**	***P*-value**
1	UCLA score	4,680	1.13	(1.09–1.17)	<0.001**	2,479	1.02	(0.96–1.09)	0.457
Men:		2,155	1.13	(1.07–1.19)	<0.001**	1,192	1.00	(0.92–1.10)	0.924
Women:		2,525	1.14	(1.07–1.20)	<0.001**	1,287	1.04	(0.96–1.13)	0.349
2	UCLA Threshold	4,712	1.38	(1.18–1.61)	<0.001**	2,492	0.98	(0.77–1.26)	0.889
Men:		2,171	1.31	(1.04–1.66)	0.021*	1,200	0.99	(0.69–1.43)	0.971
Women:		2,541	1.44	(1.17–1.76)	0.001*	1,292	0.99	(0.70–1.38)	0.933
3	Direct Item	4,813	1.51	(1.2–1.78)	<0.001**	2,523	1.05	(0.81–1.36)	0.700
Men:		2,222	1.65	(1.28–2.12)	<0.001**	1,218	1.07	(0.70–1.63)	0.762
Women:		2,591	1.44	(1.17–1.77)	0.001*	1,305	1.08	(0.77–1.52)	0.666

*All models adjusted for age, sex, education, and marital status. *<.05; **<.001.*

was also a positive association between all three indicators of loneliness and reporting at least one ED visit in the past year with ORs ranging from 1.13 to 1.51 in the sample overall. Upon adjusting for health and health behaviors, loneliness no longer had any impact on ED visits in terms of number of visits or reporting at least one visit compared to none. In relation to GP visits, associations became non-significant for two of the three indicators of loneliness (UCLA threshold and direct item loneliness) but in the case of UCLA score a small association independent of health and health behaviors persisted in the sample overall [IRR 1.03 (95% CI 1.01–1.05)]. Thus, those with higher loneliness scores on the UCLA seem to report visiting their GP a little more often irrespective of their health and health behaviors. The stratification of models by gender did not reveal the presence of any gender effects. In line with our first hypothesis therefore loneliness was associated with increased HCU, with these associations largely explained by health and health behaviors. In contrast to our second hypothesis however, and recent findings elsewhere (12), no gender effects were present in associations between loneliness and HCU.

The fact that the associations between loneliness and HCU found in this cross-sectional replication study were again small and largely explained by health and health behaviors, supports the importance of a comprehensive adjustment for potential confounding when investigating impacts of loneliness on HCU. Health and health behaviors, which have long been known to be associated with both loneliness and HCU are clearly key confounders of these associations and future studies on loneliness and HCU need to include these in order to provide a clearer picture of independent associations. While all associations with ED visits disappeared once health and health behaviors were accounted for there was still a small significant independent

association with GP visits in the sample overall implying again that impacts of loneliness on HCU independent of health where present appear to be found in general practice rather than emergency department settings (2, 3, 7, 10, 12). In line with previous studies the size of the independent association found was small (1, 9) and while there are implications for health services resources at a population level, overall, it was clear that loneliness is not a major driver of additional HCU among older adults in Northern Ireland. Rather, in line with our hypothesis, the association between loneliness and HCU was largely explained by co-occurring poorer health. This is unsurprising given how frequently the associations between loneliness and poorer physical and mental health and health behaviors have previously been demonstrated in the literature already (14, 24–26).

The presence of associations between loneliness and GP visits in this analysis however, even if largely non-independent, demonstrates the fact that lonely older adults are likely to see their GP regularly, and thus provides further support for the primary care setting as a potential opportunity for an assessment of loneliness to become as routine as checking weight, blood pressure, alcohol consumption, smoking and diet as well as a point from which to redirect toward appropriate services and tailored resources where present. This assessment could be done using a brief validated measure such as the 3-item UCLA (27) given time constraints and the seeming inaccuracy of perception (28). In addition to the selection of a standardized assessment tool however, training and referral pathways will also be required to facilitate a useful response. Unfortunately, the evidence to date on effective interventions for loneliness remains greatly limited with further high-quality studies involving large samples and diverse populations needed (29, 30).

The lack of gender effects observed here may mean that the findings of our previous analysis of TILDA represent a spurious finding (12). Clearly further research is needed to clarify the existence of any consistent gender effects in loneliness and HCU, including in other jurisdictions. This is further complicated by evidence that men and women may report loneliness differently (31).

This cross-sectional replication also provided an opportunity to test these associations in an alternative health service setting, where healthcare is free to all at the point of access. Given the findings of the current study were comparable to our analysis of the Republic of Ireland (12) in terms of the sample overall, the differing access provided by these health service settings does not appear to explain overall associations. In short, while one might expect free healthcare would normally motivate more non-medical visits, this did not appear to be the case. The question that remains unanswered and outside the scope of this paper is why there is a perception that lonely older adults are more likely to visit GPs and A&Es regardless of health, it does seem in part to be based on stereotypical assumptions and views on who is lonely and does require further consideration (32).

Strengths and Limitations

This analysis is strengthened by the population representative sample of community dwelling adults aged 50 and over in Northern Ireland which the NICOLA study provided. The fact that the NICOLA study was modeled so closely on the design of the Irish Longitudinal Study of Aging (TILDA) further strengthened this as a cross-sectional replication of our analysis of the TILDA data. Thus, the majority of variables included in our previous study were replicated exactly in the NICOLA study with data also collected in the same way (*via* CAPI; SCQ and Health assessment) meaning a precise cross-sectional replication allowing comparison of population level data for respondents with a differing health service was possible. Finally, to our knowledge, this study is the second to date to explore the role of gender in associations between loneliness and HCU and confounding by health. It is also only the second analysis of loneliness and HCU to include health behaviors.

Limitations to the current analysis included the cross-sectional nature as only one wave of NICOLA data has been made available to date. A CAPI weight as applied in our TILDA analysis was also not yet available in NICOLA. Some minor differences in the data available were also present with NICOLA lacking equivalent data in relation to the presence of cataracts, glaucoma, or age-related macular degeneration which were included as 3 of the 26 possible doctor diagnosed chronic conditions included in defined presence of at least one condition in our previous TILDA analysis. Also missing was a scale assessing anxiety symptoms. In the absence of the IPAQ and CAGE measures substitutions were made in assessing physical activity and alcohol problem and models were adjusted for age group rather than continuous age. Similar to previous papers on loneliness and HCU where only cross-sectional data were available, this study was also somewhat limited by the way in which data were collected. Namely and as in previous papers on this topic, the outcomes, HCU, were recalled for previous 12 months while loneliness had been reported in relation to the present moment during data collection (3, 10). This is a clear limitation and must be taken into account in interpreting the findings of this and previous cross-sectional analyses (3, 10, 12). Some reassurance is provided however by the very similar patterns of results revealed both cross-sectionally and longitudinally in the prior TILDA analysis where data was collected in the same way (12). Nonetheless, further research is clearly needed, and future analyses should continue to seek to address this limitation by employing prospective data while also fully adjusting for health and health behaviors.

Conclusion

This population level study sought to replicate the recent cross-sectional analysis of loneliness and HCU in older adults in the Republic of Ireland adjusting for health and health behaviors as well as investigating the role of gender in associations. Consistent associations between loneliness and HCU which largely disappeared once health and health behaviors were accounted for were again observed. A single small association between UCLA score and GP visits persisted regardless of health and health behaviors, indicating that those with higher loneliness scores report visiting their GP a little more often independent of their health and health behaviors. Contrary to recent findings in the Republic of Ireland, no gender effects were present.

DATA AVAILABILITY STATEMENT

The data analyzed in this study is subject to the following licences/restrictions: The sample comprised participants from the Northern Ireland Cohort for the Longitudinal Study of Aging (https://nicola.qub.ac.uk/). Data is available upon application to the NICOLA team. Requests to access these datasets should be directed to nicola-research@qub.ac.uk.

ETHICS STATEMENT

This was a secondary analysis of the NICOLA study which involved human participants. Ethical approval for the NICOLA study was obtained from the School of Medicine, Dentistry and Biomedical Sciences Ethics Committee, Queen's University Belfast prior to data collection.

AUTHOR CONTRIBUTIONS

AB conceived the idea for the study, analyzed the data, and wrote the first draft of the manuscript. GL provided supervision, aided the writing process, and structure of the manuscript. RO'S was the principal investigator for this project, supervised the project, provided feedback on the design, the analysis, the structure of the manuscript, and assisted in review of the current paper. All authors read and approved the final manuscript.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Decomposition and Comparative Analysis of the Prevalence of and Factors Associated With Smoking Between the Rural and Urban Elderly Population in China: A National Cross-Sectional Study

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This study aimed to compare and analyse the differences in smoking prevalence, and knowledge, attitudes, and factors associated with smoking between the rural and urban elderly population in China. In total, 6,966 participants aged 60 and above were included in this study, which assessed their smoking-related knowledge, attitudes, and perceptions toward tobacco control. The Chi-square test and logistic regression model were used for statistical analysis, and the Fairlie model was used for decomposition analysis. The overall prevalence of smoking was 25.6%; the rate was much higher in men than in women (overall: OR = 26.234; urban: OR = 31.260; rural: OR = 23.889). The rate of correct responses to all questions on smoking problems was significantly higher among the urban elderly than the rural elderly. Further, 64.18% of the participants supported printing photos of the health hazards of smoking on the cover of cigarette packs, and the rural elderly were more supportive of this. Moreover, only 36.52% of the participants supported increasing taxation and retail price of cigarettes; the urban elderly showed more support for this. Rules about smoking at home also played an important role, especially for families where smoking was not allowed at home, but with exceptions to the rule; however, this factor was only meaningful in urban families (urban: OR = 0.117). Through the Fairlie decomposition analysis, gender (-1.62%), age (-2.03%), region (13.68%), knowing about e-cigarettes (5.17%), rules about smoking at home (3.95%), and smoking-related knowledge scores (42.85%) were found to be associated with rural-urban disparities. This study focused on the differences in smoking between urban and rural areas in China. Smoking among the urban elderly was significantly less prevalent compared with the rural population. Factors including education, region, and smoking-related knowledge need to be addressed to reduce the gap between urban and rural health hazards in China.

Keywords: elderly, tobacco, smoking, rural, urban, China, cross-sectional study

INTRODUCTION

With the rapid economic growth brought about by China's reform and opening-up policy, the living conditions of Chinese residents have improved rapidly, and education levels and health literacy have increased, leading to changes in resident's behaviors, increase in national exercise time, focus on balanced diet, and other factors; these changes have led to a continuous increase in life expectancy, as people have begun to pay greater attention to individual health (1–5). Interestingly, however, there is no significant change in tobacco consumption behavior (6, 7); according to the Chinese Center for Disease Control and Prevention (CCDC) survey report in 2019, although 81.8% of the people think that smoking is harmful to health, the smoking rate in China has not changed significantly (8). Current research evidence shows that smoking is a risk factor for several chronic diseases (6, 9, 10), and as a major tobacco producer and consumer of tobacco in the global market, China lies at the heart of this health crisis (11). According to a large-scale survey conducted by the CCDC in 2018, the prevalence of smoking among individuals aged 15 and above in China was 26.6%, slightly lower than 28.3% in 2010. In 2019, the prevalence of smoking in rural areas was 28.9%, and that in urban areas was 25.1%, indicating that a large number of people still continue to smoke (8).

Many medical studies have shown that smoking is more harmful to the health of the elderly (12–15). China's population is aging rapidly; according to the annual data of China's National Bureau of Statistics (16), 253 million people were over the age of 60 in 2019, accounting for 18.1% of the total population, an increase of 51.5% from 167 million in 2009. The rapid change in the population structure has further increased the disease burden of the elderly population in China. According to a survey conducted by the CCDC in 2019, 75.8% of people over 60 years of age in China suffered from one or more chronic diseases, and the presence of multiple diseases was relatively serious, especially for cardiovascular and cerebrovascular diseases, cancer, diabetes, and chronic respiratory diseases (17). The prevalence of hypertension, diabetes, and dyslipidemia was 58.3, 19.4, and 37.2%, respectively. According to the calculation of quality-adjusted life years, residents aged ≥ 70 years accounted for 39.1% of patients with central cerebrovascular diseases, 15.4% of those with cancer, 10.5% of COPD, 6.4% of Alzheimer's disease, and 2.2% of diabetes. The prevalence rate of chronic diseases in the urban elderly (79.6%) was higher than that in the rural elderly (73.8%); the prevalence rate in the eastern (78.0%) and central (77.1%) areas was significantly higher than that in the western (72.9%) areas (17).

In China, the health of the elderly is seriously threatened by tobacco, but there are many elderly smokers in both urban and rural areas (18). The goal of the Chinese government is to control the smoking rate among people aged 15 and above to 20% by 2030 (19). To achieve this goal, the elderly will be the focus of attention and the target group of policy implementation. This article is a special study on the smoking status of the elderly in China, and it is also the first large-scale investigation report on the smoking status of the elderly in China. We analyzed the smoking-related knowledge, attitudes, and behaviors of the elderly in China, and conducted a comparative analysis of the differences in smoking-related situations between the urban and rural elderly. We also evaluated the main factors associated with smoking among the elderly, aiming to provide reference data and suggestions for the implementation of tobacco control strategies in China and other countries.

Abbreviations: CCDC, Chinese Center for Disease Control and Prevention; GATS, Global Adult Tobacco Survey; OR, Odds ratios.

MATERIALS AND METHODS

Data Sources

The research data were taken from the Global Adult Tobacco Survey (GATS)-China 2018 (20); therefore, no ethics approval was required. The GATS China 2018 was a survey conducted by the CCDC. A total of 19,376 people were interviewed in 31 provinces in mainland China, using a multistage, stratified, cluster-randomized sampling design, recruiting community-based Chinese adults aged 15 years and older, Data available here (http://ghdx.healthdata.org/record/china-global-adult-tobacco-survey-2018, Accessed 26 Jan 2022). In each sampled geographic location, the households were randomly selected, and all eligible persons in each selected household were interviewed. However, only one household member was randomly selected and interviewed using a handheld device for rostering and data collection. Interviews were conducted privately by either male or female interviewers, the detailed design report is available here: (https://nccd.cdc.gov/GTSSDataSurveyResources/Ancillary/Publications.aspx, Accessed 26 Jan 2022). Based on our research needs, we selected 7,003 samples. After eliminating invalid data, 6,966 people were included in the study, the data processing flow is shown in **Figure 1**; there were 3,507 elderly people from urban areas and 3,459 from rural areas.

Analytical Index

Demographic Data

Details regarding demographic factors included residence (urban or rural), gender (male or female), age, residential status (living alone or not alone), region (east, west, or central China), educational level (elementary education or below, secondary education, higher education, and above), annual income (<10,000 RMB, 10,000–29,999 RMB, 30,000–49,999 RMB, or ≥50,000 RMB), employment status (retired, working, or not working), current smoking status (yes or no), awareness of e-cigarettes (yes or no), and rules about smoking at home (allow, not allowed but with exceptions, never allowed, no rules, do not know, or refuse to answer).

Knowledge of Smoking

All participants were asked to respond to 10 items to evaluate smoking knowledge; the questions including statements on smoking and the relationship between smoking and the consequences of specific diseases, with 1 point for correct answers and 0 points for wrong or uncertain answers.

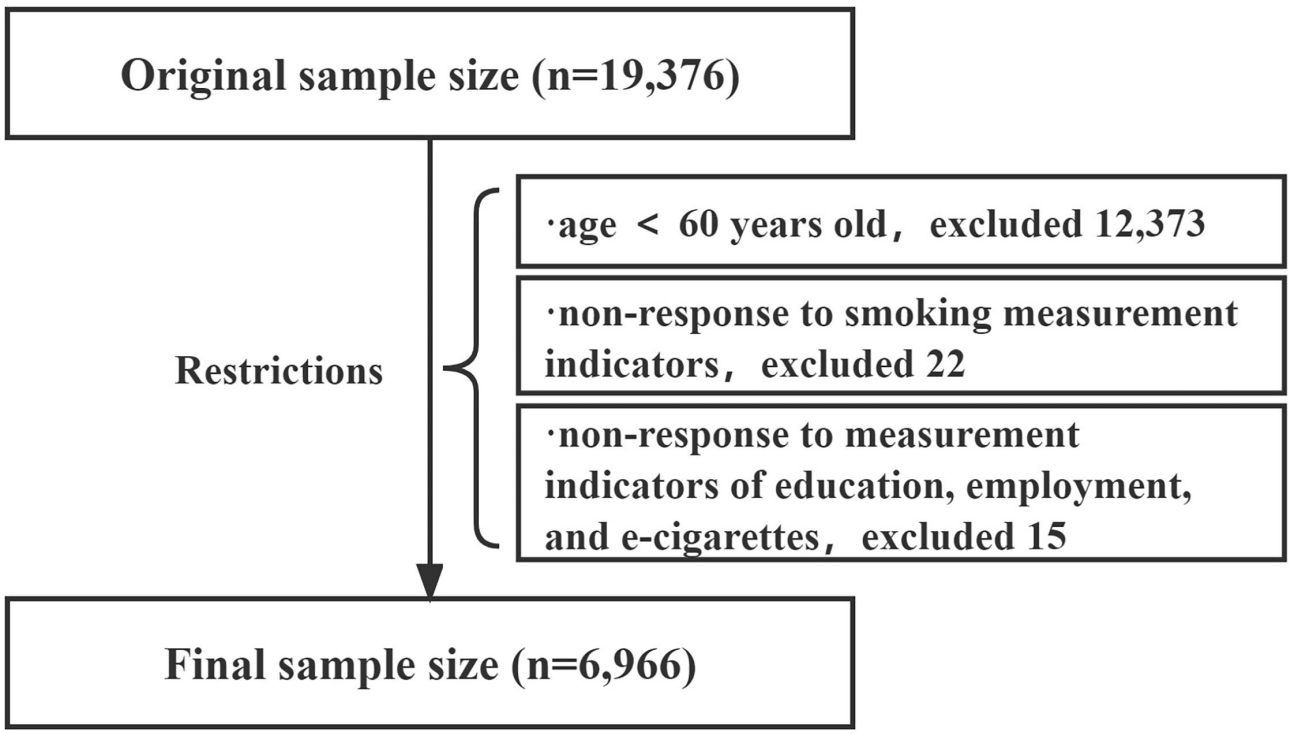

FIGURE 1 | Flowchart of study participant.

Attitudes Toward Smoking

Attitudes toward smoking were evaluated based on cigarette packaging and tobacco taxation. Respondents were shown pictures of cigarette packs with different health reminders to investigate intention of quitting among the elderly, and evaluate the role of cigarette packaging in tobacco control. The attitudes of the elderly toward tobacco taxation were evaluated through three questions and the differences in attitudes between the rural and urban elderly were analyzed.

Statistical Method

Statistical analysis was performed using SPSS 21.0. Descriptive statistics were used to describe demographic data and the proportion of answers in different groups of questionnaires. Chi-square test was used to analyse the univariate of urban and rural, the test standard was $\alpha = 0.05$, and multiple logistic regression model was established to evaluate the impact of different variables on smoking and quitting status (including $\alpha = 0.05$, excluding $\alpha = 0.10$). The Fairlie model was used for decomposition analysis; the construction of this model is explained in detail in Dr. Zhang's article (20). A two-tailed test of significance was conducted, with $P < 0.05$ as statistically significant.

RESULTS

Demographic Characteristics

A total of 6,996 elderly individuals were included in this study, of whom 3,393 (48.71%) were men and 3,573 (51.29%) were women (**Table 1**). The mean age was 69.22 (SD = 7.251) years; 50.34% of the participants lived in urban areas, 25.27% were living alone, 68.42% had a low educational level, 58.63% had an annual income < 30,000 RMB, and 58.73% still went to work. This survey showed that the prevalence of smoking among the elderly was 25.6%; the rate in urban areas was 23.0% and in rural was 28.3%, indicating a higher prevalence of smoking among the elderly people in rural areas ($P < 0.001$). Furthermore, more urban elderly people had heard of e-cigarettes ($P < 0.001$), and rural households were more likely to smoke ($P < 0.001$).

The distribution of smoking prevalence among the elderly by residence and region is shown in **Figure 2** (residence) and **Figure 3** (region). In total, the rate of smoking among men was 48.9%, and among women was 3.5%; men were more likely to smoke than women ($\chi^2 = 1{,}877.800$, $P < 0.001$). In urban areas, the rate of smoking prevalence was 45.6% in men and 2.8% in women, whereas, in the rural areas, it was 52.0% in men and 4.3% in women. According to the Chi-square test, the rural elderly men were more likely to smoke than the urban elderly men ($\chi^2 = 13.898$, $P < 0.001$), and rural women were also more likely to smoke than urban women ($\chi^2 = 5.931$, $P < 0.001$). At the regional level, the smoking rate in the eastern region was 23.2%, the central region was 27.7%, and the western region was 26.6%; there was no statistically significant difference in smoking rates between the central and western regions, while the difference between the eastern and western smoking rates and the eastern and central smoking rates were statistically significant, indicating that the smoking situation in the central and western regions was

TABLE 1 | Comparison of demographic characteristics and smoking status between the urban and rural elderly in China.

Characteristics	Urban [*n* (%)]	Rural [*n* (%)]	χ^2	*P*-value
Gender			7.257	0.007
Male	1,652 (47.1)	1,741 (50.3)		
Female	1,855 (52.9)	1,718 (49.7)		
Age			9.593	0.008
60–69 years	2,128 (60.7)	2,032 (58.7)		
70–79 years	960 (27.4)	1,057 (30.6)		
80 years or above	419 (11.9)	370 (10.7)		
Residential status			8.244	0.004
Living alone	834 (23.8)	926 (26.8)		
Not living alone	2,673 (76.2)	2,533 (73.2)		
Region			86.368	<0.001
East	1,592 (45.4)	1,196 (40.0)		
Central	1,021 (29.1)	1,249 (32.6)		
West	894 (25.5)	1,014 (29.3)		
Educational level			692.071	<0.001
Elementary education or below	1,919 (54.7)	2,847 (82.3)		
Secondary education	1,305 (37.2)	601 (17.4)		
Higher education and above	283 (8.1)	11 (0.3)		
Annual income			1031.529	<0.001
Very low (<10,000 RMB)	637 (18.2)	1,630 (47.1)		
Low (10,000–29,999 RMB)	822 (23.4)	995 (28.8)		
Middle (30,000–49,999 RMB)	822 (23.4)	426 (12.3)		
High (≥50,000 RMB)	1,084 (30.9)	295 (8.5)		
Don't know/Refuse	124 (4.0)	113 (3.3)		
Employment status			1959.293	<0.001
Retired	1,828 (52.1)	166 (4.8)		
Working	1,286 (36.7)	2,805 (81.1)		
Not working	393 (11.2)	488 (14.1)		
Current smoking status			26.152	<0.001
Smoking	805 (23.0)	979 (28.3)		
Not smoking	2,702 (77.0)	2,480 (71.7)		
Have you ever heard of e-cigarettes?			324.181	<0.001
Yes	1,010 (28.8)	397 (11.5)		
No	2,497 (71.2)	3,062 (88.5)		
Rules about smoking at home			424.361	<0.001
Allowed	995 (28.4)	1,387 (34.2)		
Not allowed but with exceptions	785 (22.4)	450 (13.0)		
Never allowed	1,131 (32.2)	607 (17.5)		
No rules	532 (15.2)	930 (26.9)		
Don't know/Refuse	64 (1.8)	85(2.5)		

the same, but the smoking situation in the eastern region was better than that in the central and western regions ($\chi^2 = 14.381$, $P < 0.001$).

Smoking-Related Knowledge

The response rate for correct answers to all the questions was higher among the urban elderly than the rural elderly (all $P < 0.001$) (**Table 2**). The question with the highest correct response rate was code 5; 73.9% of the elderly believed that smoking can cause serious diseases. The question with the lowest correct response rate was code 10; 88.8% of the elderly believed that the harm caused by low-tar cigarettes is inconsistent with regular cigarettes.

The average smoking-related knowledge score was 4.12 (SD = 3.068), among which the score for the urban elderly was 4.78 (SD = 3.076) and the rural elderly was 3.44 (SD = 2.907); 55.1% of the elderly had low smoking-related knowledge scores (**Table 3**). There were more elderly people in rural areas with low smoking

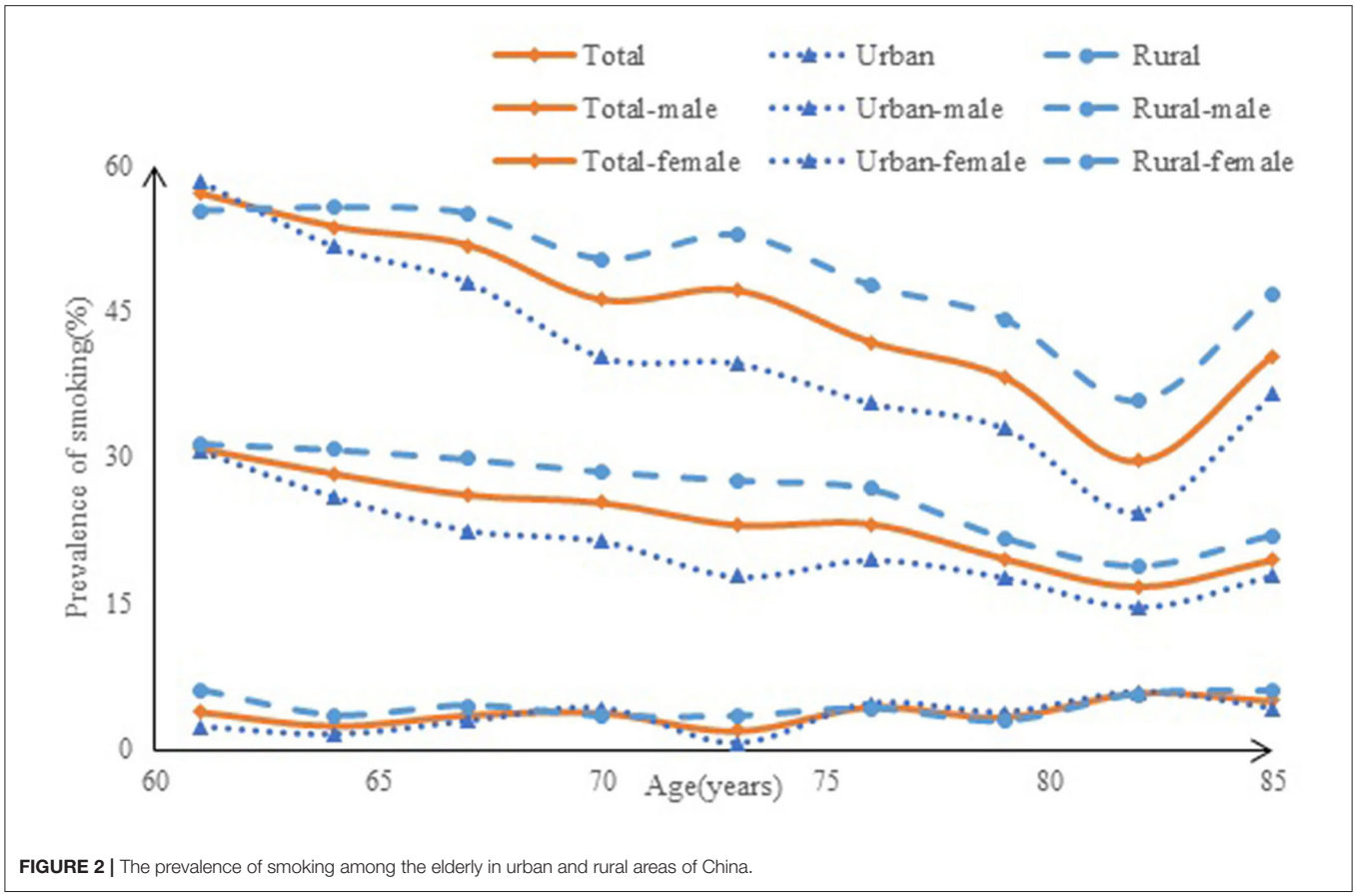

FIGURE 2 | The prevalence of smoking among the elderly in urban and rural areas of China.

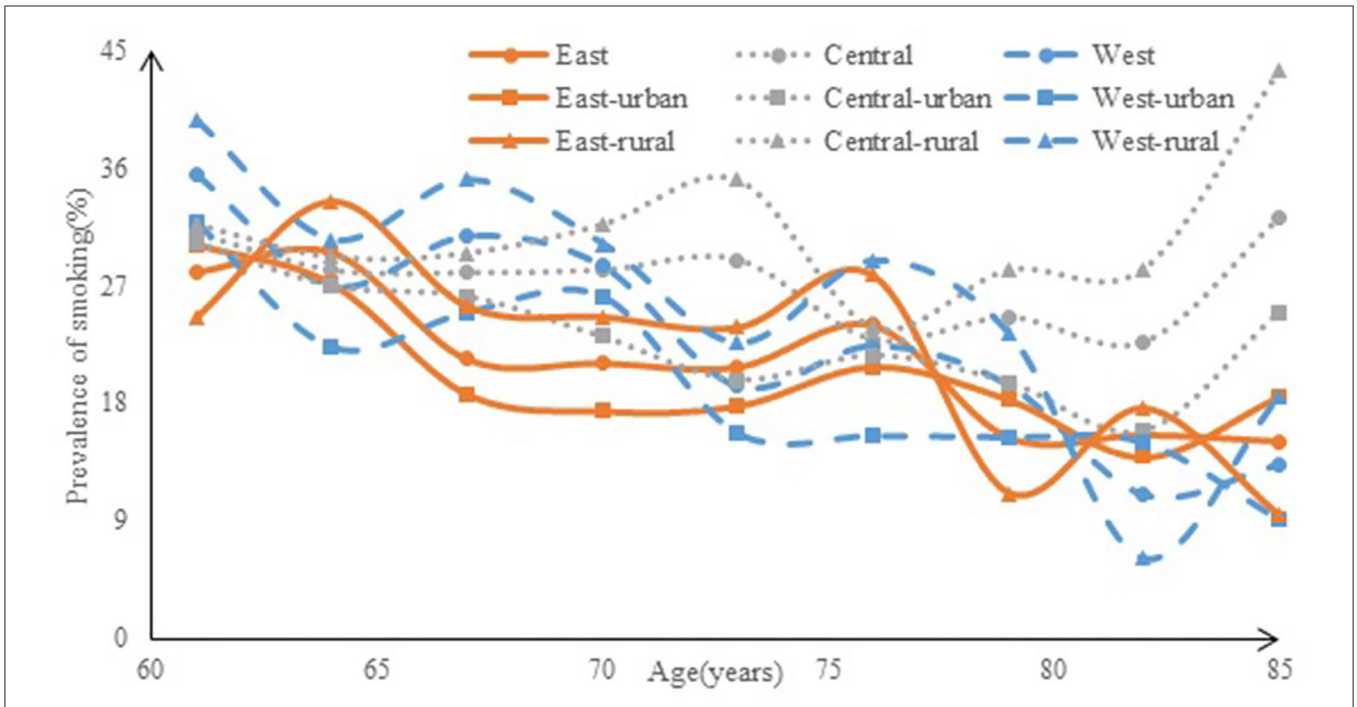

FIGURE 3 | The prevalence of smoking among the elderly by region.

TABLE 2 | Responses to smoking-related knowledge among the urban and rural elderly.

Code	Questions about smoking-related knowledge	Yes [*n* (%)]	No (Uncertain) [*n* (%)]	χ^2	*P*-value
1.	Second-hand smoke can cause serious illness among non-smokers.	3,480 (50.0)	3,486 (50.0)	328.220	<0.001
	Urban	2,130 (60.7)	1,377 (39.3)		
	Rural	1,350 (39.0)	2,109 (61.0)		
2.	Second-hand smoke can cause heart disease in adults.	1,976 (28.4)	4,990 (71.6)	176.898	<0.001
	Urban	1,245 (35.5)	2,262 (64.5)		
	Rural	731 (21.1)	2,728 (78.9)		
3.	Second-hand smoke can cause lung diseases in children.	3,071 (44.1)	3,895 (55.9)	346.953	<0.001
	Urban	1,932 (55.1)	1,575 (44.9)		
	Rural	1,139 (32.9)	2,320 (67.1)		
4.	Second-hand smoke can cause lung cancer in adults.	3,136 (45.0)	3,830 (55.0)	377.156	<0.001
	Urban	1,982 (56.5)	1,525 (43.5)		
	Rural	1,154 (33.4)	2,305 (66.6)		
5.	Smoking can cause serious illnesses.	5,145 (73.9)	1,821 (26.1)	64.072	<0.001
	Urban	2,737 (78.0)	779 (22.0)		
	Rural	2,408 (69.6)	1,051 (30.4)		
6.	Smoking can cause stroke (blood clots in the brain that may cause paralysis).	2,389 (34.3)	4,577 (65.7)	50.141	<0.001
	Urban	1,343 (38.3)	2,164 (61.7)		
	Rural	1,046 (30.2)	2,413 (69.8)		
7.	Smoking can cause heart disease.	2,891 (41.5)	4,075 (58.5)	53.603	<0.001
	Urban	1,606 (45.8)	1,901 (54.2)		
	Rural	1,285 (37.1)	2,174 (62.9)		
8.	Smoking can cause lung cancer.	4,700 (67.5)	2,266 (32.5)	159.375	<0.001
	Urban	2,613 (74.5)	894 (25.2)		
	Rural	2,087 (60.3)	1,372 (39.7)		
9.	Smoking can cause erectile dysfunction.	1,104 (15.8)	5,862 (84.2)	42.368	<0.001
	Urban	655 (18.7)	2,852 (81.3)		
	Rural	449 (13.0)	3,010 (87.0)		
10.	Do you think low-tar cigarettes are just as harmful as regular cigarettes?	777 (11.2)	6,189 (88.8)	113.287	<0.001
	Urban	531 (15.1)	2,976 (84.9)		
	Rural	246 (7.1)	3,213 (92.9)		

TABLE 3 | Distribution of smoking-related knowledge scores.

Scores	Urban	Rural	Overall	χ^2	*P*-value
0–4	1,581[a] (45.1)	2,256[b] (65.2)	3,837 (55.1)	302.057	<0.001
5–7	1,025[a] (29.2)	732[b] (21.2)	1,757 (25.2)		
8–10	901[a] (25.7)	471[b] (13.6)	1,372 (19.7)		

[a,b]Denote the statistical outcomes of the Chi-square pairwise comparison; the same characteristic indicates significance at P > 0.05, and a different characteristic indicates significance at P < 0.05.

knowledge scores, and more elderly people in cities in other segments, the overall score of the urban elderly was better than that of the rural elderly ($P < 0.001$).

Attitudes Toward Smoking

Cigarette Packages

The packaging of Chinese cigarette boxes resembles a delicate artwork; **Figure 4** shows some common cigarette packages in the Chinese market. The packet cover has a simple slogan: smoking is harmful to your health, and smoking cessation is healthy as soon as possible. The results of the survey showed that 42.66% of the participants noticed the health warning on cigarette packages, and the urban elderly were more likely to notice it ($P < 0.001$); people who smoked were more likely to notice the warning in both urban ($P < 0.001$) and rural ($P < 0.001$) areas than those who did not smoke (**Table 4**). Moreover, only 29.91% of the participants reported that the health warning on the packets made them think about quitting; most people (67.82%) thought the warning was useless, and there was no significant difference in this understanding between

FIGURE 4 | Some common cigarette packages in the Chinese market.

smokers and non-smokers in both urban ($P = 0.387$) and rural ($P = 0.050$) areas.

When these pictures were replaced with pictures that affect human health such as those in **Figure 5**, 47.13% of the participants said that the warning led them to think about quitting; the rate of support for the pictures increased to 17.22%, and there was no significant difference in this understanding between smokers and non-smokers in urban ($P = 0.855$) or rural ($P = 0.515$) areas. Thus, the pictures in **Figure 5** were more effective than those in **Figure 4** to make participants willing to quit smoking (**Table 5**), because the harmful effects of smoking are more obvious in **Figure 5** ($P < 0.001$). In total, 64.18% of the participants supported printing such a pictorial warning (**Figure 5**) on cigarette packages, and the rural elderly were more supportive of it ($P = 0.007$); non-smokers were more supportive of printing these pictures than smokers in both urban ($P < 0.001$) and rural ($P < 0.001$) areas.

In summary, cigarette packets still play an important role in tobacco control, and printing vivid pictures of adverse health consequences on cigarette packs can help reduce smoking prevalence among the elderly.

Tobacco Taxation

Only 36.52% of the participants supported increasing the tax on cigarettes and retail price of cigarettes; the urban elderly were more supportive of this ($P < 0.001$), and non-smokers were more supportive of it than smokers in both urban ($P < 0.001$) and rural ($P < 0.001$) areas (**Table 6**).

If there was an increase in the tax on cigarettes, 64.59% of the participants supported that part of the money should be spent on tobacco control; here too, the urban elderly showed more support ($P < 0.001$). Further, 76.14% of the participants supported the notion that part of the money should be spent on paying the costs of health insurance, and the urban elderly people were more supportive of this ($P < 0.001$). Regarding these two issues, non-smokers expressed greater support than smokers, in both urban and rural areas (all $P < 0.001$).

In China, a small number of elderly people supported an increase in tobacco taxation, and the supporters preferred to spend this part of the money on health insurance.

Sociodemographic Factors Associated With Smoking Status

A stepwise multiple logistic regression model was used to explore the factors that influenced smoking behavior among the elderly. Sociodemographic variables and smoking-related knowledge scores with statistically significant differences were used as independent variable X, and smoking status was set as dependent variable Y (0 = no smoking, 1 = smoking); the results of the model results are shown in **Table 7**. Gender, age, region, education, knowing about e-cigarettes, rules about smoking at home, and scores of smoking-related knowledge were major risk factors for smoking among the elderly; participants who were male, had a lower age (60–69 years), belonged to the central region, had an elementary education level or below, were allowed or never allowed or had no rules about smoking at home, had knowledge about e-cigarettes, and had low (0–4) or high (8–10) smoking-related knowledge scores were more likely to smoke. However, region was not a major factor for smoking among the urban elderly, and rules about smoking at home were not a major factor among the rural elderly.

Interestingly, when smoking was not allowed at home but there were exceptions to the rule, people found it easier not to smoke, whereas, those with low or high smoking-related knowledge scores were more likely to smoke.

Decomposition Analysis

This study aimed to determine the disparities in smoking prevalence and factors associated with it between the rural and urban elderly in China. The disparities between the two groups are shown in **Table 8**. In total, 53.45% of the disparities were enlightened by the factors considered, and 46.55% were caused by the factor of urban and rural residence. In addition, the results confirmed that gender (-1.62%), age (-2.03%), region (13.68%), knowing about e-cigarettes (5.17%), rules about smoking at home (3.95%), and smoking-related knowledge scores (42.85%)

TABLE 4 | Responses to the health warning on cigarette packages among urban and rural elderly.

Attitudes toward smoking	Urban [*n* (%)]	Rural [*n* (%)]	χ^2	*P*-value	Urban				Rural			
					Smoker [*n* (%)]	Non-smoker [*n* (%)]	χ^2	*P*-value	Smoker [*n* (%)]	Non-smoker [*n* (%)]	χ^2	*P*-value
Have you noticed any health warning on cigarette packages?			59.913	<0.001			616.242	<0.001			496.905	<0.001
Yes	1,591[a] (45.4)	1,381[b] (39.9)			669[a] (83.1)	922[b] (34.1)			669[a] (68.3)	712[b] (28.7)		
No	1,050[a] (29.9)	1,340[b] (38.7)			111[a] (13.8)	939[b] (34.8)			260[a] (26.6)	1,080[b] (45.3)		
Didn't see any cigarette packages	866[a] (24.7)	738[b] (21.3)			25[a] (3.1)	841[b] (31.1)			50[a] (5.1)	688[b] (27.7)		
Have warning labels on cigarette packages led you to think about quitting? (Sample size:1,364)			22.911	0.001			1.900	0.387			5.999	0.050
Yes	163[a] (24.0)	245[b] (35.8)			153[a] (23.8)	10[a] (27.0)			233[a] (36.1)	12[a] (30.8)		
No	501[a] (73.7)	424[b] (62.0)			476[a] (74.0)	25[a] (67.6)			400[a] (62.0)	24[a] (61.5)		
Don't know	16[a] (2.4)	15[a] (2.2)			14[a] (2.2)	2[a] (5.4)			12[a] (1.9)	3[b] (7.7)		
Randomly show 1 of 5 pictures to respondents (**Figure 5**)			3.846	0.427			0.886	0.927			5.188	0.269
1. Smoking and second-hand smoking cause lung cancer.	607 (18.7)	540 (20.3)			136 (18.3)	471 (18.8)			150 (19.9)	390 (20.4)		
2. Smoking causes chronic obstructive pneumonia.	675 (20.8)	519 (19.5)			156 (21.0)	519 (20.7)			165 (21.9)	354 (18.5)		
3. Smoking causes yellow teeth, bad breath, and periodontal disease.	656 (20.2)	551 (20.7)			144 (19.4)	512 (20.4)			151 (20.1)	400 (20.9)		
4. Smoking may cause impotence.	666 (20.5)	523 (19.6)			151 (20.4)	515 (20.5)			149 (19.8)	374 (19.5)		
5. Smoking causes peripheral vascular disease.	646 (19.9)	533 (20.0)			155 (20.9)	491 (19.6)			137 (18.2)	396 (20.7)		
If you see such a health warning on a cigarette package, would you consider to stop smoking? (Sample size:1,780)			0.234	0.890			0.313	0.855			1.326	0.515
Yes	791[a] (47.2)	48[a] (46.6)			303[a] (40.2)	18[a] (37.5)			488[a] (52.9)	30[a] (54.5)		
No	746[a] (44.5)	45[a] (43.7)			378[a] (50.1)	26[a] (54.2)			368[a] (39.9)	19[a] (34.5)		
Don't know/Refuse to answer	140[a] (8.3)	10[a] (9.7)			73[a] (9.7)	4[a] (8.3)			67[a] (7.3)	6[a] (10.9)		
Do you support printing such a pictorial warning (**Figure 5**) on cigarette packages?			9.999	0.007			64.628	<0.001			19.212	<0.001
Yes	2,201[a] (62.8)	2,270[b] (65.6)			452[a] (56.1)	1,749[b] (64.7)			666[a] (68.0)	1,604[a] (64.7)		
No	711[a] (20.3)	601[b] (17.4)			243[a] (30.2)	468[b] (17.3)			189[a] (19.3)	412[a] (16.6)		
Don't know	595[a] (17.0)	588[a] (17.0)			110[a] (13.7)	485[b] (17.9)			124[a] (12.7)	464[b] (18.7)		

[a,b]*Are the results of the Chi-square test pairwise comparison; the same characteristic indicates significance at P > 0.05, and a different characteristic indicates significance at P < 0.05.*

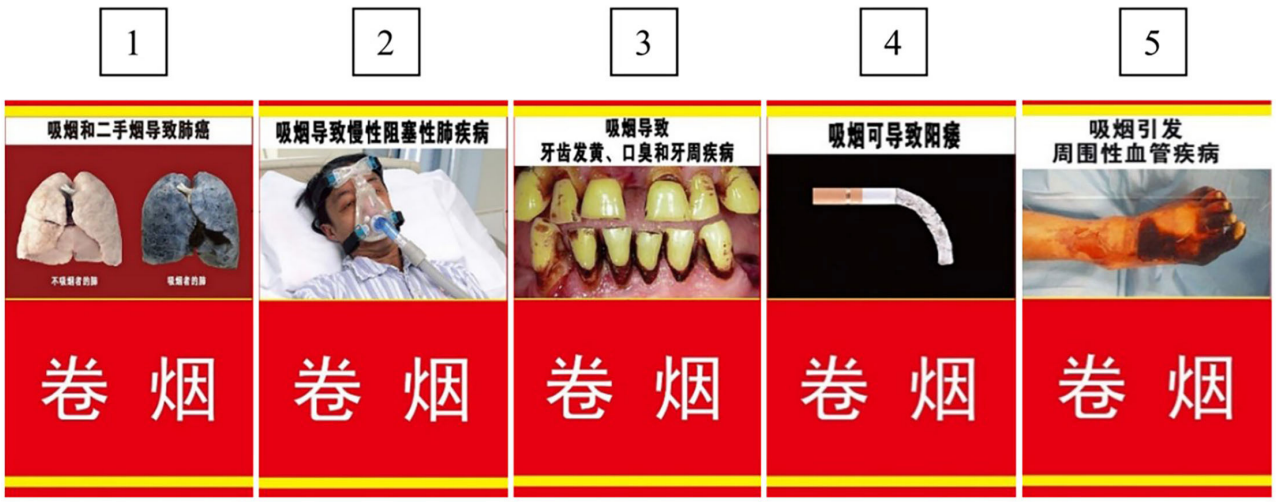

FIGURE 5 | Five pictures showing adverse effects of smoking.

TABLE 5 | Comparison of two types of pictures on cigarette packets to stop smoking.

Stop smoking	Figure 4	Figure 5	χ^2	*P*-value
Yes	408[a] (29.9)	839[b] (47.1)	185.879	<0.001
No	925[a] (67.8)	791[b] (44.4)		
Don't know/Refuse	31[a] (2.3)	150[b] (8.4)		

[a,b]Are the statistical outcomes of the Chi-square test pairwise comparison; the same characteristic shows significance at P > 0.05, and a different characteristic shows significance at P < 0.05.

significantly explained the variations in smoking behavior ($P < 0.05$).

DISCUSSION

To the best of our knowledge, this is the first large-scale comparative study to conduct a decomposition analysis of the prevalence of smoking between rural and urban areas, specifically focusing on the elderly population (aged 60 years and above) in China. This study revealed the distribution of smoking prevalence by gender and region, providing new empirical evidence for smoking behavior among the elderly. In addition, it assessed smoking-related knowledge, attitudes, and demographic characteristics of the elderly in urban and rural areas in China and analyzed the decomposition of each factor.

These results showed an overall 25.6% prevalence rate for smoking among the elderly, where the prevalence in urban areas was 23.0% and in rural areas was 28.3%. In total, the rate of prevalence was 48.9% in men and 3.5% in women; in rural areas, the rate was 45.6% in men and 2.8% in women, whereas, in urban areas, it was 52.0% in men and 4.3% in women. However, in both urban and rural China, smoking prevalence among men was much higher than that among women (overall: OR = 26.234; urban: OR = 31.260; rural: OR = 23.889). At the regional level, the rate of smoking prevalence in eastern, Central, and western China was 23.2%, 27.7%, and 26.6%, respectively; people in the central region were more likely to smoke than those in the eastern and western regions (central region, OR=1.265), but this difference was only found in rural areas (central region, OR = 1.530).

According to the *China Smoking Hazardous Health Report 2020,* released by the CCDC in 2021, the smoking prevalence among people aged 15 and above was 26.6% in 2018; the smoking prevalence in men was 50.5% and in women was 2.1% (21). Moreover, the prevalence in urban and rural areas was 25.1 and 28.9%, respectively (21). Overall, our results are similar to those of Ding et al. (22); smoking rates decreased with age in both urban and rural areas, and in both men and women, the smoking rate among the elderly was slightly lower than the national average in China. Notably, in both urban and rural areas, the smoking rate among men decreased with age, but hardly changed with age among women.

Our study revealed that the rate of correct responses to all smoking-related problems was significantly higher among the urban elderly compared with the rural elderly, perhaps because urban residents have better educational opportunities and can learn more about the effects of smoking (20). The stepwise multiple logistic regression model showed that gender, age, region, education, knowing about e-cigarettes, rules about smoking at home, and smoking-related knowledge scores were major risk factors for smoking in the elderly; age and education were found to be protective factors against smoking. However, it was not that people with higher smoking-related knowledge scores are less likely to smoke; only moderate smoking-related knowledge scores served as protective factors against smoking. Some studies have shown that this may be because people with higher scores are those who had better academic qualifications,

TABLE 6 | Responses to tobacco taxation among the urban and rural elderly in China.

Questions about increasing taxation and retail price of cigarettes	Urban [*n* (%)]	Rural [*n* (%)]	χ^2	*P*-value	Urban				Rural			
					Smoker [*n* (%)]	Non-smoker [*n* (%)]	χ^2	*P*-value	Smoker [*n* (%)]	Non-smoker [*n* (%)]	χ^2	*P*-value
Do you support an increase in the taxation and retail price of cigarettes?			66.015	<0.001			367.060	<0.001			160.767	<0.001
Yes	1,444[a] (41.2)	1,100[b] (31.8)			205[a] (25.5)	1,239[b] (45.9)			255[a] (26.0)	845[b] (34.1)		
No	914[a] (26.1)	1,041[b] (30.1)			419[a] (52.0)	495[b] (18.3)			448[a] (45.8)	593[b] (23.9)		
Don't know/No opinion/Refuse	1,149[a] (32.8)	1,318[b] (38.1)			181[a] (22.5)	968[b] (35.8)			276[a] (28.2)	1,042[b] (42.0)		
If there was an increase in the tax on cigarettes, do you think part of the money should be spent on tobacco control (e.g., support cessation services and warning against tobacco hazards advocacy)?			18.595	<0.001			76.204	<0.001			28.419	<0.001
Yes	2,351[a] (67.0)	2,148[b] (62.1)			486[a] (60.4)	1,865[b] (69.0)			578[a] (59.0)	1,570[b] (63.3)		
No	242[a] (6.9)	278[a] (8.0)			110[a] (13.7)	132[b] (4.9)			117[a] (12.0)	161[b] (6.5)		
Don't know/No opinion/Refuse	914[a] (26.1)	1,033[b] (29.9)			209[a] (26.0)	705[a] (26.1)			284[a] (29.0)	749[a] (30.2)		
If there was an increase in the tax on cigarettes, do you think part of the money should be spent on paying some of the costs of health insurance?			31.319	<0.001			33.284	<0.001			23.424	<0.001
Yes	2,759[a] (78.7)	2,545[b] (73.6)			600[a] (74.5)	2,159[b] (79.9)			701[a] (71.6)	1,844[a] (74.4)		
No	153[a] (4.4)	143[a] (4.1)			64[a] (8.0)	89[b] (3.3)			66[a] (6.7)	77[b] (3.1)		
Don't know/No Opinion/Refuse	595[a] (17.0)	771[b] (22.3)			141[a] (17.5)	454[a] (16.8)			212[a] (21.7)	559[a] (22.5)		

[a,b]*Are the statistical outcomes of Chi-square test pairwise comparison; the same characteristic indicates significance at P > 0.05, and a different characteristic indicates significance at P < 0.05.*

TABLE 7 | Results of the logistic regression for sociodemographic characteristics associated with smoking status.

Variable	Overall		Urban		Rural	
	OR	95%CI	OR	95%CI	OR	95%CI
Gender						
Female	1.00		1.00		1.00	
Male	26.234**	(21.528, 31.969)	31.260**	(22.942, 42.594)	23.889**	(18.431, 30.962)
Age						
Low (60–69 years)	1.00		1.00		1.00	
Middle (70–79 years)	0.501**	(0.393, 0.640)	0.422**	(0.295, 0.604)	0.556**	(0.400, 0.775)
High (80 years or above)	0.688**	(0.533, 0.887)	0.756	(0.523, 1.120)	0.626**	(0.443, 0.886)
Region						
East	1.00		-		1.00	
Central	1.265**	(1.067, 1.499)	-	-	1.530**	(1.209, 1.937)
West	1.026	(0.865, 1.217)	-	-	1.094	(0.875, 1.367)
Education level						
Elementary education and below	1.00		1.00		1.00	
Secondary education	0.475**	(0.323, 0.698)	0.493**	(0.323, 0.752)	0.107*	(0.013, 0.908)
Higher education and above	0.483**	(0.332, 0.701)	0.491**	(0.331, 0.728)	0.117*	(0.014, 0.991)
Have you ever heard of e-cigarettes?						
No	1.00		1.00		1.00	
Yes	1.764**	(1.486, 2.095)	1.686**	(1.334, 2.123)	1.844**	(1.419, 2.395)
Rules about smoking at home						
Allowed	1.00		1.00		-	
Not allowed, but with exceptions	0.308**	(0.172, 0.552)	0.117**	(0.038, 0.358)	-	-
Never allowed	0.981	(0.538, 1.790)	0.429	(0.138, 1.329)	-	-
No rules	1.179	(0.684, 2.147)	0.628	(0.202, 1.951)	-	-
Don't know/Refuse	0.640	(0.355, 1.153)	0.415	(0.134, 1.288)	-	-
Scores of smoking-related knowledge						
0–4	1.00		1.00		1.00	
5–7	0.674**	(0.558, 0.814)	0.606**	(0.465, 0.791)	0.751*	(0.570, 0.989)
8–10	1.023	(0.834, 1.256)	0.946	(0.717, 1.247)	1.136	(0.831, 1.553)

*Significant at $P < 0.05$; **Significant at $P < 0.01$.

occupations that are more inclined to mental work or retired, may be subject to greater mental stress or bored, and compared with elderly people who scored low, those with high scores were often from urban areas, with a higher constant pension, and thus, had stronger purchasing power for cigarettes (6, 7, 20).

In this study, we found that living alone, annual income, and occupation are no longer the main factors influencing smoking behavior among the elderly smoking; these results are different from previous studies (23, 24). It is worth noting that people who had heard of e-cigarettes were more likely to smoke; however, this may be because smokers are more likely to hear about e-cigarettes, which is consistent with existing survey results among adults (25–27). At the same time, we found that family rules can also play a role, especially where smoking at home is not allowed but there are exceptions to the rule (overall: OR = 0.308; urban: OR = 0.117); nevertheless, this factor was only significant in urban families.

Elderly people in both urban and rural areas supported printing photos of the serious health hazards of smoking on the cover of cigarette packs. At present, most of the designs on Chinese cigarette packs are artistic and exquisite, which elicits a desire for collection and is not conducive to smoking control (28). An appeal should be urgently made to the Chinese government to draw attention to this detail; the existing cover designs should be changed and replaced with pictures showing the harmful effects of smoking (29, 30).

In China, a small number of elderly people supported an increase in tobacco taxation, and the supporters preferred to spend this money to cover health insurance costs. Studies by scholars such as Nigar Nargis and Xiao Hu showed that the current price of cigarettes in China is decreasing, and people who buy low-priced cigarettes often smoke more frequently. The scholars believe that raising the price of cigarettes and thus making cigarettes less affordable could have a larger impact on reducing the number of cigarettes smoked, particularly for elderly smokers, smokers with low levels of education, and smokers from rural areas, which, in turn, could benefit these vulnerable groups by reducing their health burden and economic costs attributed to smoking (31, 32).

TABLE 8 | The Fairlie decomposition model of smoking status between urban and rural.

Terms of decomposition			**Smoking status**	
Difference			0.05348886	
Explained (%)			0.02858828 (53.45)	
Non-explained (%)			0.02490058 (46.55)	
Contribution to differences	***β***	***P*-value**	**Contribution (%)**	**[95%CI]**
Explained				
Gender	0.0132741	<0.001	−1.62	(0.0119426, 0.0146057)
Age	−0.0005792	0.008	−2.03	(−0.0010063, −0.0001521)
Residential status	−0.0004633	0.606	46.43	(−0.002223, 0.0012964)
Region	0.0039109	<0.001	13.68	(0.0021276, 0.0056941)
Educational level	0.0101457	0.054	35.49	(−0.0001549, 0.0204464)
Employment status	0.0014767	0.842	7.57	(−0.0130856, 0.0160389)
Annual income	0.0021653	0.661	−51.45	(−0.0075007, 0.0118312)
Have you ever heard of e-cigarettes?	−0.0147092	<0.001	5.17	(−0.0212032, −0.0082152)
Rules about smoking at home	0.0011291	0.001	3.95	(0.0004849, 0.0017732)
Scores of smoking-related knowledges	0.0122492	<0.001	42.85	(0.0063375, 0.0181609)

Using the Fairlie model, we conducted a decomposition analysis and found that gender (-1.62%), age (-2.03%), region (13.68%), knowing about e-cigarettes (5.17%), rules about smoking at home (3.95%), and scores of smoking-related knowledges (42.85%) were associated with rural-urban disparities in smoking.

Based on the differences in smoking between the urban and rural elderly population, our conclusions have strong policy recommendations. First, we need to focus on the men living in rural areas, and the elderly with low levels of education; Chinese family doctors should assume the function of health education to help them realize the health hazards of smoking. Second, based on regional disparities, we need to pay attention to the elderly smoking situation in the central and western regions of China; it has been recommended to funds for tobacco control should be allotted to the central and western regions (20). Finally, we suggest that the Chinese government should increase the public awareness of the health hazards of smoking, reduce or ban the advertising of e-cigarettes (25), compel pictures of the health hazards of tobacco to be printed on the cover of cigarette packets (29, 30), and increase the tax on tobacco and use the money to cover health insurance, thus benefiting public health and welfare (31–33). In summary, smoking is still highly prevalent among the elderly in China, and the government should continue to increase tobacco control efforts to promote healthy lifestyles for the elderly.

Limitations

This study has several limitations which should be noted. First, China is a country with a very large elderly population; the amount of cross-sectional survey data used in this study was limited and did not cover the entire elderly population. Second, smoking among the elderly is affected by many factors, and only some of these were analyzed in the current study. Despite these limitations, the results are useful in comparing the differences in smoking between the elderly in urban and rural areas in China, and provide guidelines for strategies to control smoking among the elderly in China. We aim to collect more data and analyse more factors in follow-up studies to verify the rationality of our results.

CONCLUSION

This study focused on the differences in smoking between the elderly residents of urban and rural areas in China. Smoking among the urban elderly was significantly less prevalent than among the rural population. Factors including education, region, and propaganda need to be addressed to reduce the gap between urban and rural health hazards in China. Our findings can help provide empirical evidence to develop health policies and strategies to reduce the differences in health risk factors between China's urban and rural elderly population.

DATA AVAILABILITY STATEMENT

The datasets analyzed in this study can be found on the GATS website: http://ghdx.healthdata.org/record/china-global-adult-tobacco-survey-2018 (accessed on 26 January 2022).

ETHICS STATEMENT

The data for this study were taken from the GATS survey, which is organized by the CCDC, and has been approved by the National Ethics Committee, the data analyzed here are available in the public domain. Therefore, separate ethical approval was not required for this study.

AUTHOR CONTRIBUTIONS

LY and JS designed the study. ZZ, YX, and JW controlled the quality of the data and performed statistical analysis. LY,

MD, and LL managed and checked all the data. LY, ZZ, JW, and YX contributed to manuscript preparation, editing, and review. All authors have read, checked, and approved the final manuscript.

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Effect of Acupuncture for Mixed Urinary Incontinence in Women: A Systematic Review

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Background: Mixed urinary incontinence increasingly undermines women's quality of life. Previous studies showed some effects of acupuncture for MUI, but no systematic review has been done to evaluate the efficacy and safety of acupuncture for MUI in women.

Objective: To systematically review the efficacy and safety of acupuncture for women with MUI.

Methods: Ten databases (i.e., PubMed, Web of Science, Embase, ClinicalTrials.gov, the Cochrane Library, CBM, Scoups, CNKI, VIP and WANFANG DATA) were searched up to July 19th, 2021, using tailored search strategies with keywords not limited to "female," "mixed urinary incontinence," "acupuncture," and "randomized controlled trial," etc. RCTs and quasi-RCTs were included if investigating effect of any type of acupuncture for female patients with MUI. Data were extracted from eligible studies, and risks of bias were assessed according to the Cochrane Handbook from seven aspects using the RevMan 5.4 software.

Results: A total of three randomized studies with 591 women were included. The risk of bias among the studies varied, with major concerns on blinding of participants and outcome assessor. Liu's study (497) mainly showed that electroacupuncture's effect on reduction of numbers of incontinence, urgency, nocturia episodes, and amount of urine leakage etc. was not inferior to that of PFMT-Solifenacin group at 12, 24, and 36 weeks. Zhan's study (60) showed that electroacupuncture reduced significantly more amount of urine leakage than Tolterodine at 8 weeks, with no data on incontinence episodes frequency. All 3 studies reported that acupuncture significantly increased the quality of life assessed by ICIQ score. In addition, incidence of acupuncture-related adverse events was rare, while antimuscarinic agents related adverse events were common in two studies.

Conclusion: Although acupuncture showed some benefit for women with MUI, more evidences were required to draw a solid conclusion of effectiveness and safety of acupuncture for women with MUI.

Systematic Review Registration: https://www.crd.york.ac.uk/PROSPERO, identifier: CRD42021224600.

Keywords: mixed urinary incontinence, women, systematic review, acupuncture, effect

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INTRODUCTION

Mixed urinary incontinence (MUI), as a type of urinary incontinence (UI), presents with involuntary leakage associated with urgency and also with exertion, effort, sneezing or coughing, which is more bothersome than either stress or urgency incontinence alone (1–3). MUI was predicted to affect more women than men (4) and its epidemiological data varied widely. For example, prevalence rates of MUI among women were 0.7–26.6, 15.7–36.6, 9–18, and 40% in China, United State, Egypt, and England, respectively (5–8).

Pathophysiological mechanisms of MUI are unclear (9). It might be a combination of the mechanisms of stress urinary incontinence (SUI) and urgency urinary incontinence (UUI), namely, intrinsic urethral sphincter deficiency, urethral hypermobility, detrusor overactivity, or combinations of above factors (10). Although MUI is less common than stress urinary incontinence, previous studies have shown that women with MUI may have lower level of quality-of-life than those with SUI or UUI alone (11).

Nowadays pelvic floor muscle training (PFMT) is recommended as the first-line therapy for MUI (12), even if it focuses more on the stress component and requires 3–6 months to reach its full effect (1). Its success depends on the patient's knowledge of the training program and adherence (13). Pharmacological managements including antimuscarinic agents, Beta 3-adrenergic agonists and Duloxetine are recommended as the second-line therapy (2, 14), however, the former two medicines are only effectively for the urgency component of MUI rather than the stress component (15, 16), while Duloxetine is on the contrary (17). Surgery is considered only when stress urinary incontinence is the pre-dominant component of MUI and failed with conservative treatments (2), and yet surgery might also worsen the symptoms of urgency for patients with MUI (18). Hence, management of mixed incontinence is very challenging due to poor response to current therapeutic approaches, and lacking of treatment tackling both stress and urgency symptoms of MUI (2).

Acupuncture is widely accepted as an alternative treatment. Existing studies (19–21) show that acupuncture can improve symptoms for patients with urinary incontinence, but they focused on pure SUI or pure UUI. There were no systematic reviews evaluating the effectiveness and safety of acupuncture for female with MUI. Therefore, we conducted this systematic review to investigate whether acupuncture has effect on MUI among female patients.

METHODS

The systematic review was conducted in the light of the Cochrane Handbook for Systematic Review of Interventions (22) and was registered at the National Institute for Health Research PROSPERO, International Prospective Register of Systematic Reviews https://www.crd.york.ac.uk/PROSPERO, Registration Number: CRD42021224600.

Literature Research

Ten databases including PubMed, Web of Science, Embase, ClinicalTrials.gov, the Cochrane Library-Trials, Scoups, CBM, CNKI, VIP and WANFANG DATA were searched from inception up to July 2021. The keywords included "female," "mixed urinary incontinence," "urinary incontinence," "acupuncture," "electroacupuncture," "scalp acupuncture," "auricular acupuncture," "intradermal acupuncture," "abdominal acupuncture," "dry needle," "fire needle," or "elongated needle," "randomized controlled trial," "quasi-randomized controlled trial," "RCTs," etc. The tailored search strategy was developed for each database, and the search was completed on July 19th, 2021 (refer to **Appendix A** for detailed search strategies).

Inclusion and Exclusion Criteria

Studies would be included if they were (1) investigating adult female patients diagnosed with MUI: the symptoms should combine both SUI and UUI symptoms; (2) randomized controlled trials (RCTs) or quasi-RCTs; (3) comparing any type of acupunctures (including manual acupuncture (MA), electroacupuncture (EA), scalp acupuncture, auricular acupuncture, intradermal acupuncture, abdominal acupuncture, dry needle, fire needle or elongated needle) with surgery, sham acupuncture, medicine, any other non-surgical therapies, or no treatment; (4) evaluating outcome variables on amount of urine leakage in 1 h, urinary incontinence episodes, micturition frequency, and nocturia episodes in 24 h, severity of urinary urgency, quality of life, and etc. No limit was placed for time of publication and language.

Studies would be excluded if they were (1) patients with pure SUI or pure UUI; (2) comparing one type of acupuncture with another type of acupuncture; (3) case report or series, cross-sectional studies, self-controlled studies, case-control studies, cohort studies, other observational studies or laboratory experiments; (4) reviews, protocols, secondary analysis, conference abstracts or posters; (5) not providing outcome data or information.

Study Selection and Data Extraction

All the search results were downloaded and managed by the EndNote (version X8). Two independent reviewers (ZL and HC) reviewed titles and abstracts of all retrieved articles according to the inclusion and exclusion criteria. Then full texts of articles were retrieved from above mentioned databases where necessary and reviewed carefully by the two reviewers (ZL and HC) to confirm eligible studies, and any disagreement was resolved by the supervisor (ZL).

When studies had multiple publications, the one reporting the latest or complete outcome data was included. Another two researchers (XW and SY) extracted data from the original publications, including authors' name, country, year of publication, study design, sample size, patient's mean age, treatment type and regimen of experiment and control group, frequency and duration of treatments, follow-up time, outcome measures and results, and adverse events.

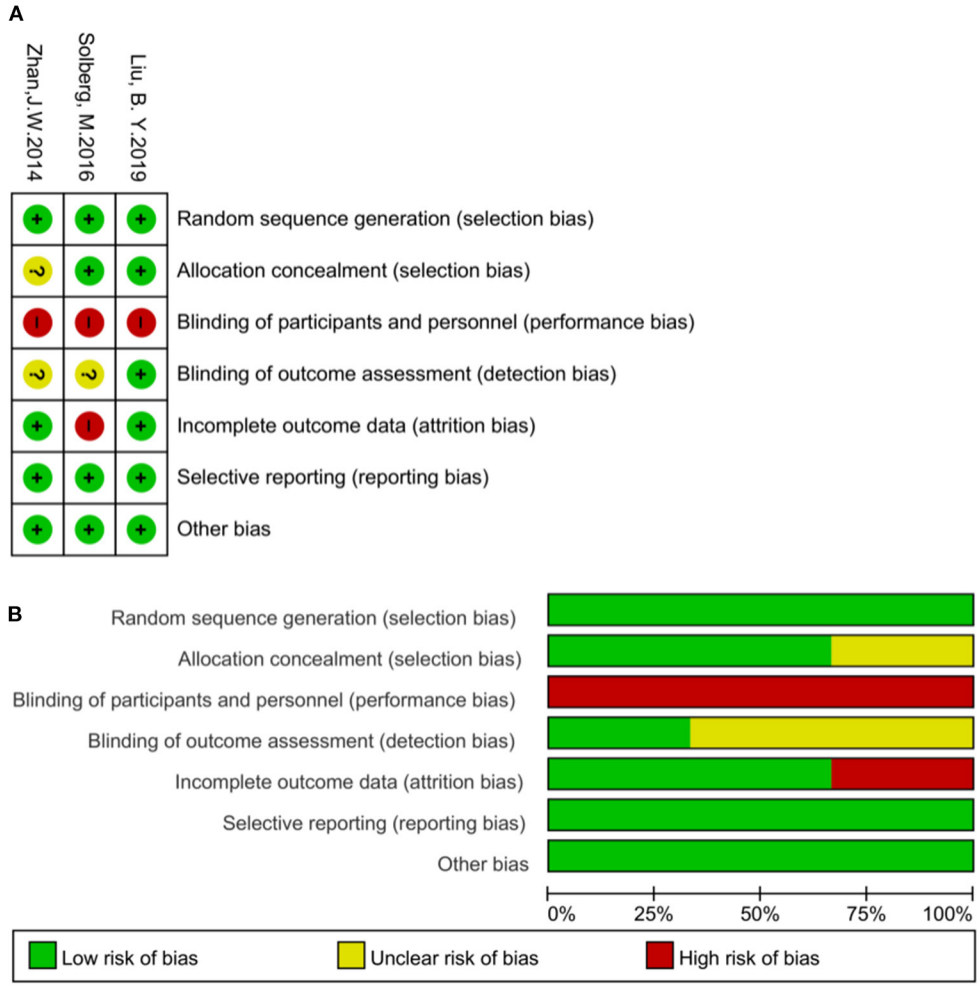

FIGURE 1 | (A) Risk of bias summary: review authors' judgements about each risk of bias item for each included study. **(B)** Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages for all included studies.

Assessment of Risk of Bias

Risk of bias of each study included was assessed according to the Cochrane Handbook from seven aspects, including random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessor, incomplete outcome data, selective reporting and other bias by using software- Review Manager 5.4 (22). Two independent researchers (ZL and HC) assessed included studies for risk of bias, and any disagreement was resolved by discussion.

Data Analysis and Synthesis

For continuous outcome variables, the mean difference (MD) with 95% confidence intervals (CIs) was used to present treatment effect between treatment groups. For dichotomous variables, risk ratio (RR) with 95% CIs was adopted to report difference on treatment effects.

Meta-analysis would be undertaken to synthesize outcome variables using dedicated software-Review Manager 5.4 only if the interventions were homogeneous based on clinical criteria. Whereas, qualitative analysis would be done if high heterogeneity was found among included studies.

RESULTS

Literature Search and Study Selection

There were 157 studies identified from ten databases, out of which 25 were reviewed in full text. Two studies were excluded as independent data on MUI were not available (23, 24). Eventually three RCTs were eligible and included in the analysis. The flowchart of selection process of studies was shown in **Figure 1**.

Characteristics of the Included Studies

The three included trials enrolled 591 women with MUI. Liu et al.'s study described MUI type of patients (48.3% stress-predominate, 35.8% urge-predominate, 15.9% balanced) (25), while the other two studies (26, 27) did not distinguish MUI type of patients. Substantial variation was found on design of study and control group among included studies, of which one

compared EA with Tolterodine (26), one compared MA with PFMT and waiting, respectively (27), and one compared EA with solifenacin plus PFMT (25). Apart from duration of single treatment session (30 min on average), high heterogeneity was found among treatment regimen in acupuncture group across studies, including type of acupuncture (EA and MA), frequency and total duration of treatment, acupoints selected, intensity and frequency of electric current of EA, etc (**Table 1**).

In terms of outcome variables, amount of urinary leakage was assessed in Liu et al.'s and Zhan et al.'s study by pad test (25, 26). Number of incontinence episode, micturition, nocturia episodes, urgency and patients using urine pads, as well as improvement degree by the Patient Global Impression of Improvement (PGI-I) and patient satisfaction, were only evaluated in Liu et al.'s study using 72-h bladder voiding diary (25). Quality of life was assessed in all three studies (25–27) by the International Consultation Incontinence Questionnaire Short Form (ICIQ-SF). Adverse events were reported by Liu et al. and Solberg et al.'s studies (25, 27). **Table 2** summarized the outcomes of included studies.

Assessment of Risk of Bias

Among the three studies included in this review, all had random sequence generation, Liu et al. and Solberg et al. reported concealment of allocation (25, 27), Zhan et al.'s study (26) did not report how allocation concealment was done. None of the studies (25–27) blinded subjects in consequence of open-label trials which compared acupuncture with drugs, PFMT or no intervention, while Liu et al.'s study (25) reported blinding of outcome evaluators. Solberg et al.'s study (27) had high risk of attrition bias as its dropout rate was >40% and did not report how the missing data was dealt with. There was no reporting bias or other bias identified in any of the studies. Risk of bias assessment is presented in **Figure 2**.

Effect of Acupuncture

EA vs. PFMT and Solifenacin

Liu et al.'s study (25) reported a multicenter, randomized controlled, non-inferiority trial to compare the efficacy and safety of EA with a combination of PFMT and solifenacin for women with MUI.

The study reported that the percentage of reduction from baseline in mean 72-h incontinence episode frequency (IEF) over weeks 1–12 (primary outcome) was comparable in EA and PFMT-solifenacin group (37.83 vs. 36.49%, $P > 0.05$). Non-inferiority for the percentage of reduction from baseline in mean 72-h IEF in EA group was sustained up to 36 weeks since initiation of the treatment.

Change in amount of urine leakage measured by 1-h pad test, as recommended by the International Continence Society (28), was not significantly different between the two groups at week 4 ($P = 0.8$) and week 12 ($P = 0.36$). The proportions of participants with at least 50% reduction in the mean 72-h IEF were also comparable between the two groups weeks 1–12 ($P = 0.77$), weeks 13–24 ($P = 0.52$), and weeks 25–36 ($P = 0.44$), respectively.

Improvements were observed on all other secondary outcome measures in both groups, including change in 72-h urgency/incontinence/nocturia episodes, number of participants using urine pads and weekly mean use of urine pads, and no significant difference between groups was found at any of the follow-up assessments except for the number of participants using urine pads during weeks 1–12 ($P < 0.001$).

The study reported that the changes in the ICIQ-SF score were similar in EA and PFMT-solifenacin groups at weeks 12, 24, and 36 without statistical differences ($P = 0.37$, $P = 0.17$, $P = 0.43$, respectively). Notably, the decline of ICIQ-SF score in EA group were higher than the minimum clinically important difference (MCID) of 4 (29).

In addition, the EA group had better satisfaction (satisfaction and marked satisfaction) rates compared to PFMT-solifenacin group at week 12 (71.6 vs. 60.68%) with a statistical difference ($P = 0.01$).

Total incidence of adverse events in EA group was significantly lower than that in PFMT-solifenacin group (16.47 vs. 36.69%, $P < 0.001$). Four percent of patients in EA group reported EA related mild subcutaneous hematoma and did not require any treatment, while, 28.22% of patients in PFMT-solifenacin group reported digestive system symptoms, especially dry mouth (25%), which led to poor tolerance and patient compliance.

EA vs. Tolterodine

Zhan et al.'s study (26) reported a single-center RCT of 60 women with MUI to investigate the clinical effect of EA in comparison with Tolterodine. The study adopted similar treatment regimen to Liu et al.'s study (25) in terms of frequency of treatment (3-time per week) and electric current for EA (10/50 Hz), but with two more acupoints (ST36, SP6) and less total treatment duration (8 weeks).

The study adopted 24 h-pad test to evaluate the change on amount of urine leakage, which provides more information for the estimation of the incontinence severity (30), and ICIQ-SF score for quality of life. It was found that the patients in EA group had more reduction from baseline on among of urine leakage compared with that in tolterodine group (-2.1 ± 2.26 vs. -0.64 ± 0.97, $P = 0.001$), and the change on ICIQ-SF score from baseline in EA group was significantly more than that in tolterodine groups at week 8 (-7.09 ± 3.00 vs. -3.17 ± 2.73, $P < 0.001$). However, neither outcome data at longer follow up time, nor any kinds of adverse event was reported in this study. Additionally, it only mentioned the random number table for patient's allocation without any description on allocation concealment.

Acupuncture vs. PFMT vs. Waiting

Solberg et al. (27) conducted a three-arm RCT to examine the efficacy of acupuncture in comparison with PFMT and waiting groups among 34 women with MUI in a 12-week period. The manual acupuncture (30-min per time) was applied for 12 times in 12 weeks, and PFMT (10-min per time) was conducted once a day for 12 weeks. However, only 20 women completed the trial in total, with 8 in MA group, 6 in PFMT group and 6 in waiting group, and the dropout rates were as high as 25% in MA group, 40% in PFMT group, and 50% in waiting group, respectively.

TABLE 1 | Characteristics of studies included in the review.

Author (year, country, design)	Population		Sample Size (drop-outs)			Age (years, mean ± SD)			Intervention			Follow-up (weeks)		Outcome
	T	C	T		C	T		C	T		C	T	C	
Zhan (2014, China, RCT)	FMUI		30 (0)		30 (0)		Not reported		Electroacupuncture 1. Acupoints: BL33, BL35, ST36, SP6. 2. BL33, BL35: a depth of 50 to 60 mm. 3. 30-min/time at 10/50 Hz, 0.1–5.0 mA 4. 3-time/week for 8 weeks.		Tolterodine 2 mg orally, one tablet, once a day for 8 weeks	None		1. Urine leakage measured by pad test (g)/24 h 2. ICIQ-SF
Solberg (2016, Norway, RCT)	FMUI		12 (4)	10 (4)	12 (6)	60.75 ± 14.98	63.63 ± 15.20	52.50 ± 14.37	Manual acupuncture 1. Acupoints: CV3, CV4, CV6, SP6, KI3, KI7, BL31-34, BL23, BL28, GV4, GV20 2. 30-min/time 3. 12 times in 12 weeks.	Pelvic floor muscle training (PFMT) 1. One individual consultation with A specialist trained female physio-therapist before PFMT 2. Writing an exercise diary every day 3.10-min/time, daily for 12 weeks	No treatment	12		1. ICIQ-SF 2. Adverse event

(Continued)

TABLE 1 | Continued

Author (year, country, design)	Population		Sample Size (drop-outs)		Age (years, mean ± SD)		Intervention		Follow-up (weeks)		Outcome
	T	C	T	C	T	C	T	C	T	C	
Liu (2019, China, RCT)	FMUI (Stress-dominant: 53.01% Urge-dominant: 33.33% Balanced: 13.65%)	FMUI (Stress-dominant: 43.55% Urge-dominant: 38.31% Balanced: 18.15%)	249 (4)	248 (13)	54.70 ± 10.01	53.70 ± 9.40	Electroacupuncture 1. Acupoints: BL33, BL35. 2. A depth of 50 to 60 mm. 3. 30-min at 10/50 Hz, 0.1–5.0 mA. 4. 3-time/week for 12 weeks.	Solifenacin + pelvic floor muscle training 1. 5 mg orally, once a day for 36 weeks 2. Intensive exercises (1–12 wks: once/week; 13–36 wks: once/month) + homebased exercise (3 times/day) for 36 weeks	24	None	1. Percentage change in 72 h IEF 2. Reduction ≥ 50% in 72 h-IEF 3. Urgency/urination/nocturia episodes /72 h 4. Urine leakage measured by the 1 h pad test (g) 5. Weekly mean no. of urine pads used 6. No. of participants using urine pads 7. ICIQ-SF 8. Patient satisfaction 9. Improvement degree 10. Adverse event

T, treatment group; C, control group; SD, standard deviation; FMUI, female with mixed urinary incontinence; RCT, randomized control trial; ICIQ-SF, International Consultation on Incontinence Questionnaire-Short Form; IEF, incontinence episode frequency.

TABLE 2 | Summary of outcomes.

References	Outcome measured		Experiment group			Control group			Difference of changes	
			Baseline	After treatment	Changes	Baseline	After treatment	Changes	MD or RR (95% CI)*	*P*-value*
Zhan et al. (26)	Urine leakage measured by pad test (g)/24 h (Mean ± SD)		18.27 ± 4.68	16.17 ± 4.94	−2.10 ± 2.26	15.61 ± 3.43	14.97 ± 3.84	−0.64 ± 0.97	−1.46 (−2.34, −0.58)	0.001
	ICIQ-SF (Mean ± SD)		16.30 ± 1.80	9.21 ± 3.34	−7.09 ± 3.00	14.42 ± 2.08	11.25 ± 3.50	−3.17 ± 2.73	−3.92 (−5.37, −2.47)	<0.001
Solberg et al. (27)	ICIQ-SF (Mean ± SD)		11.00 ± 3.06	5.97 ± 3.66	−5.03 ± 1.57	7.25 ± 2.26 (PFMT)	6.37 ± 3.31	−0.88 ± 2.93 (PFMT)	−4.15 (−6.73, −1.57)	0.002
						10.75 ± 3.06 (waiting)	9.62 ± 3.51	−1.13 ± 1.76 (waiting)	−3.90 (−5.68, −2.12)	<0.001
	Adverse events [*n* (%)]			25.00%(2/8)			16.67%(1/6) (PFMT)		1.50 (0.71, 12.94)	0.71
							0.00%(0/6) (waiting)		3.89 (0.22, 68.67)	0.35
Liu et al. (25)	Percentage change in 72 h IEF	1–12 wks			−37.83 ± 33.25			−36.49 ± 59.30	−1.34 (−9.78, 7.10)	<0.001
		13–24 wks			−58.20 ± 40.13			−56.69 ± 40.82	−1.52 (−8.63, 5.6)	0.68
		25–36 wks			−64.20 ± 36.79			−65.48 ± 37.44	1.28 (−5.24, 7.81)	0.70
	Reduction ≥ 50% in 72 h-IEF [*n* (%)]	1–12 wks		109/248 (44.00%)			112/239 (46.90%)		0.94 (0.77, 1.14)	0.52
		13–24 wks		174/245 (71.00%)			164/235 (69.80%)		1.02 (0.91, 1.14)	0.77
		25–36 wks		190/245 (77.60%)			189/235 (80.00%)		0.96 (0.88, 1.06)	0.44
	Urgency episodes/72 h (Mean ± SD)	1–12 wks	8.4 ± 9.4	5.78 ± 11.40	−2.62 ± 4.63	8.5 ± 8.3	5.51 ± 9.59	−2.99 ± 4.70	3.70 (−0.45, 1.19)	0.38
		13–24 wks		3.65 ± 11.45	−4.75 ± 4.55		3.73 ± 9.62	−4.77 ± 4.66	0.02 (−0.79, 0.83)	0.96
		25–36 wks		2.85 ± 11.40	−5.55 ± 4.63		2.55 ± 9.55	−5.55 ± 4.74	0.00 (−0.82, 0.82)	1

(Continued)

TABLE 2 | Continued

References	Outcome measured		Experiment group			Control group			Difference of changes	
			Baseline	After treatment	Changes	Baseline	After treatment	Changes	MD or RR (95% CI)*	*P*-value*
	Urine leakage measured by pad test (g)/h (Mean ± SD)	Week 4	19.70 ± 25.70	12.96 ± 32.96	−6.74 ± 9.54	18.9 ± 19.80	11.94 ± 24.05	−6.96 ± 9.68	0.22 (−1.47, 1.91)	0.8
		Week 12		7.54 ± 33.55	−12.16 ± 8.17		7.41 ± 24.92	−11.49 ± 8.28	−0.67 (−2.12, 0.78)	0.36
	Weekly mean use of urine pads (Mean ± SD)	1–12 wks	8.50 ± 1.33	8.00 ± 1.00	−0.50 ± 1.20	9.00 ± 1.50	8.75 ± 1.67	−0.25 ± 1.60	−0.25 (−0.50, 0.00)	0.05
		13–24 wks		7.00 ± 1.00	−1.50 ± 1.20		8.25 ± 1.67	−0.75 ± 1.60	−0.75 (−1, −0.50)	<0.001
		25–36 wks		7.5 ± 1.00	−1.00 ± 1.20		8.25 ± 1.67	−0.75 ± 1.60	−0.25 (−0.50, 0.00)	0.05
	No. of participants using urine pads [*n* (%)]	1–12 wks	136/249 (54.62%)	86/248 (34.68%)		150/248 (60.48%)	105/240 (43.75%)		0.57 (0.47, 0.70)	<0.001
		13–24 wks		68/244 (27.87%)			80/237 (34.60%)		0.83 (0.63, 1.08)	0.16
		25–36 wks		59/244 (24.1%)			72/237 (30.38%)		0.78 (0.59, 1.07)	0.13
	IEF/72h (mean ± SD)	1–12 wks	11.90 ± 9.90	7.34 ± 12.17	−4.56 ± 4.63	11.70 ± 9.80	7.33 ± 11.99	−4.37 ± 4.66	−0.19 (−1.03, 0.65)	0.66
		13–24 wks		4.63 ± 12.22	−7.27 ± 4.55		4.75 ± 12.02	−6.95 ± 4.62	−0.32 (−1.13, 0.49)	0.44
		25–36 wks		3.59 ± 12.41	−8.31 ± 4.23		3.48 ± 12.22	−8.22 ± 4.30	−0.09 (−0.84, 0.66)	0.81
	Urination episodes /72 h (mean ± SD)	1–12 wks	31.20 ± 11.90	27.97 ± 14.58	−3.23 ± 5.64	29.90 ± 9.40	26.28 ± 10.51	−3.62 ± 5.70	0.39 (−0.61, 1.39)	0.44
		13–24 wks		25.24 ± 14.36	−5.96 ± 5.96		24.28 ± 10.12	−5.62 ± 6.07	−0.34 (−1.40, 0.72)	0.53
		25–36 wks		24.18 ± 13.8	−7.02 ± 6.68		23.79 ± 9.13	−6.11 ± 6.83	−0.91 (−2.10, 0.28)	0.13
	Nocturia episodes/72 h (mean ± SD)	1–12 wks	3.90 ± 3.00	3.11 ± 3.10	−0.79 ± 2.05	3.80 ± 3.10	2.93 ± 3.57	−0.87 ± 1.77	0.08 (−0.26, 0.42)	0.64

(Continued)

TABLE 2 | Continued

References	Outcome measured		Experiment group			Control group			Difference of changes	
			Baseline	After treatment	Changes	Baseline	After treatment	Changes	MD or RR (95% CI)*	*P*-value*
		13–24 wks		2.52 ± 3.36	−1.38 ± 1.81		2.47 ± 3.53	−1.33 ± 1.81	−0.05 (−0.37, 0.27)	0.76
		25–36 wks		2.32 ± 3.44	−1.58 ± 1.73		2.22 ± 3.57	−1.58 ± 1.77	0.00 (−0.31, 0.31)	1
	ICIQ-SF (mean ± SD)	1–12 wks	12.70 ± 2.50	8.74 ± 3.12	−3.96 ± 2.86	12.90 ± 2.20	9.17 ± 3.29	−3.73 ± 2.90	−0.23 (−0.74, 0.28)	0.37
		13–24 wks		6.26 ± 4.49	−6.44 ± 3.90		6.93 ± 4.36	−5.97 ± 3.78	−0.47 (−1.15, 0.21)	0.17
		25–36 wks		5.64 ± 4.20	−7.06 ± 3.66		6.1 ± 4.27	−6.80 ± 3.70	−0.26 (−0.91, 0.39)	0.43
	Patient satisfaction[a] [*n* (%)]	Week 12		71.60% (174/243)			60.68% (142/234)		1.18 (1.04, 1.34)	0.01
		Week 36		76.23% (186/244)			71.37% (167/234)		1.07 (0.96, 1.19)	0.23
	Improvement degree[b]	Week 12		63.11% (154/244)			54.27% (127/234)		1.16 (1.00, 1.35)	0.05
		Week 36		73.47% (180/245)			70.64% (166/235)		1.15 (0.77, 1.72)	0.49
	Adverse events [*n* (%)]			41/249 (16.47%)			91/248 (36.69%)		0.45 (0.32, 0.62)	<0.001

MD, mean difference; RR, Relative Risk; SD, standard deviation; IEF, incontinence episode frequency; ICIQ-SF, International Consultation on Incontinence Questionnaire-Short Form.

**MD, RR, and P-value were calculated based on data provided in the original papers using Revman V5.4. MD was calculated as mean difference of treatment effect (post-treatment value minus baseline value) in each group.*

[a]Satisfaction with treatment outcome measured on a 5-point Likert scale (marked dissatisfaction to marked satisfaction).

[b]Improvement degree measured by Participant Global Impression Improvement on a 7-point Likert scale (marked worsening to marked improvement).

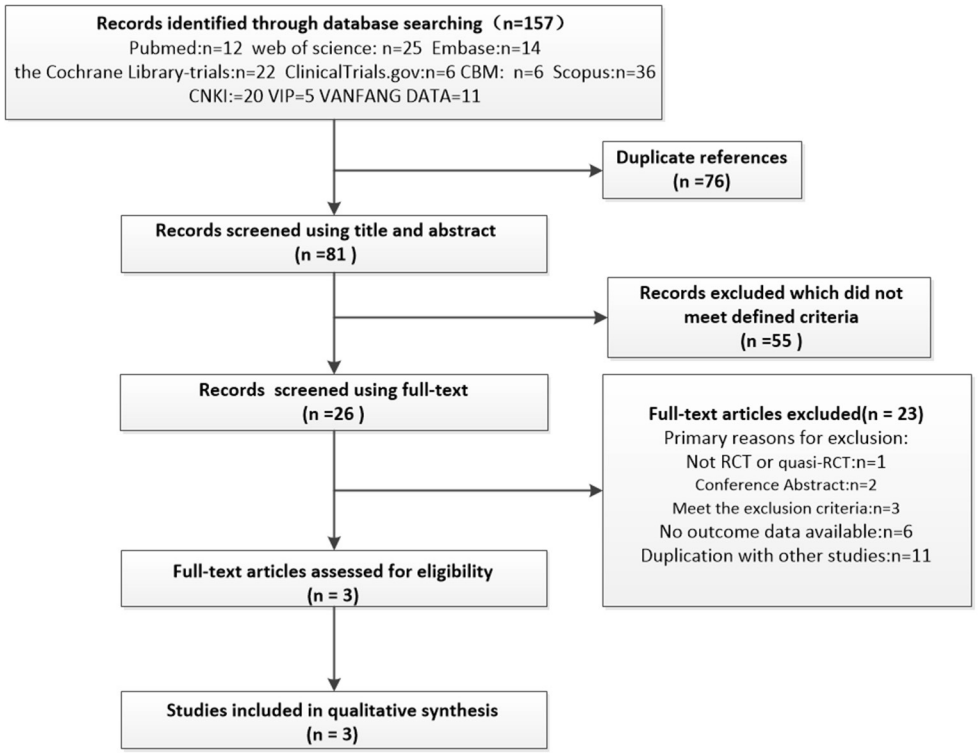

FIGURE 2 | The flowchart of the selected studies.

The study showed that the reduction of ICIQ-SF score from baseline in MA group was significantly more than that in either PFMT (-5.03 ± 1.57 vs. -0.88 ± 2.93, $P = 0.002$) or waiting (-5.03 ± 1.57 vs. 1.13 ± 1.76, $P < 0.001$) groups at week 12. However, no data on amount of urine leakage, numbers of incontinence episodes or micturition etc was reported, nor did the long-term effect of treatment in either group. Two women experienced adverse events (one with fatigue and one with worsened incontinence after the initial few therapies) in acupuncture group, one woman reported worsened incontinence in PFMT group at the beginning.

DISCUSSION

Two included studies showed that EA could reduce the amount of urine leakage. One study with sound quality and large sample size showed that the effect of EA was not inferior to PFMT-solifenacin on improvement of incontinence, and another study with relatively small sample size reported that EA showed more benefit on reduction of involuntary loss of urine than Tolterodine. All three included studies indicated EA/MA could improve patient's quality of life. However, the risk of bias among the three studies varied, with major concerns on risk of blinding of participants and outcome assessor. And small sample size (26, 27) and high drop-out rate (27) were found in two third of included studies made it even more challenging to draw a conclusion on the effect of acupuncture on MUI.

As we know, the underlying mechanism of acupuncture on urinary incontinence has been discussed in a number of previous studies, which showed that sacral, pudendal and pelvic nerve had a vital role in pathogenesis and treatment of urinary continence (31). Acupuncture on the lumbosacral points may strengthen the function of sympathetic and pudendal nerves, suppressing excessive contractions and overactivity of detrusor, and improving bladder compliance to treat urgent incontinence (32). In addition, it may also promote the contraction of the pelvic floor muscle, increasing the stability of the pelvic floor structure to relieve the symptom of stress incontinence (33). However, rigorous evidence to proof above mechanisms and effect of acupuncture on MUI is not yet adequate to guide clinical practice, compared with evidences on acupuncture for stress urinary alone (34).

As found in this review, studies tried to provide evidences on acupuncture's effect using diverse outcome measurements. As a recommended measurement to quantify the amount of urine leakage for patient with UI, the pad test was often used with a length of 1- or 24-h (35). In this review, two studies reported that the effect of EA was equivalent or better than that of interventions of control groups by comparing changes on amount of urine leakage between the two groups (25, 26). However, the pad test was not able to provide specific information to help researchers to trace whether the decreased

amount of urine leakage was from improvement of stress or urgency symptoms or both after acupuncture treatment (36). In contrast, the 72-h voiding diary, another recommended approach, could separately quantify the change on stress and urgent incontinence by recording the numbers of each type of urinary incontinence (37). With such measurement, Liu et al.'s study added further evidences in favor of EA on MUI at the completion of treatment at 12 weeks and longer follow-up at 36 weeks, in comparison to active treatments (PFMT and Solifenacine) (25). In addition, all 3 included studies (25–27) provided data on quality of life, and showed that both EA and MA could generate clinically significant improvement on quality of life measured by ICIQ-SF scores with a MCID of 4 (29). Such results were consistent with previous systematic review of 15 studies (38). However, given the high heterogeneity found among population (severity of symptoms etc.), study design (especially design of control group and statistical methods used), treatment regimens (i.e., the selection of acupoints, intensity of electric current, frequency and length of treatment) and outcome measures, as well as inadequate number of studies included, it was unlikely to conduct a meta-analysis to estimate the pooled effect size.

In terms of the safety of acupuncture, two studies reported adverse events (25, 27), and found that the incidence rate of adverse events of acupuncture was comparable with PFMT alone (27), but significantly lower than that of PFMT-solifenacin (25). It was well known that the frequent occurrence of adverse events of antimuscarinic agents, such as dry mouth and constipation, can lead to patients' poor compliance and thus reduce treatment effect (39), either used alone or combined with other treatments. For safety consideration, novel and alternative treatments for urgent or mix incontinence is worth exploring and more evidences are required.

It is also worth mentioning that none of the studies used placebo/sham acupuncture as control group to evaluate the net effect size of acupuncture. Although Solberg's trial (27) compared the effect of acupuncture with no treatment (waiting for acupuncture or PFMT), the small sample size (34 participants) and a high drop-out rate (more than 40%) undermined the reliability of its conclusion. This has shed a light for future studies of acupuncture for MUI that placebo/sham acupuncture as control group should be considered to provide more data on net effect of acupuncture.

The study has several limitations. First, the number of studies retrieved and included in this review was very limited. And varied levels of risk of bias and heterogeneity found across studies on proportion of patients with various types of MUIs, treatment regimen, outcome measures selection and sample size etc made it impossible to synthesize the result of individual study. As a result, we cannot provide an overall estimation of the effect size of acupuncture on MUI. Secondly, due to the limited information on baseline characteristics and outcome data collected from the three studies, it was impossible to weigh out the effect size of acupuncture on either urgent or stress component of MUI. In addition, the review only focused on female patients due to the overwhelming incidence of MUI in women compared with men, still it could hinder the generalizability of the result to male population.

CONCLUSION

Although acupuncture showed some benefit on reducing the amount of urine leakage and number of incontinence episodes for women with MUI, more evidences were required to draw a solid conclusion of effectiveness and safety of acupuncture among women and even broader population with MUI. Furthermore, it is necessary to optimize study design (i.e., using placebo/sham acupuncture/no treatment as control group), standardize the outcome measurement and use of EA and MA, etc. in order to generate more rigorous evidence to guide the clinical practice in the future.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

ZLi: conceptualization. ZLo, HC, and SY: study selection and data extraction. XW and SY: software and analysis. ZLo, HC, and ZLi: writing. All authors have read and agreed to the published version of the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.827853/full#supplementary-material

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The Impact of Dependency Burden on Urban Household Health Expenditure and Its Regional Heterogeneity in China: Based on Quantile Regression Method

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Background: The aging population has led to a growing health expenditure burden. According to the National Bureau of Statistics of China, the old-age dependency ratio rose from 10.7% in 2003 to 17.8% in 2019, and health expenditure increased from 658.410 billion yuan in 2003 to 5812.191 billion yuan in 2019 in China.

Methods: This paper utilizes the quantile regression method to discuss the influencing factors of health expenditure in urban China based on the China Household Finance Survey (CHFS), especially dependency burden. Moreover, its regional heterogeneity is also compared.

Results: The old-age dependency ratio, age, family size, self-rated health status, and income significantly impact the health expenditure of urban families in the quantile regression of the national sample. Dependency burden and other variables on urban household health expenditure have great regional heterogeneity. The relationship between urban health expenditure and residential areas in western China is more stable than that in eastern and central China.

Discussion: Government should improve the healthcare system suitable for the older adult population as soon as possible. The government of western China should pay more attention to the introduction of professional medical talents and the configuration of precision medical equipment to improve the health system in western China.

Keywords: dependency burden, health expenditure, regional heterogeneity, quantile regression method, aging

INTRODUCTION

The aging population has led to a growing medical and health expenditure burden worldwide. For example, people over the age of 65 increased from 96.92 million in 2003 to 176.03 million in 2019, an increase of 81.62%. The old-age dependency ratio rose from 10.7% in 2003 to 17.8% in 2019, with a growth rate of 66.36% in China (National Bureau of Statistics of China, 2020). As a result, the health expenditure increases too rapidly. Global scholars have given great importance to health expenditure since the 1950s and found that the influencing factors of health expenditure mainly include income level, education level, medical insurance, and so on.

Income Level and Health Expenditure

The influence of income on health expenditure is mostly positive. For example, Newhouse (1) found that the continuous growth of health expenditure was positively correlated with income in the United States. Ross et al. (2) used 3-year cross-sectional data of the Health and Retirement Study (HRS) to find that the preventive health expenditure of poor workers was lower than that of higher-income workers. Costa-Font et al. (3) concluded that the income elasticity of health expenditure is <1, and Reeves and Kee (4) found that the income elasticity of health expenditure is only 0.5. In China, Hou and Ren (5) used panel data to show that total health expenditure would increase with gross domestic product (GDP) growth. Xu and Chen (6) analyzed the health expenditure of urban and rural residents in 29 provinces of China and concluded that the health expenditure of rural residents was more sensitive to income. Tian and Qu (7), Xu et al. (8), and Xie et al. (9) suggest that income difference is an important reason for the difference in health expenditure between urban and rural residents.

Education and Health Expenditure

In addition to income level, education level also affects the health needs of residents, which in turn affects health expenditure. Mwabu et al. (10) found that the improvement in education level would enhance health awareness and make them more willing to pay more for health expenditure in Kenya. Hjortsberg (11) found that education level was one of the most important factors that affect the health expenditure of Zambian residents. Sato (12) used the two-digit model to find that the demand for healthcare services is directly proportional to education in Ghana. Mackenbach et al. (13) found that absolute inequalities in acceptable mortality due to healthcare conditions remained stable over time between low and high levels of education, while relative inequalities widened between 1980 and 2010 in 17 European countries. In China, Tian et al. (14) showed that health expenditure is significantly positively correlated with education level, especially in western China. Dai and Li (15) used a spatial autoregressive model to find that the health expenditure of urban residents is negatively correlated with education level. Zhang et al. (16) adopted the dynamic generalized moment estimation method and showed a negative relationship between health expenditure and per capita education years in rural regions.

Health Insurance and Health Expenditure

Countries around the world hope to improve health insurance to reduce the medical burden on residents. Hurd and McGarry (17) found that older adults with medical insurance have a higher probability of using medical care services. Biro (18) and Kavosi et al. (19) found that medical insurance effectively affects health expenditure in Europe. Azam (20), Wu et al. (21), and Sepehri and Vu (22) all confirmed that urban residents' participation in medical insurance can effectively avoid the persecution of family catastrophic medical expenses. In China, Fang et al. (23) concluded that the health expenditure of families without social medical insurance was significantly higher than that of insured families (23). According to the panel data of the Chinese Longitudinal Healthy Longevity Survey (CLHLS), Wang and Zheng (24) found that the promotion effect of medical insurance on health expenditure had significant differences between urban and rural regions. Xiong and Huang (25) used the Blinder–Oaxaca decomposition model and found that medical insurance policy is an important factor that leads to the differences in health expenditure between urban and rural residents.

Dependency Burden on the Older Adults and Health Expenditure

Healthcare consumption increases with age due to the dependency burden. Fuchs (26) pointed out that the growth rate of health expenditure for the older adults was higher than GDP. Carreras et al. (27) used a two-part model to prove that aging will cause an increase in health expenditure to a certain extent. In China, Li et al. (28) showed that the health expenditure of residents aged 65 and above increased most drastically in Beijing. Tan et al. (29) showed that families with older adults had significantly higher demand for health services and health expenditure than those without older adults. At the same time, some scholars believe that there is no great relationship between population aging and health expenditure. For example, Barros (30) used the statistical data of organisation for economic co-operation and development (OECD) countries to study the determinants of the increase in total health expenditure and found that aging was not the cause of the increase in total health expenditure.

To sum up, global scholars have discussed the possible influencing factors of health expenditure from different dimensions. Most studies believe that income level, education level, and health insurance impact health expenditure. However, few studies discussed the effect of population aging (represented by dependency burden) on health expenditure or have not reached uniform conclusions. Therefore, this paper tries to use the quantile regression method to discuss the influencing factors of health expenditure in urban China based on the China Household Finance Survey (CHFS), especially dependency burden. Moreover, its regional heterogeneity is also compared. The quantile regression method is used because it can capture the characteristics of urban household health expenditure in different quantiles nationwide and among regions and more accurately describe the influencing factors of health expenditure.

It should be noted that the latest data on CHFS was released in 2017 when we wrote the paper, and its data samples covered 400,011 households and 127,012 individuals in 29 provinces (municipalities and autonomous regions). It involves household demographic characteristics, assets and liabilities, insurance and security, income and expenditure, and other micro-household financial data. Furthermore, the rejection rate of CHFS is low, and the demographic characteristics are very similar to the data published by the National Bureau of Statistics of China.

MATERIALS AND METHODS

Variable Selection

Explained Variable—Household Health Expenditure

Household health expenditure is divided by the total population of each household based on the personal ID calculation generated by the tracking of the respondents by sorting out the answers to the CHFS questionnaire "how much did your family spend on

TABLE 1 | Description of each variable.

Variable types	Variable name	Abbreviation	Variable declaration
Explained variable	Household health expenditure per capita	lnPE	Take the logarithm of the total health expenditure per urban household in the past year
Core explanatory variable	Dependency burden (old-age dependency ratio)	OR	Proportion of the population aged 65 or above in the working population per household
Other explanatory variables	Age	Age	The age of the head of each household in 2017
	Gender	Gender	Gender of head of household (male = 1; Female = 2)
	Marital status	M	Marital status of head of household (unmarried = 1; Married = 2)
	Education Level	jy	Education level of head of household (no schooling = 0; Primary school = 6; Junior high school = 9; High school = 12; Technical secondary school/Vocational high school =13; Junior college/Higher vocational =15; Bachelor degree =16; Master =19; PhD = 22). The different numbers correspond to the number of years of study at each stage in China.
	Family size	Number	The total number of people per household
	Self-rated health	P	Household head's self-rated physical condition (good =1; General = 2; Poor = 3)
	Household incomes per capita	lnPI	The total income per household in the last year divided by the total number of people in the household. Take the logarithm
	Social medical insurance	YB	No social health insurance = 1; Basic medical insurance for urban workers = 2; Basic medical insurance for urban residents = 3; New rural cooperative medical insurance = 4
	Location	Location	urban= 1, country = 2

healthcare last year." In the process of data collation, considering the sufficient sample size, the missing value and uncertain invalid data in the original data of family health expenditure are first removed and then divided by the total population of each family to obtain the per capita health expenditure of the family. At the same time, by observing the QQ chart and boxplot of the per capita health expenditure of the family, we can see that the median of the dependent variable is small and has a large outlier. The QQ chart is a curve with asymmetry, which differs greatly from the normal QQ line. In general, the per capita health expenditure of the family in the sample data does not meet the normal distribution. Second, to reduce the volatility of the variable itself, the family per capita health expenditure is logarithmically transformed. The reason for doing this is that the logarithm will not change the nature and correlation of the data, but the scale of variables is compressed, the data are more stable, and the collinearity and heteroscedasticity of the model are weakened.

Core Explanatory Variable—Dependency Burden

The key indicator of dependency burden is the old-age dependency ratio. Most studies use the old-age dependency ratio to measure the degree of population aging. Different from the previous literature, this paper calculates the proportion of the older adult population (aged 65 and above) to the working-age population (aged 15–64) according to the characteristics of the micro-household database, so as to measure the dependency burden for the older adults. Therefore, the higher the old-age dependency ratio is, the more significant part of the value created by the working population will be used for the consumption of the older adults, which will put a heavier dependency burden on the society and reduce the income of the working population.

Other Explanatory Variables

Other explanatory variables include age, education level, marital status, and others. The specific processing process is shown in **Table 1**.

Data Source

The empirical data of this paper are from the household database published by China Household Finance Survey (CHFS), which is a nationwide sample survey designed to collect relevant information about household finance at the micro-level. CHFS is being conducted every 2 years since its inception in 2009. It has successfully carried out random household sampling surveys nationwide for four times in 2011, 2013, 2015, and 2017. This paper selects the data samples that cover 40,011 households and 127,012 individuals in 29 provinces in China Household Finance Survey (2017), involving micro-household financial data such as household demographic characteristics, assets and liabilities, insurance and security, income and expenditure, and so on. Finally, 19,787 households were selected as empirical samples by eliminating the missing value and outliers of the sample data. The rejection rate of CHFS was low and the sample size was abundant, while the missing values and outliers were few. Therefore, deleting them in the case of a large sample size had less effect on the results.

Empirical Methods and Model Setting

Classical regression such as ordinary least squares (OLS) is focused on "mean regression" and is susceptible to extreme

TABLE 2 | Summary statistics of variables.

Region of sample	Variables	Obs	Mean	Std. Dev.	Min	Max
Nationwide	lnPE	19,787	6.904	1.726	−1.609	13.305
	OR	19,787	0.251	0.373		
	age	19,787	55.688	13.939	18	117
	jy	19,787	9.233	4.167		22
	number	19,787	3.421	1.825		23
	lnPI	19,787	9.504	1.467	−3.352	14.732
Eastern China	lnPE	11,018	6.915	1.718	−1.609	13.305
	OR	11,018	0.247	0.37		
	age	11,018	55.537	13.84	18	117
	jy	11,018	9.301	4.128		22
	number	11,018	3.414	1.787		22
	lnPI	11,018	9.501	1.469	−2.842	14.732
Central China	lnPE	4,439	6.878	1.742		12.899
	OR	4,439	0.262	0.381		
	age	4,439	56.15	14.186	18	100
	jy	4,439	9.077	4.233		22
	number	4,439	3.413	1.853		23
	lnPI	4,439	9.484	1.481	−3.352	14.262
Western China	lnPE	4,330	6.903	1.73	0.511	12.569
	OR	4,330	0.249	0.371		
	age	4,330	55.599	13.927	20	93
	jy	4,330	9.221	4.196		22
	number	4,330	3.445	1.891		23
	lnPI	4,330	9.531	1.448	−2.436	14.527

values because the objective function for minimization is residual squared and $\sum_{i=0}^{n} e_i{}^2$. Therefore, Koenker and Bassett (31) put forward the quantile regression method, which uses the residual error absolute value of the weighted average (such as $\sum_{i=0}^{n} |e_i|$) to minimize the objective function and thus not affected by extreme value and relatively stable. More importantly, quantile regression can provide comprehensive information on different quantiles.

Due to the imbalance between economic development and the allocation of medical resources in China, the health expenditure of most families remains at a low level compared with that of developed countries in Europe and the United States. However, it is not excluded that some families have high health expenditures due to special reasons, which may lead to the uneven distribution of health expenditure allocation. This case will cause errors if mean regression is still used to estimate the overall model. Therefore, the quantile regression method is used, because it can capture the characteristics of urban household health expenditure in different quantiles nationwide and among regions and more accurately describe the influencing factors of health expenditure. The model is set as Equation 1:

$$lnPE_i = \beta_0 + \beta_1 OR_i + \beta_2 age_i + \beta_3 gender_i + \beta_4 M_i + \beta_5 jy_i + \beta_6 number_i + \beta_7 P_i + \beta_8 PI_i + \beta_9 YB_i + \beta_{10} location_i + \varepsilon_i \quad (1)$$

where $lnPE_i$ is the logarithm of the per capita health expenditure of the urban household i, $OR_i$is the old-age dependency ratio of the urban household i; age_i is the age of the head of household i; $gender_i$ indicates the gender of the head of household i. M_i is the marital status of the head of household i; jy_i represents the educational level of the head of household i; $number_i$ is the size of the household i. P_i represents the overall self-rated health status of the household i (including head of household); PI_i represents the per capita income of household i, YB_i represents the type of social medical insurance, and ε_i is the random interference term.

TABLE 3 | National sample quantile regression results.

Variables	QR_10	QR_25	QR_50	QR_75	QR_90
OR	0.804***	0.856***	0.624***	0.588***	0.626***
	(0.096)	(0.078)	(0.067)	(0.076)	(0.097)
age	0.006***	0.011***	0.014***	0.014***	0.012***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
gender_2	0.172***	0.255***	0.139***	0.152***	0.105
	(0.045)	(0.056)	(0.048)	(0.053)	(0.068)
M_2	0.188***	0.262***	0.117**	0.095	0.047
	(0.043)	(0.061)	(0.057)	(0.074)	(0.105)
jy	0.023***	0.021***	0.008	−0.001	0.005
	(0.005)	(0.001)	(0.006)	(0.006)	(0.008)
number	−0.110***	−0.113***	−0.121***	−0.112***	−0.116***
	(0.008)	(0.013)	(0.010)	(0.013)	(0.016)
P_2	0.370***	0.424***	0.428***	0.325***	0.213***
	(0.041)	(0.048)	(0.041)	(0.047)	(0.056)
P_3	0.948***	1.141***	1.078***	0.886***	0.786***
	(0.068)	(0.059)	(0.050)	(0.056)	(0.088)
lnPI	0.113***	0.120***	0.114***	0.090***	0.074***
	(0.015)	(0.015)	(0.016)	(0.019)	(0.025)
YB_2	0.418***	0.479***	0.499***	0.358***	0.223*
	(0.113)	(0.092)	(0.106)	(0.110)	(0.134)
YB_3	0.082	0.187*	0.274**	0.150	0.158
	(0.142)	(0.105)	(0.111)	(0.119)	(0.142)
YB_4	−0.098	−0.041	0.142	0.036	−0.133
	(0.106)	(0.087)	(0.104)	(0.106)	(0.131)
location_2	−0.075	−0.148**	−0.271***	−0.306***	−0.251***
	(0.050)	(0.058)	(0.053)	(0.060)	(0.075)
Constant	2.906***	3.289***	4.577***	6.149***	7.506***
	(0.213)	(0.208)	(0.220)	(0.259)	(0.329)
Observations	19,787	19,787	19,787	19,787	19,787

Robust standard errors in parentheses $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.
The numbers in brackets below the regression coefficients represent robust standard error.

RESULTS

Descriptive Statistics

To better display the distribution characteristics of variables in the model, a descriptive summary of relevant variables in nationwide, eastern China, western China, and central China is shown in **Table 2**. Eastern China includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan; central China includes Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan; western China includes Sichuan, Chongqing, Guizhou, Yunnan, Tibet,

Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang, Guangxi, and Inner Mongolia. The relevant data of Hong Kong, Macao, Taiwan, Tibet, and Xinjiang Uygur Autonomous Region are not included in the database, so they are not included in the analysis.

In **Table 2**, we can see the general characteristics of each continuous variable:

Among the three regions, the average logarithm of the per capita health expenditure of urban families in eastern China is RMB 6.915 yuan, exceeding the national average (RMB 6.904 yuan), whereas the mean of the central and western China is RMB 6.878 and 6.903 yuan, respectively, lower than the average of the national sample family per capita health expenditure. Therefore, the average value of explained variables is the highest in eastern China, indicating that eastern families' overall level of per capita health expenditure is higher.

The mean value of the old-age dependency ratio showed the trend of central China greater National greater western China greater eastern China, and the mean value from high to low was 0.262, 0.251, 0.249, and 0.247. At the same time, by comparing the standard deviation of the old-age dependency ratio between the national sample and each region, it can be seen that the aging degree of the samples in each region is similar to a small gap, indicating that the old-age dependency ratio gap between families is reasonable and the sample selection is representative. In addition, the mean of family size, education level, and age in the three regions are very close to the national average. According to the per capita income of urban families after logarithm, the eastern region has the best economic development among the three regions. Therefore, the maximum sample value of per capita health expenditure in the eastern region is 14.732, which is higher than that in the central region (14.262) and western region (14.527). However, the mean of per capita household income showed a trend of western region > eastern region > central region, with the maximum mean of 9.531 in the western region and the minimum mean of 9.484 in the central region, and only the mean of the western region exceeded the national average (9.504).

Empirical Results of Quantile Regression Model

In this paper, the explained variables were divided into families with different levels of health expenditure, with quantile boundaries of 10, 25, 50, 75, and 90%, respectively.

Nationwide

As can be seen from **Table 3**, the old-age dependency ratio, age, family size, self-rated health status, and per capita family income all significantly impact the explained variables at each subpoint of per capita family health expenditure. Gender, marriage, education level, and place of residence significantly influence

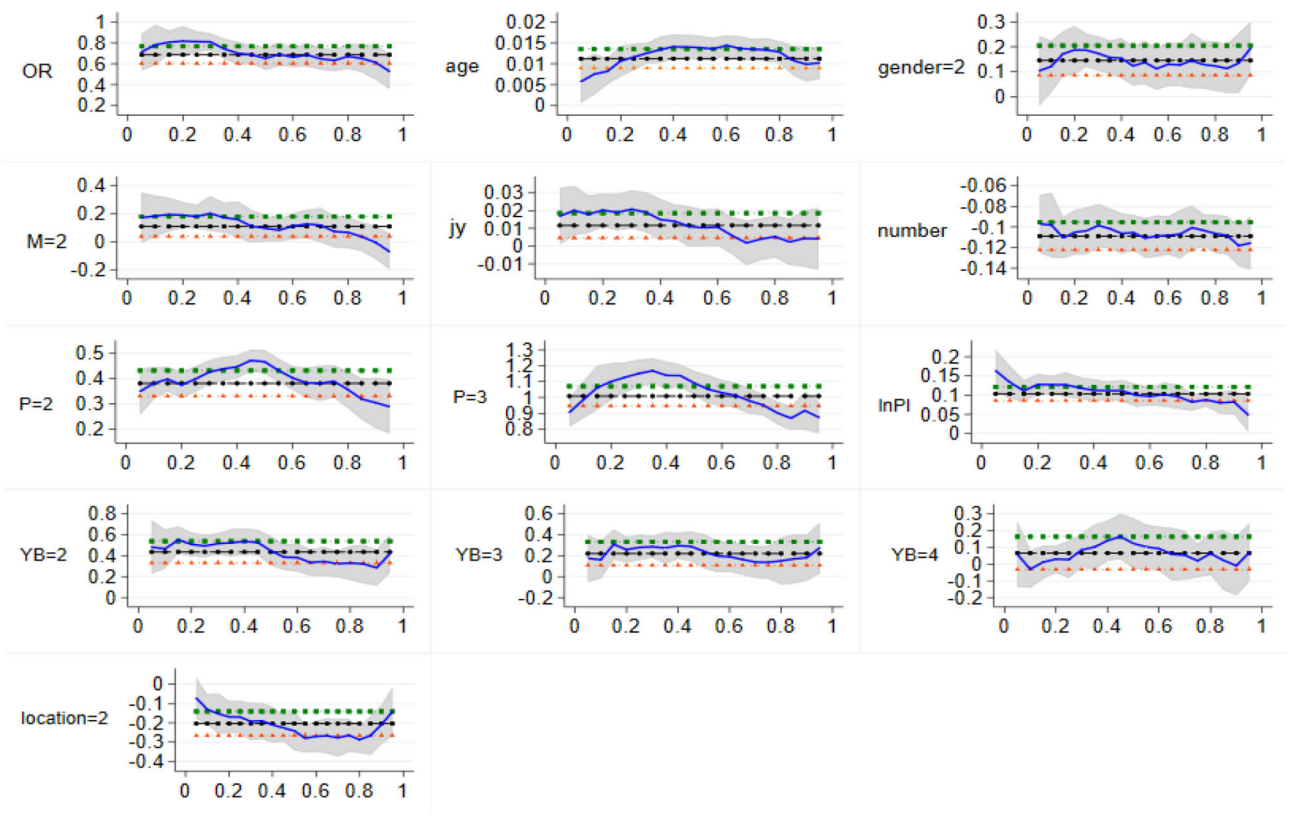

FIGURE 1 | Change of quantile regression coefficient of the national sample. The vertical coordinate is the estimated value, whereas the horizontal coordinate is the different quantiles.

the sample range of per capita health expenditure of the family, whereas the influence of social medical insurance is complicated due to various categories.

The old-age dependency ratio has a significant effect on the per capita health expenditure of the family. With the increase of quantile (0.1→ 0.25→ 0.5→ 0.75→ 0.9), the quantile regression coefficient of the old-age dependency ratio showed a U-shaped trend of rising first and then decreasing (0.096→ 0.078→ 0.067→ 0.076→ 0.097). The results show that the old-age dependency rate has the greatest impact on the health expenditure of families with lower health expenditure. At the same time, the standard error of the estimated coefficient decreased first and then increased (0.079→ 0.065→ 0.045→ 0.05→ 0.067), indicating that the estimation of the quantile regression coefficient at both ends of the conditional distribution is not accurate, but the difference in accuracy is small. Therefore, population aging has a greater impact on families with lower levels of health expenditure in China and a smaller impact on families with higher levels of health expenditure.

The influence of age on family health expenditure was significantly positive at each subsite of the national sample. The standard error of the estimated coefficients is consistent, indicating that the impact of age on family health expenditure is relatively stable. With the increase of age, health expenditure increases steadily. Female-headed households have a higher level of health expenditure per capita than the male-headed sample. Married people have a significant positive impact on health expenditure at 0.1, 0.25, and 0.5 subpoints, and the family with lower health expenditure has the greatest impact. The education level of residents is only a significant variable at 0.1 and 0.25 subpoints and has a similar effect on families with low health expenditure, with no significant difference. The regression results of family size show that health expenditure is inversely correlated with the total population, and the health expenditure of a family decreases by 11–12% with each additional family member.

The influence of self-rated health status on the per capita health expenditure of the family is more prominent among all the influencing factors, especially in the sample group with poor self-rated health status. Compared with the residents with good self-rated health status, the impact of the sample with average self-rated health status on the per capita health expenditure of the family shows an inverted "U" trend, which increases first and then decreases. Therefore, when residents self-rated their health status as average, households with moderate health expenditure changed the most, accounting for 42.8%. Meanwhile, poor self-rated health status was the most prominent influencing factor. The standard error of the estimated coefficient showed a U-shaped trend of decreasing first and then increasing (0.068→ 0.059→ 0.050→ 0.056→ 0.088), indicating that the accuracy of the distribution estimation of the household per capita health expenditure is slightly lower.

The effect of social medical insurance and residence on per capita health expenditure is not uniform. First of all, taking the sample group without any social medical insurance as a reference, urban employment insurance can significantly increase health expenditure and have a greater promotion effect on health expenditure with medium and low levels of health expenditure. Place of residence has no significant effect on the per capita health expenditure of families with a low level of health expenditure. The impact of residence on the per capita health expenditure of families at other subloci generally showed an inverted U-shaped trend of rising first and then decreasing. From 0.25 subloci to 0.9 subloci, the regression coefficients were −0.148,−0.271,−0.306, and−0.251, respectively, that is, compared with families living in urban areas. The per capita health expenditure of households in rural areas has decreased significantly.

Based on the quantile regression results of the national sample, **Figure 1** describes the changes and characteristics of the regression coefficient and confidence interval of per capita health expenditure of urban households at different quantile levels. The abscissa represents each subpoint of the per capita health expenditure of urban households, which varies isometric from 0.01 to 0.99, and the ordinate represents the regression coefficient of each explanatory variable in the regression model. It can be seen from **Figure 1** that the blue curve describes the variation characteristics of the estimated

TABLE 4 | Regression results of household health expenditure in eastern China.

Variables	QR_10	QR_25	QR_50	QR_75	QR_90
OR	0.895***	0.927***	0.515***	0.639***	0.707***
	(0.118)	(0.095)	(0.090)	(0.093)	(0.123)
age	0.003	0.010***	0.015***	0.015***	0.008**
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
gender_2	0.207**	0.210***	0.065	0.084	0.067
	(0.084)	(0.062)	(0.065)	(0.071)	(0.074)
M_2	0.262***	0.219***	0.132*	0.054	0.043
	(0.094)	(0.079)	(0.078)	(0.078)	(0.118)
jy	0.009	0.016**	0.006	0.004	0.005
	(0.010)	(0.008)	(0.008)	(0.008)	(0.010)
number	−0.116***	−0.092***	−0.126***	−0.104***	−0.117***
	(0.020)	(0.018)	(0.015)	(0.016)	(0.020)
P_2	0.358***	0.423***	0.428***	0.343***	0.355***
	(0.064)	(0.063)	(0.055)	(0.061)	(0.067)
P_3	1.057***	1.172***	1.108***	0.960***	0.880***
	(0.100)	(0.071)	(0.069)	(0.066)	(0.104)
lnPI	0.068***	0.110***	0.096***	0.066***	0.087***
	(0.022)	(0.020)	(0.023)	(0.021)	(0.029)
YB_2	0.514***	0.465***	0.366**	0.232*	0.106
	(0.120)	(0.130)	(0.151)	(0.118)	(0.172)
YB_3	0.234	0.257**	0.188	0.120	0.097
	(0.154)	(0.129)	(0.159)	(0.128)	(0.166)
YB_4	−0.237**	−0.081	−0.005	−0.105	−0.202
	(0.113)	(0.120)	(0.147)	(0.111)	(0.166)
location_2	0.065	−0.138*	−0.276***	−0.334***	−0.195**
	(0.081)	(0.077)	(0.072)	(0.074)	(0.087)
Constant	3.568***	3.520***	4.906***	6.448***	7.601***
	(0.298)	(0.287)	(0.312)	(0.283)	(0.403)
Observations	11,018	11,018	11,018	11,018	11,018

Robust standard errors in parentheses $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.
The numbers in brackets below the regression coefficients represent robust standard error.

coefficients of explanatory variables at different quantile levels, and the gray area represents the confidence intervals of the coefficients of each explanatory variable. In addition, for the three lines, the black dotted line in the middle represents the coefficient estimation of each explanatory variable in the OLS regression model, and the green and orange-red dotted lines on both sides represent the 95% confidence interval of each coefficient in the OLS regression model. It can be seen from the observation that, at both ends of the conditional distribution of the explained variables, the confidence interval of the estimated coefficients of each explanatory variable gradually widens, which indicates that the standard deviation of the estimated coefficient is gradually increasing, and the volatility of the estimated coefficient is constantly increasing.

Eastern China

The quantile regression results of the study on influencing factors of urban family health expenditure in eastern China are shown in **Table 4**.

As can be seen from **Table 4**, the main influencing factors of urban health expenditure in eastern China are the old-age dependency ratio, family size, self-rated health status, and income. The above three variables all significantly affect the health expenditure condition distribution.

First, the effect of the old-age dependency ratio on per capita health expenditure is 89.5%, larger than the national sample of 80.4%, indicating that families with low health expenditure in eastern China are more affected by population aging than the national average. The influence of control variables, such as gender, marriage, family size, and demand variables, such as self-rated health status, on dependent variables was similar to that of the national sample, and there was no abnormal situation. Meanwhile, the regression coefficient between per capita household health expenditure and per capita household income was 0.068, lower than 0.113 of the national sample. The possible reason is that the economic level of the eastern region is leading in the whole country, so the health expenditure of urban families is less affected and constrained by the income parity. Compared with the sample without any social medical insurance, the per capita health expenditure of the families of NRCMS participants is lower, indicating that these families have received the benefits of NRCMS and reduced their family health expenditure.

Second, health expenditure with middle-level health expenditure is significantly correlated with old-age dependency ratio, age, marriage, family size, self-rated health status, per capita household income, and residence. Among them, the effect of the old-age dependency ratio on per capita health

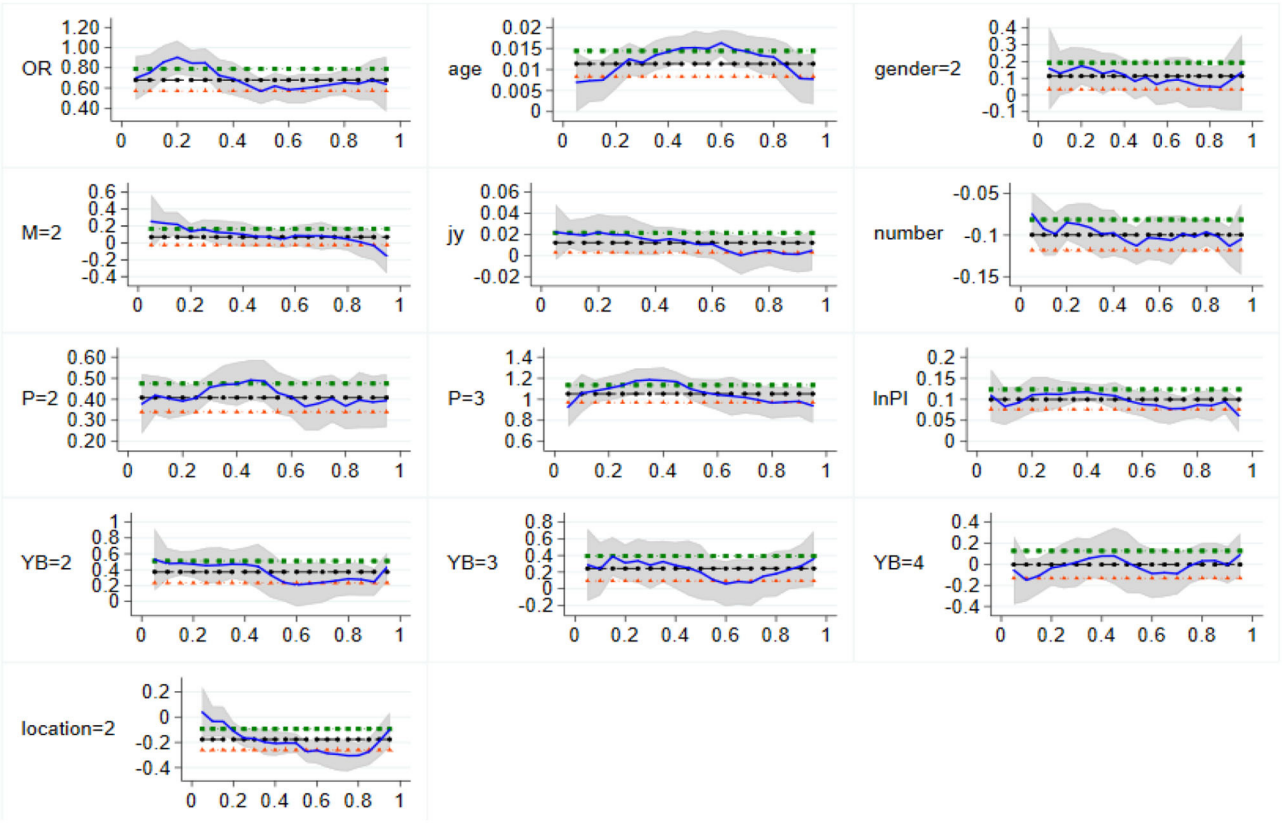

FIGURE 2 | Variation of quantile regression coefficients in Eastern China. The vertical coordinate is the estimated value, whereas the horizontal coordinate is the different quantiles.

TABLE 5 | Regression results of household health expenditure in the central region.

Variables	QR_10	QR_25	QR_50	QR_75	QR_90
OR	0.714***	0.840***	0.756***	0.625***	0.619***
	(0.121)	(0.139)	(0.119)	(0.108)	(0.183)
age	0.000	0.011***	0.012***	0.015***	0.013**
	(0.002)	(0.003)	(0.003)	(0.003)	(0.006)
gender_2	0.180*	0.267***	0.348***	0.353***	0.262**
	(0.097)	(0.100)	(0.088)	(0.072)	(0.131)
M_2	0.039	0.255**	0.130	0.244**	0.185
	(0.063)	(0.100)	(0.110)	(0.104)	(0.208)
jy	0.009	0.012	0.010	−0.016	−0.004
	(0.009)	(0.012)	(0.010)	(0.010)	(0.015)
number	−0.116***	−0.110***	−0.112***	−0.110***	−0.123***
	(0.017)	(0.021)	(0.020)	(0.022)	(0.032)
P_2	0.366***	0.290***	0.352***	0.299***	0.077
	(0.056)	(0.088)	(0.077)	(0.074)	(0.122)
P_3	0.956***	1.084***	1.004***	0.806***	0.608***
	(0.111)	(0.109)	(0.088)	(0.088)	(0.145)
lnPI	0.164***	0.142***	0.131***	0.147***	0.120***
	(0.027)	(0.030)	(0.018)	(0.033)	(0.036)
YB_2	0.200**	0.369***	0.634***	0.302	−0.029
	(0.092)	(0.130)	(0.196)	(0.263)	(0.186)
YB_3	−0.154	−0.024	0.257	0.024	−0.275
	(0.127)	(0.142)	(0.202)	(0.264)	(0.221)
YB_4	−0.226***	−0.223*	0.239	0.047	−0.501***
	(0.066)	(0.126)	(0.191)	(0.259)	(0.154)
location_2	−0.173**	−0.099	−0.181*	−0.233***	−0.154
	(0.068)	(0.099)	(0.102)	(0.090)	(0.136)
Constant	3.157***	3.291***	4.275***	5.468***	7.253***
	(0.324)	(0.385)	(0.347)	(0.458)	(0.525)
Observations	4,439	4,439	4,439	4,439	4,439

*Robust standard errors in parentheses*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*
The numbers in brackets below the regression coefficients represent robust standard error.

expenditure reaches the minimum at this level. Every increase in the old-age dependency ratio by one unit can only increase per capita health expenditure by 51.5%, which is far less than the regression coefficients of 89.5 and 92.7% at 0.1 and 0.25 subpoints. It shows that population aging has the least influence on the average health expenditure per family in eastern China. The greater impact of residence on per capita health expenditure may be related to the gradual improvement of family health expenditure. With the increasing demand of family for medical and health services, the influence of medical resources and professional services on family health expenditure is also increasing. The promotion effect of social medical insurance on the per capita health expenditure of the family is gradually decreasing. The same reason is that the improvement in the family health expenditure makes the medical and health service become the necessary consumption expenditure of the family. Therefore, the influence of other factors becomes smaller.

To sum up, the eastern region urban family medical expenditure on health-related factors influences the effect of the size and significance as the family per capita health spending sample conditional distribution varies. **Figure 2** shows the eastern region of the changing trends and characteristics of quantile regression coefficients, which helps in a more intuitive understanding of regression results and characteristics. It shows that it has a stable influence on the sample of the condition distribution of the explained variables, can be an important factor that affects urban family medical and health care in the eastern region, and plays an important role in the development of health service and healthcare system in the eastern region.

Central China

The regression results of the central region are shown in **Table 5**.

As can be seen from **Table 5**, factors that significantly impact each subpoint of urban family health expenditure in central China include the old-age dependency ratio, gender, family size, and per capita income. Significantly different from the regression results of the national sample and the eastern region, the effect of the old-age dependency ratio on per capita health expenditure was stable at each subsite with less change. From 0.1 subsite to 0.9 subsite, the regression coefficients of old-age dependency ratio were 0.714, 0.840, 0.756, 0.625, and 0.619, respectively. In addition, similar to the eastern region, the correlation coefficient between families with lower health expenditure and the old-age dependency ratio is the largest. Although there is no large regression coefficient of 0.927 in the eastern region, there is no significant difference in the regression coefficient of the old-age dependency ratio in the eastern region. The increase in age does not necessarily lead to an increase in health expenditure per capita in households with low levels of health expenditure, which may be due to the improvement of living standards of the population, the gradual increase in health awareness, and the improvement of diet and health habits. As a result, physical fitness has improved greatly, so increasing age does not necessarily mean increased demand for health services. Different from the regression results of the first two parts, gender has become a significant variable in the conditional distribution of explained variables in central China. The regression coefficient increases significantly, indicating that the female head of the household in central China can greatly promote family health expenditure. At the same time, the education level has become a completely insignificant variable. That is, there is no correlation between the health expenditure of urban families and the level of education of residents in central China.

At the same time, similar to the influence of residence in the eastern region, the residence in the central region has the greatest influence on the per capita health expenditure of families with high health expenditure, with a regression coefficient of 0.233, lower than 0.334 in the eastern region. This may be because the medical and health resources and

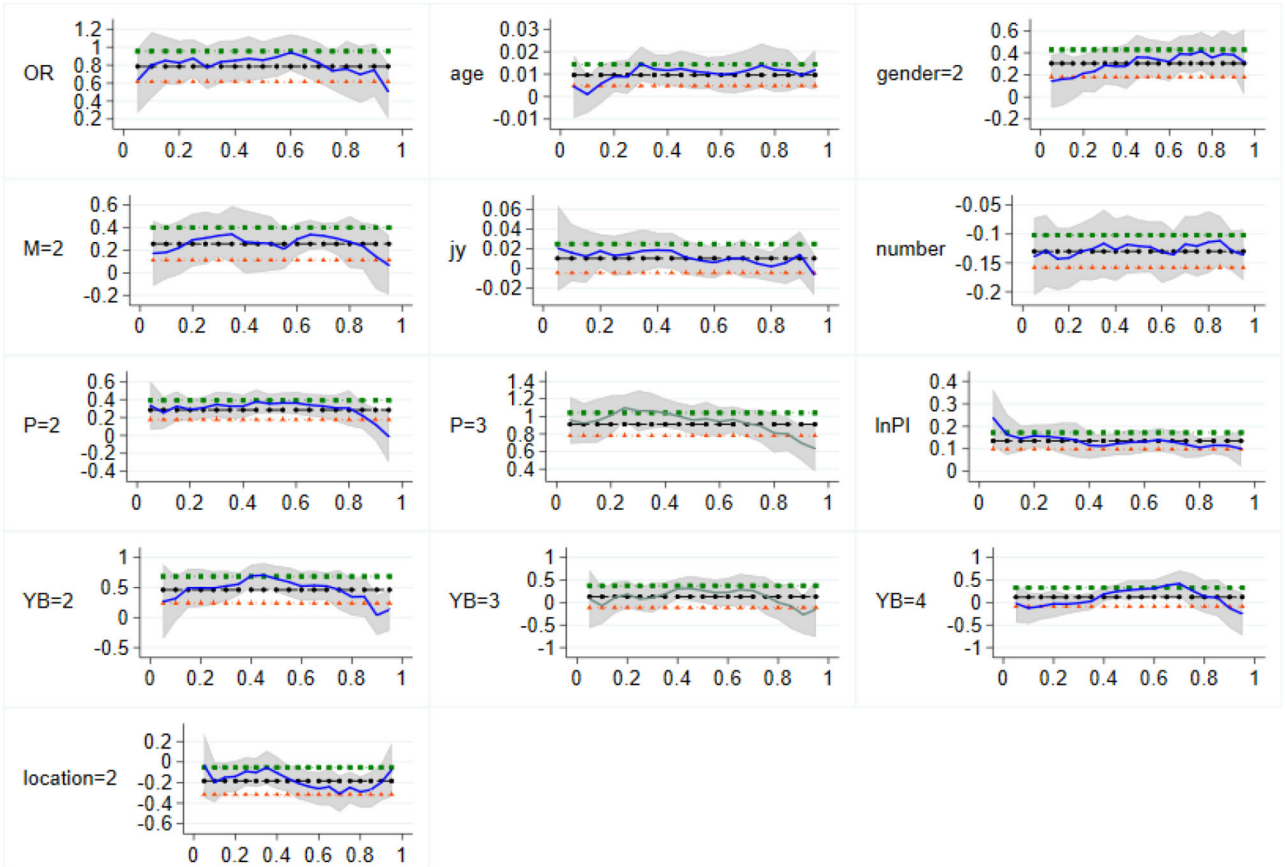

FIGURE 3 | Variation of sample quantile regression coefficients in Central China. The vertical coordinate is the estimated value, whereas the horizontal coordinate is the different quantiles.

professionals in the eastern region are richer than those in the central region, so the medical cost of urban families in the eastern region is higher, and the use of medical and health services is more convenient and comprehensive. Thus, the health expenditure of urban families in the eastern region is higher. Refer to **Figure 3** for the specific variation characteristics of the regression coefficients of each variable.

Western China

The regression results of the western region are shown in **Table 6**.

According to the quantile regression results shown in **Table 6**, it can be seen that:

First of all, the influence of the old-age dependency ratio on the health expenditure of urban families in western China is generally weaker than that in eastern and central China. Similarly, the influence of families with a lower old-age dependency ratio on health expenditure is the largest at each subsite. In addition, the regression coefficients of the old-age dependency ratio at 0.25 subpoint in eastern, central, and western regions were 0.927, 0.840, and 0.743, respectively, which may be related to the different degrees of aging in different regions. At the same time, the robust standard error of the estimation coefficient of the old-age dependency ratio was larger than that of the eastern and central regions, and the size of the standard error was 0.198, 0.147, 0.140, 0.176, and 0.118 from the low loci to the high loci, indicating that the estimation of quantile regression coefficient at the right end of the conditional distribution was more accurate. The quantile regression coefficient of the left end of the conditional distribution is different. That is, the increase in per capita health expenditure of urban families in western China is <19.8% and close to 11.8% when the old-age dependency ratio increases by one unit.

Second, gender and marital status only have a significant positive impact on the per capita health expenditure of families with low health expenditure, while there is a positive correlation between the level of health expenditure of families with medium or lower level and residents' education level. In addition, the effects and characteristics of family size and self-rated health status on per capita health expenditure are similar to those in eastern and central China, which are both important influencing factors. At the same time, the central region of the family healthcare spending has no obvious relation with residents affected by education level. It shows that the education level of urban areas in western China is

TABLE 6 | Regression results of household health expenditure in western China.

Variables	QR_10	QR_25	QR_50	QR_75	QR_90
OR	0.542***	0.743***	0.513***	0.444**	0.483***
	(0.198)	(0.147)	(0.140)	(0.176)	(0.118)
age	0.014***	0.015***	0.015***	0.015***	0.015***
	(0.005)	(0.004)	(0.004)	(0.005)	(0.003)
gender_2	0.048	0.307***	0.062	0.103	0.033
	(0.128)	(0.100)	(0.107)	(0.113)	(0.067)
M_2	0.146	0.376***	0.185	−0.013	−0.064
	(0.131)	(0.117)	(0.129)	(0.150)	(0.104)
jy	0.031**	0.045***	0.025**	0.007	0.014
	(0.016)	(0.013)	(0.012)	(0.015)	(0.011)
number	−0.146***	−0.139***	−0.111***	−0.136***	−0.128***
	(0.034)	(0.028)	(0.020)	(0.028)	(0.017)
P_2	0.380***	0.507***	0.547***	0.328***	0.188**
	(0.120)	(0.095)	(0.091)	(0.107)	(0.077)
P_3	0.804***	1.130***	1.208***	0.750***	0.793***
	(0.147)	(0.121)	(0.103)	(0.136)	(0.133)
lnPI	0.106***	0.105***	0.080**	0.083**	0.013
	(0.038)	(0.037)	(0.033)	(0.039)	(0.023)
YB_2	0.925***	0.648***	0.659***	0.805***	0.598***
	(0.162)	(0.125)	(0.207)	(0.265)	(0.212)
YB_3	0.308	0.207	0.480**	0.690**	0.528***
	(0.188)	(0.209)	(0.223)	(0.278)	(0.203)
YB_4	0.657***	0.279*	0.429**	0.543**	0.506**
	(0.145)	(0.143)	(0.204)	(0.258)	(0.206)
location_2	−0.236*	−0.277**	−0.449***	−0.348**	−0.546***
	(0.140)	(0.118)	(0.112)	(0.136)	(0.107)
Constant	2.176***	2.796***	4.395***	5.928***	7.726***
	(0.485)	(0.467)	(0.449)	(0.555)	(0.334)
Observations	4,330	4,330	4,330	4,330	4,330

*Robust standard errors in parentheses*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*
The numbers in brackets below the regression coefficients represent robust standard error.

relatively backward as a whole. There is still a large space for development.

Third, the impact of per capita household income on per capita household health expenditure shows a U-shaped trend of decline first and then rise, and families with high levels of health expenditure are not affected by per capita household income, indicating that there is a large gap in economic level between urban families in western China. Based on the analysis of the regression results and coefficients of the above influencing factors, **Figure 4** shows the detailed variation trend of the quantile regression coefficients of different influencing factors of urban household health expenditure in western China. Compared with residents without any social medical insurance, urban employment insurance can significantly increase the per capita health expenditure of families at each subpoint, and with the increase of subpoints, the regression coefficients are 0.925, 0.648, 0.659, 0.805, and 0.598, respectively.

Robustness Test

To test the robustness of the quantile regression model, this paper used elderly population coefficient (EPC, i.e., each household age 65 and older population ratio of the total population) instead of the old-age dependency ratio. The regression results of the nationwide sample are shown in **Table 7**.

Compared with **Table 3**, the significance of each variable in different quantiles does not obviously change after the old-age dependency ratio is replaced by EPC in **Table 7**. For example, in **Table 3**, the old-age dependency ratio regression coefficients from low-score loci to high-score loci were 0.804, 0.856, 0.624, 0.588, and 0.626, respectively. In **Table 7**, the regression coefficients of EPC from 0.1 to 0.9 were 0.925, 0.908, 0.663, 0.615, and 0.656, respectively. There was a significant positive correlation between them and health expenditure. Therefore, it can be proved that the regression results of the empirical study in this paper have strong robustness. However, it is worth noting that the robust standard error of the regression estimation coefficient of the old-age dependency ratio is 0.096, 0.078, 0.067, 0.076, and 0.097, respectively, whereas the robust standard error of EPC is 0.103, 0.080, 0.069, 0.078, and 0.092, respectively. Therefore, the old-age dependency ratio is slightly more accurate in estimating the conditional distribution of the national sample. Therefore, this study chooses the old-age dependency ratio as the measurement index of population aging, rather than EPC.

DISCUSSION

Main Conclusion

This paper explores the impact of the dependency burden on urban household health expenditure and its regional heterogeneity in China based on the micro-data of CHFS. A total of 19,787 valid samples were obtained and the quantile regression method was used due to the skewness of the distribution of explained variables and the possible extreme values. Some useful results were found.

First, the old-age dependency ratio, age, family size, self-rated health status, and income significantly impact the health expenditure of urban families at the national sample quantile regression [similar to Carreras et al. (27), Ross et al. (2), Hou and Ren (5), and Xie et al. (9)]. The impact of gender on health expenditure of low health expenditure families is significant. Marriage has a significant impact on the health expenditure of families with moderate and lower levels of health expenditure. This shows that individuals in marriage pay more attention to their own health problems and their impact on the family. Education level only has a positive effect on families with low health expenditure. This conclusion is further confirmed in Hjortsberg (11) and Tian et al. (14). Only the basic medical insurance for urban workers has significantly impacted health expenditure. This is basically the same as Sepehri and Vu (22), but opposite to Xu and Chen (6), which is an upward trend, the particularity of national conditions in China led to the cognitive difference in this problem.

Second, dependency burden and other variables on urban household health expenditure have great regional heterogeneity. For instance, the old-age dependency ratio has a significant effect

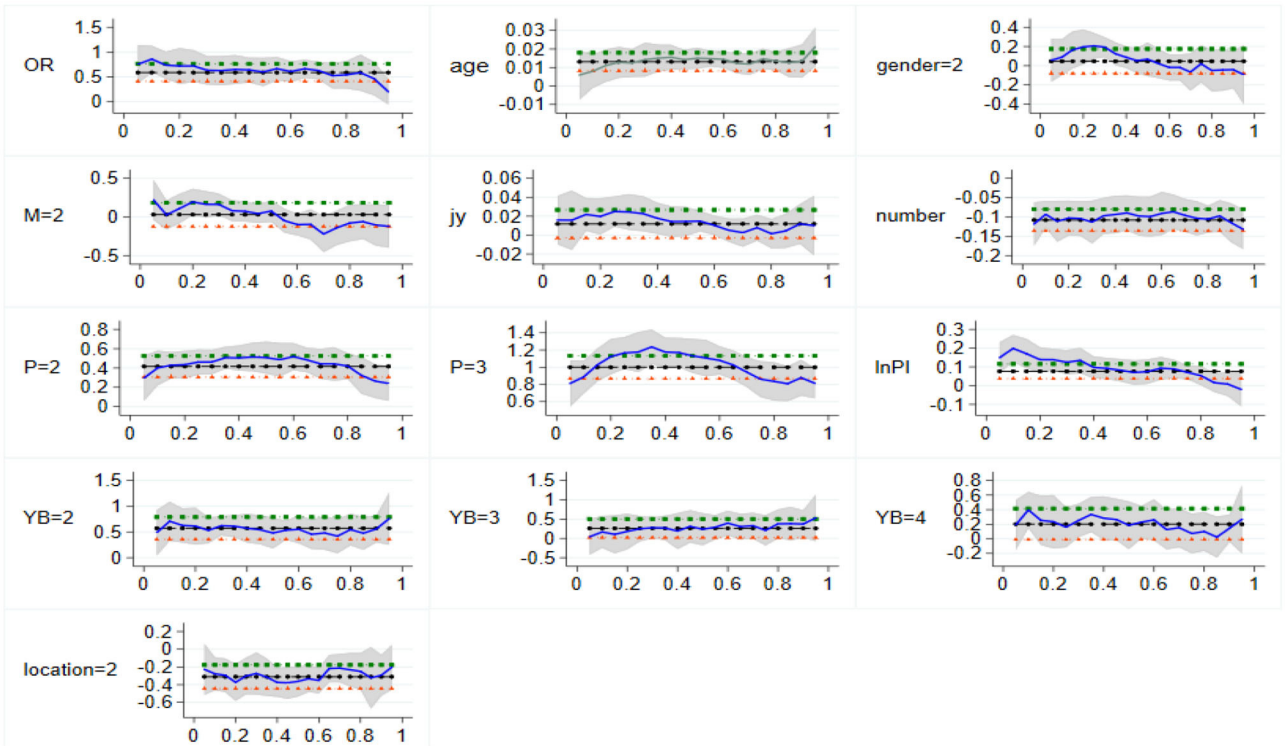

FIGURE 4 | Change of quantile regression coefficient in Western China. The vertical coordinate is the estimated value, whereas the horizontal coordinate is the different quantiles.

on the per capita health expenditure; however, it is most obvious in eastern China [similar to Li et al. (28)]. This may have much to do with the cost of providing for the aged in eastern China. Due to the higher overall economic level, medical expenses and other pension costs in eastern China are much higher than those in western and central China. In addition, gender has the most significant effect on health expenditure in central China. In contrast, marriage and education level have a different effect on health expenditure in all the three regions [consistent with Mackenbach et al. (13)]. Family size, self-rated health status, and income have significant and stable effects on each region. Social medical insurance for the influence of various regions is more complicated. In addition, the relationship between social medical insurance and health expenditure shows more closely in western China (23, 25) reached the same conclusion. This may be related to the low economic level of western China, the lower the income, the stronger the dependence on medical insurance.

Policy Implications

The above conclusions can help us put forward some policy recommendations.

First, government agencies should unite with all social strata to establish a multi-level social security system for aged care and formulate relevant policies to establish a medical care system for the older adult population suitable for economic development as soon as possible.

Second, the aging population greatly affects health expenditure in eastern China. This reflects the higher level of economic development in the eastern region, which leads to the early emergence of a low birth rate, low natural growth rate, and low death rate in the population structure of the eastern region, and the aging degree is deep. The aging problem in the eastern region cannot be improved significantly in the short term, so the medical institution service system related to the older adult population in the eastern region should be improved as soon as possible to ensure that the medical needs and old-age services of the elderly can be satisfied.

Third, the correlation between the urban health expenditure and their residence is the most stable and strong in western China. The differences in residential areas represent the lack of medical and health resources such as medical institutions and medical professionals between urban and rural families. Therefore, we should pay attention to the introduction of professional medical personnel and the configuration of precision medical equipment in the western region to improve the medical and health system in the western region.

CONCLUSION

There are some improvements in this study. For example, this paper selects the old-age dependency ratio as the core explanatory variable such as the fiscal policy factor (32, 33), which may

TABLE 7 | Robustness test results.

Variables	QR_10	QR_25	QR_50	QR_75	QR_90
EPC	0.925***	0.908***	0.663***	0.615***	0.656***
	(0.103)	(0.080)	(0.069)	(0.078)	(0.092)
age	0.005**	0.011***	0.014***	0.014***	0.011***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
gender_2	0.190***	0.252***	0.140***	0.148***	0.096
	(0.059)	(0.058)	(0.050)	(0.054)	(0.064)
M_2	0.160***	0.259***	0.114*	0.098	0.039
	(0.055)	(0.066)	(0.060)	(0.075)	(0.092)
jy	0.025***	0.022***	0.008	0.000	0.006
	(0.007)	(0.007)	(0.006)	(0.007)	(0.008)
number	−0.108***	−0.106***	−0.116***	−0.111***	−0.112***
	(0.011)	(0.014)	(0.011)	(0.013)	(0.016)
P_2	0.363***	0.415***	0.429***	0.330***	0.223***
	(0.046)	(0.050)	(0.042)	(0.049)	(0.053)
P_3	0.947***	1.138***	1.090***	0.899***	0.800***
	(0.071)	(0.059)	(0.051)	(0.056)	(0.086)
lnPI	0.106***	0.117***	0.111***	0.090***	0.075***
	(0.013)	(0.016)	(0.016)	(0.019)	(0.024)
YB_2	0.435***	0.496***	0.512***	0.348***	0.229*
	(0.113)	(0.089)	(0.113)	(0.111)	(0.121)
YB_3	0.095	0.203*	0.290**	0.149	0.156
	(0.141)	(0.105)	(0.118)	(0.119)	(0.129)
YB_4	−0.107	−0.035	0.150	0.034	−0.126
	(0.105)	(0.085)	(0.111)	(0.107)	(0.119)
location_2	−0.036	−0.144**	−0.273***	−0.298***	−0.242***
	(0.059)	(0.059)	(0.054)	(0.060)	(0.073)
Constant	3.003***	3.300***	4.596***	6.126***	7.499***
	(0.198)	(0.220)	(0.226)	(0.260)	(0.315)
Observations	19,787	19,787	19,787	19,787	19,787

*Robust standard errors in parentheses*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.*
The numbers in brackets below the regression coefficients represent robust standard error.

omit other important variables that have not been paid attention to. Thus, the selection of research indicators is bound to have greater progress and improvement space in the future. From the sample data, this paper only uses the cross-sectional data of CHFS in 2017, while explanatory variables such as family health expenditure and population aging are dynamic processes and may show different characteristics in different time periods. Therefore, to a certain extent, the research in this paper cannot reflect the characteristics and trends of family medical expenses in different years, and the conclusions may have some limitations. All these need to be further improved in the future.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

The data of this study came from China Household Finance Survey (CHFS) datasets (publicly available datasets). All methods were carried out in accordance with relevant guidelines and regulations (Declaration of Helsinki).

AUTHOR CONTRIBUTIONS

XX: conceptualization, writing, and editing. QW: methodology and software. CL: data curation and project administration. All authors contributed to the article and approved the submitted version.

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Social and Regional Factors Predict the Likelihood of Admission to a Nursing Home After Acute Hospital Stay in Older People With Chronic Health Conditions: A Multilevel Analysis Using Routinely Collected Hospital and Census Data in Switzerland

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If hospitalization becomes inevitable in the course of a chronic disease, discharge from acute hospital care in older persons is often associated with temporary or persistent frailty, functional limitations and the need for help with daily activities. Thus, acute hospitalization represents a particularly vulnerable phase of transient dependency on social support and health care. This study examines how social and regional inequality affect the decision for an institutionalization after acute hospital discharge in Switzerland. The current analysis uses routinely collected inpatient data from all Swiss acute hospitals that was linked on the individual level with Swiss census data. The study sample included 60,209 patients 75 years old and older living still at a private home and being hospitalized due to a chronic health condition in 199 hospitals between 2010 and 2016. Random intercept multilevel logistic regression was used to assess the impact of social and regional factors on the odds of a nursing home admission after hospital discharge. Results show that 7.8% of all patients were admitted directly to a nursing home after hospital discharge. We found significant effects of education level (compulsory vs. tertiary education OR = 1.16 (95% CI: 1.03–1.30), insurance class (compulsory vs. private insurance OR = 1.24 (95% CI: 1.09–1.41), living alone vs. living with others (OR = 1.64; 95% CI: 1.53–1.76) and language regions (French vs. German speaking part: OR = 0.54; 95% CI: 0.37–0.80) on the odds of nursing home admission in a model adjusted for age, gender, nationality, health status, year of hospitalization and hospital-level variance. The language regions moderated the effect of education and insurance class but not of living alone. This study shows that acute hospital discharge in older age is a critical moment of transient dependency especially for socially disadvantaged patients. Social and health care should work coordinated together to avoid unnecessary institutionalizations.

Keywords: older age, chronic health conditions, hospital discharge, nursing home, social inequality, regional inequality, multilevel analysis, Switzerland

INTRODUCTION

Worldwide countries face the challenge of providing adequate, affordable and patient-centered health and social care to their aging populations (1). Most people wish to age healthily, live an independent and socially integrated life in their communities and stay at home, if possible till the end of their life (2, 3). "Aging in place" integrated in one's community is also considered as key element of the quality of life in old age (4). However, the majority of the older persons are suffering from one or multiple chronic health conditions (CHC) e.g., diabetes, cardiovascular diseases or depression (5) and an increasing number of older people with functional limitations need health care and support with the activities of daily living (6, 7). Coping successfully with CHC in the sense of stabilizing the course of the disease, preventing exacerbation and avoidable hospitalizations requires a high degree of self-management, personal and social resources as well as access to adequate health care (8, 9).

If a hospitalization becomes inevitable in the course of a chronic disease, discharge from acute hospital care in older individuals is often associated with temporary or persistent frailty, functional limitations and the need for help with daily activities. Thus, this represents a particularly vulnerable phase of transient dependency on social support and health care. So, after an acute hospital stay a critical question for the older patient, his or her family and for the hospital discharge team is whether to discharge to the patients' home or to a nursing home (2, 10). Hospital discharge decision-making is described as a complex process involving stakeholders with a range of expertise, experience and perspectives. The older patient's voice is often not included enough in this process, especially under the time pressure of shortened length of stay (11, 12). Being transferred directly from acute hospital into long-term care is a common pathway, but is seen critical (13). Nursing home admission, often termed institutionalization, is a significant life event for older persons and often associated with negative outcomes such as restricted quality of life and loss of social network as well as a high burden for public and private finances (14). It may often be unavoidable, especially in the case of cognitive impairment, but should not take place unnecessarily or prematurely.

The risk of suffering from one or multiple CHC follows a social pattern. The lower the socioeconomic status (SES) of an individual, the higher the risk of chronic diseases and multimorbidity such as mental health disorders, diabetes, chronic respiratory diseases or cardiovascular diseases (15, 16). Several studies have found that the social context of a person's life determines not only the risk of exposure and the degree of susceptibility but also the course and outcome of a disease depending on the capability to cope with the disease (8, 17, 18). However self-management of CHC is too often discussed from a purely individualistic perspective, ignoring the social and cultural context in which this process happens (19, 20). "Central to these critiques is a hyper-individualistic conception of patients as autonomous self-regulating subjects making self-serving decisions" (19).

The Commission on Social Determinants on Health (CSDH) set up by the WHO published a conceptual framework to explain the complexity of the different impact levels and pathways between social aspects and health (21). In this framework they distinguish between (1) *structural determinants on the macro-level* (socioeconomic and political context) which generate and maintain social hierarchies and defining socioeconomic positions of groups and individuals and (2) *intermediary determinants on the meso-level* with categories such as material circumstances, behavioral and biological factors, psychosocial factors as well as the health care system. The structural determinants include the characteristic of the welfare state, which is postulated to have a significant impact on social inequality in health by framing the type of health care system in a society and in mediating the effects of the social determinants on health. Applying this concept to the goal of a high quality of life and "aging in place" it can be concluded that intermediary determinants have an impact on the risk of chronic diseases and functional limitations that make it difficult for socially disadvantaged groups to live independently in old age. Structural determinants cause these disadvantages, but, at the same time, may mitigate them with appropriate interventions (e.g., access to community services and care at home for all).

Beckfield et al. (22) propose an institutional theory of welfare states on the distribution of health in a population. They highlight the impact of "meso-level rule-like arrangements" (e.g., neighborhood resources, the local health care system) and of macro-level institutions (e.g., access to social and health care systems) "to create winners and losers in social life" and in this way determine social inequalities in health (p. 231).

Although the question of social predictors of non-home discharge or new institutionalizations after a hospital discharge is of great individual and societal importance, surprisingly little research exists to date on this topic. Several studies analyze the decision-making process from a hospital's perspective showing the relevance of hospital-level factors like quality of the discharge management. But these studies do not focus on the social situation of the patients [e.g., (12, 23, 24)]. There exists a broad range of studies as well as meta-analyses on the question of social predictors of nursing home admissions or institutionalizations in the general population (10, 14, 25–28). In a meta-analysis including 77 studies analyzing the predictors of nursing home admission in the general population of the USA, Gaugler et al. (14) found strong evidence, that the presence of a spouse reduces and being white increases the likelihood of living in a nursing home, independent of health status and demographic variables; for living alone they found no clear evidence. A second meta-analysis including 36 studies from different developed countries found strong evidence for a higher likelihood of living in a nursing home among persons with limited financial resources. They found moderate evidence for an association with a poor social network and inconclusive evidence for such an association with living alone and low education (10). However, there are few studies analyzing the social predictors of new institutionalization after hospital discharge. Gilbert et al. (29) studied the likelihood of admission to a nursing home after fall-related hospitalizations in England. They included age, gender, comorbidity level (Charlson Comorbity Index) and area deprivation (rurality, ethnicity, and deprivation index) in their

model and found a higher risk associated with highest age, severe comorbidity and living in a non-deprived all-white area. The last result may be surprising, but it is in line with a broad consensus in the international literature, that migration background is negatively associated with the use of nursing homes (27). Agosti et al. (30) analyzed the association between the likelihood of home or non-home discharge in 1,849 patients in Italy and the question of living alone or with others. They controlled for age, gender, a range of health indicators including cognitive impairment and functional limitation and found living alone to be an important predictor of non-home discharge. In another study in Italy, Marengoni et al. (31) studied the allocation of the place of residence after the discharge of 830 patients admitted to an acute geriatric ward in association with living alone, having a caregiver, multimorbidity, physical functioning, and cognitive status. They only found functional status to be a significant predictor of discharge to nursing homes but given the small N of cases admitted to nursing homes ($N = 23$), this result may not be seen as conclusive. Harrison et al. (2) described the characteristics of patients entering a nursing home after hospitalization in a retrospective cohort study in one hospital in Scotland. They found that people discharged to nursing homes were predominantly female, widowed, older and living alone. However these were only descriptive results which were not adjusted for covariates such as health status, etc.

For many countries (e.g., the USA, Canada, UK, Germany) substantial regional variations in permanent placements in nursing homes are reported and seen as an indicator for local disparity in access and effectiveness of health and social care for older persons to promote and maintain their independence (32–36). In conclusion, our review identified few studies taking a comprehensive approach to analyzing the question of social inequality in nursing home admission after hospital discharge and few studies using representative samples. Two meta-analyses investigating the likelihood of institutionalization in the whole population found inconclusive evidence for social determinants. The few studies focusing on the phase after a hospital discharge are often restricted to only one aspect of the social situation or only one health condition (e.g., fall-related health problems). There is also the problem of limited explanatory power due to methodological limitations. To the best of our knowledge and in accordance with Harrison et al. (2) we conclude that the topic of social inequalities in admission to nursing homes after acute hospitalization in older people are poorly researched to date.

In Switzerland, the federal legislation determines the basic framework of social and health insurance, but the 26 cantons are responsible for the conceptualization and implementation of old age policy and inpatient acute and long-term care. This leads to considerable regional disparities regarding access to specific health care for older people, including palliative care (37–39). A total of 154,634 individuals 65 years old and older were living in a nursing home in Switzerland in 2018, corresponding to a rate of 70.5 women and 33.4 men per 1,000 individuals in this age group. This proportion rises markedly with increasing age, with 1.5% of the population between 65 and 79 years old and 15% of the population above 79 years (40). There are 60.9 nursing home places per 1,000 individuals 65 years old and older in Switzerland, with substantial cantonal disparities, ranging from 46 places (Canton Wallis) to 101 places (Canton Appenzell Ausserrhoden) per 1,000 individuals in this age group (see also **Figure 1A**). The disparity in health care infrastructure for older persons is reflected in **Figures 1A,B** showing the density of nursing home places and the use of ambulant home care (SPITEX) in the cantons of Switzerland.

Based on cluster analyses of the data of 29 OECD countries to classify the different healthcare systems, Reibling et al. (41) conclude that the healthcare system in Switzerland is unique in Europe and forms a cluster with the USA only, portrayed as systems with high supply and low public but high private (out-of-pocket) expenditures. All residents in Switzerland have a compulsory basic health insurance, but this insurance class does not cover all services needed. For example dental care or household assistance after a hospital discharge are not covered. These services are covered by private and semi-private supplementary insurance only. In addition, there is a high proportion of cost-sharing. It is therefore not surprising that an outstanding high proportion of people in Switzerland experience financial barriers to health care: 22% of adults (31% of low-income adults, defined as member of households with an income less than half of the median household income) reported cost-related access problems to medical care in the preceding 12 months. This rate is at least twice as high as in countries such as Germany, the Netherlands, Sweden or the UK (42).

The aim of the present study is to analyze whether there are social inequalities in the likelihood of admission to nursing homes after an acute hospital stay in the older population with chronic conditions. In accordance with the CSDH framework, we will focus on intermediary social determinants such as education level, income and social support and at the same time on disparities between the language regions as indicators for the impact of structural determinants on the macro-level, while controlling for hospital-level characteristics. Based on the literature on the cumulative effect of multiple social disadvantages and exposures (43, 44), we want to analyze possible interaction effects between the three social predictors on the risk of nursing home admission. Lastly, we also test for a possible moderator effect of the regional characteristics on the relationship between social predictors and outcome, by including interaction terms between language regions and social predictor variables.

We hypothesize that: (a) people high in resources (education, supplementary insurance and social support) are less likely to be institutionalized after acute hospital stay independent of gender, age, nationality, type of chronic condition and comorbidities as well as clustering effects on hospital-level; (b) the likelihood depends on the language region; (c) the language region moderates the relationship between social determinants and the likelihood of new institutionalizations.

METHOD

Data Sources and Linkage Procedure

The database used for this study was established within the project "Social Inequalities and Hospitalisations (SIHOS)."

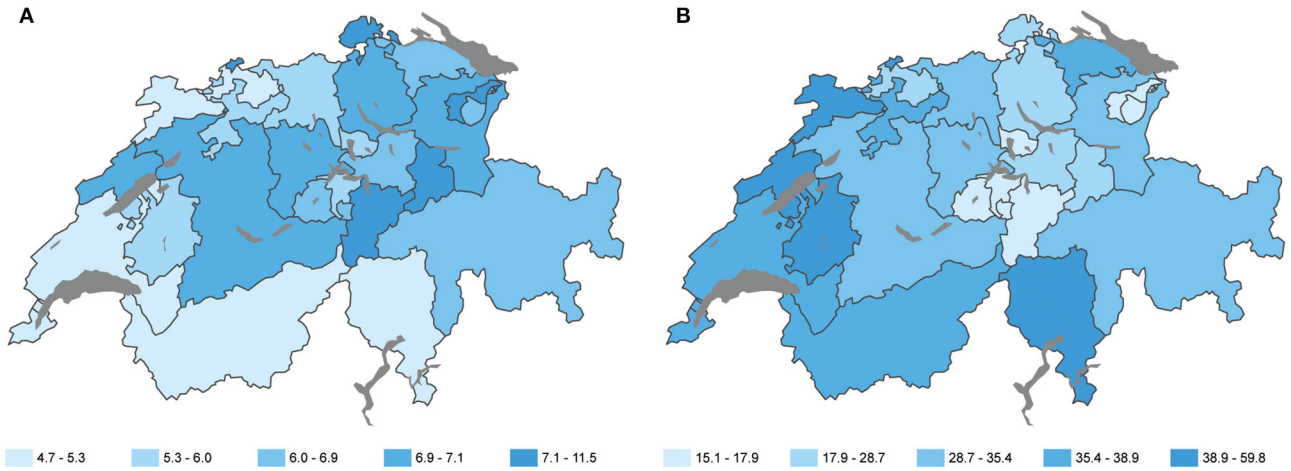

FIGURE 1 | Nursing home places and use of ambulant long-term care in the language regions. **(A)** Number of nursing home places per 1,000 individuals 65 years old and more. **(B)** Number of people using ambulant home care (SPITEX) per 1,000 individuals in the cantons of Switzerland 2016 (Swiss Health Obervatory, 2021; reprinted with permission by Swiss Health Observatory).

SIHOS is part of the National Research Program 74 "Smarter Health Care," which is promoting innovative health services research and helping to tackle the practical challenges of caring for the chronically ill in Switzerland.[1] Thanks to the partial revision of the Statistical Surveys Ordinance in the year 2014, different public census data and administrative hospital data could be linked for the first time on an individual level in Switzerland. The SIHOS database was created to include demographic and socioeconomic variables as well as information on hospital stays and stays in nursing homes, resulting in a unique retrospective cohort database. For this study we used data from two sources: (1) the medical statistics of the Swiss hospitals (MS) administered by the Federal Statistical Office (FSO), which registers all hospital discharges. Data collection is mandatory for all Swiss hospitals. The MS is an administrative data set used amongst others as a data base for the DRG financing system of the Swiss hospitals. The second data source (2) is the Structural Survey (SE), part of the census of Switzerland, a representative sample of around 200,000 people, which is collected every year. We obtained data from five waves of the SE (2010–2014). The data were collected and anonymized by the FSO using a hashing procedure. For a detailed description of the different data sources and the linkage procedure see (45). The database underwent comprehensive validation and the matched records were evaluated for completeness and correctness. There was no evidence of bias, because the subsample of hospitalizations successfully linked to individuals is to be regarded as a random selection of the study population with one exception: the under-representation of some non-European migration groups happening as a result of inconsistent writing of unfamiliar names. For details of the evaluation process, see (45). The *source population* of the SIHOS-study includes all individuals 15 years and older living in Switzerland in a private home, who were hospitalized (as inpatients) in an acute hospital at least one time between the years 2010 and 2016. The SIHOS *database population* consists of all individuals of the source population who participated in the public census in one of the Structural Survey waves between 2010 and 2014, for which a successful linkage between census data and medical data could be created.

[1]http://www.nrp74.ch

Study Sample

This study included individuals 75 years old and older at the time of hospitalization who had at least one acute hospital admission between 2010 and 2016 related to a chronic condition and who had been living at home before hospital admission. Excluded were patients who were admitted only to a rehabilitation ward, who died during their hospital stay or were hospitalized not due to a chronic health condition. In accordance with our question on the influence of the language regions, hospitals and their patients were excluded for which no clear identification of a language region could be made or in which fewer than 5 patients were represented in the study sample (for the selection of cases see flow chart, **Figure 2**).

For individuals with more than one acute hospitalization, the last acute hospital admission during observation time was included in the study. For our research question, the last hospitalization was of greater interest than e.g., the first one, because after a permanent nursing home admission, the individual drops out of the study sample. Following the logic of our sample selection, it is more probable that the last hospitalization during our observation time is the crucial moment when nursing home admission occurs. To control for the effect of multiple hospital stays of one individual the number of hospitalizations during the observation time was included as a covariate in the model. The sample defined in this way consisted of 60,209 individuals. The sample characteristics are described in **Table 1**.

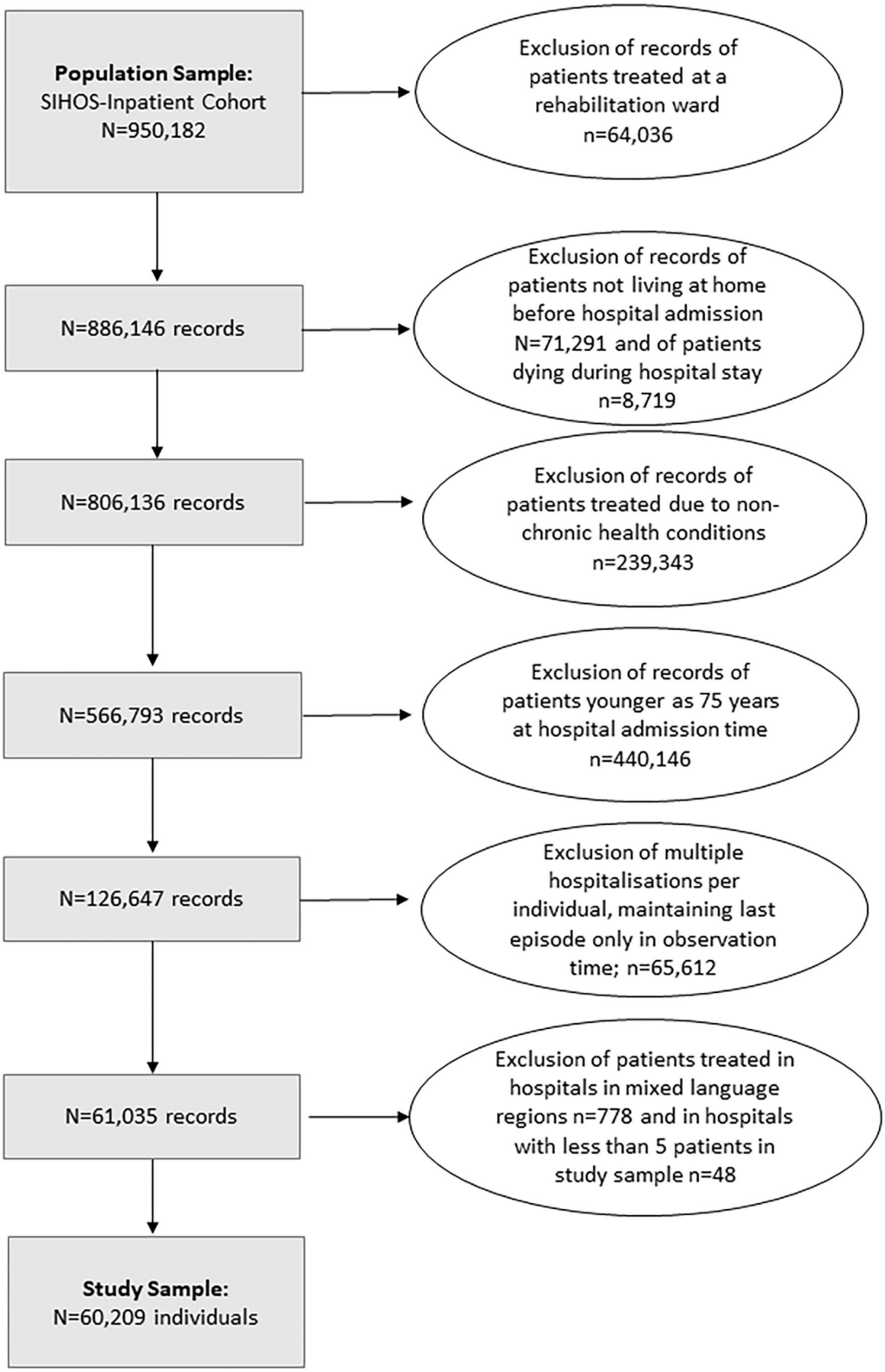

FIGURE 2 | Flow chart of selection of cases to define the study sample ($N = 60,209$ individuals).

TABLE 1 | Descriptive characteristics of the study sample, *N*, percentages.

	Admission to nursing home		Admission to other places	
	n	%	*n*	%
Total sample	4,691	7.8	55,518	92.2
Gender				
Male	1,797	6.4	26,130	93.6
Female	2,894	9.0	29,388	91.0
Age groups				
75 to 79	813	3.4	23,381	96.6
80 to 84	1,299	6.8	17,941	93.2
85 and older	2,579	15.4	14,196	84.6
Nationality				
Swiss	4,404	8.0	50,565	92.0
EU/EFTA	266	5.5	4,567	94.5
Other states	21	5.2	384	94.8
Missing values	0	0.0	2	100.0
Education level				
Compulsory	2,256	9.2	22,171	90.8
Upper-secondary	1,929	7.2	24,682	92.8
Tertiary	506	5.5	8,665	94.5
Hospital insurance class				
Compulsory	3,516	8.7	36,680	91.3
Semi-private	793	6.1	12,187	93.9
Private	382	5.4	6,647	94.6
Missing values	0	0.0	4	100.0
Single household				
Lives with other people	1,969	5.6	32,891	94.4
Lives alone in household	2,722	10.7	22,627	89.3
Principal diagnosis				
Malignant neoplasms	666	9.9	6,036	90.1
Cardiovascular diseases	1,218	7.2	15,642	92.8
Chronic respiratory diseases	123	8.7	1,286	91.3
Diabetes	57	12.3	407	87.7
Musculoskeletal diseases	584	4.5	12,539	95.5
Mental disorders	415	22.9	1,401	77.1
Dementia-related disorders	352	39.9	531	60.1
Other chronic diseases	1,276	6.7	17,676	93.3
Number of somatic comorbidities elixhauser				
None	671	4.2	15,170	95.8
One	801	5.3	14,265	94.7
Two	970	8.0	11,218	92.0
Three to four	1,558	12.0	11,461	88.0
Five and more	691	16.9	3,404	83.1
Mental comorbidity	605	14.2	3,668	85.8
Dementia-related comorbidity	608	28.6	1,521	71.4
Language region of hospital				
German	3,163	8.3	34,791	91.7
French	1,105	6.5	15,902	93.5
Italian	423	8.1	4,825	91.9

Variables

The Outcome Variable

The outcome variable for this analysis is (1) admission to a nursing home after hospital discharge vs. (0) discharge to another place. This information is assessed by the hospitals as part of the medical statistics, MS. Discharge to another place most often includes returning home, being transferred to a rehabilitation clinic or to a second acute hospital. The problem of a possible misclassification bias in the outcome variable in the form of specific patient paths is discussed in section Discussion (e.g., older individuals who lived at home being admitted to an acute hospital, then being discharged to a rehabilitation clinic and finally moving permanently to a nursing home after the rehabilitation treatment).

As *covariates* we include gender with (1) female (0) male; age at hospital admission in three categories (0) 75 to 79 years, (1) 80 to 84 years old and (2) over 85 years old; nationality with three categories (0 = Swiss nationality; 1 = EU / EFTA states; 2 = other nationalities); year of hospitalization with seven categories (2010 = 0; 2011 = 1; 2012 = 2; 2013 = 3; 2014 = 4; 2015 = 5; 2016 = 6).

Health Status

Health status is described using five variables. First, we used the *main diagnosis* of the acute hospitalization (ICD10-GM diagnosis codes registered in the acute hospitals) grouped according to Clinical Classification Software[2] (CCS Level 1). Eight dummy variables (1 = disease present, 0 = not present) were included in the statistical model representing the following common chronic disease groups: (a) malignant neoplasms, (b) cardiovascular diseases, (c) chronic respiratory diseases, (d) diabetes, (e) musculoskeletal diseases, (f) mental disorders, (g) dementia-related disorders, taking into account the "dagger and asterisk" system in ICD-10 (considering symptoms of dementia as underlying disease and as manifestation) and (h) other chronic conditions. We then included three variables for the amount of comorbidities diagnosed in the hospitals taking into account up to ten additional diagnoses: (a) *number of somatic comorbidities* (46) in five categories, (0) none, (1) one, (2) two, (3) three to four, (4) five and more somatic comorbidities; (b) *mental comorbidity* (0 = none) (1 = yes) and (c) *dementia-related comorbidity* (0 = none) (1 = yes). For details of the grouping procedures, indicating the ICD codes used, see **Supplementary Additional Table 1**. Lastly, we controlled for the (d) number of hospitalizations before the index (=last) hospitalization grouped in the following categories: none (0), one (1), two (2), three to four (3) and five and more (4).

Three variables are included in the model as *predictor variables of the social situation*. As an indicator for educational attainment, the SIHOS database includes the *highest educational qualification* achieved in three categories, (0) tertiary level qualification (university or college degree), (1) upper secondary level qualification (mainly vocational education) and (2) compulsory education or less (corresponds with an educational duration of nine years). Educational attainment is a classic indicator of vertical social inequality and displays a strong and consistent relationship with risks of disease and mortality in a population (47). The variable *household type* with the two categories (1)

[2]CSS = Clinical Classifications Software, developed by the Healthcare Cost and Utilisation Project (HCUP), financed by the US Agency for Healthcare Research and Quality, adapted for Switzerland by Daniel Zahnd, BFH.

living alone and (0) living with other people in a private household is used as an indicator for a person's social resources. Living alone does not preclude the possibility of having a large social network, but in the case of older people living alone it often means that there is a lack of immediate, everyday support at home, which is especially needed after a hospital discharge. Since there is no direct information on income in our data set, we use *hospital insurance class* with three categories, (0) private, (1) semi-private and (2) general insurance class as a proxy variable for financial resources. To validate this association, we analyzed the relationship between income classes in Switzerland and average expenditure on supplementary hospital insurance. The representative sample of the Household Budget Survey (FSO) showed a clear relationship between income class and expenditure for supplementary hospital insurance (private or semi-private insurance class) for individuals living alone and also for households with couples in the population 65 years old and older. There was a 3.4-fold increase in expenditure for individuals living alone and a 2.7-fold increase in expenditure for couples in the highest income class compared to the lowest[3]. Another new study shows that the Swiss population with private or semi-private hospital insurance have a higher income and a higher level of education compared to the population without supplementary insurance (48). We therefore assume that this variable may be used as proxy for the financial resources of the patients. At the same time, in its function as a financial incentive system, the insurance class seems to have an impact on the use of health care and type of treatment during hospital stay (48, 49).

Language Region of Hospitals

For data protection reasons, the SIHOS data set does not contain any geographical information on the hospital or individual level, but includes a variable assessing the main language spoken by the patients. Assuming that a hospital in which the majority of patients (70% and more) indicate German (including Romansh), French or Italian as their main language is located in the respective region, most hospitals can be assigned to the three main language regions. Seven out of 221 hospitals are in a mixed language region and were excluded from the study sample. The variable language region has three categories with (0) German-speaking part, (1) French-speaking part and (2) Italian-speaking part.

Methods of Analysis

The SIHOS database was imported into the statistic software program SPSS (Version 26.0). Validation procedures were carried out in SPSS 26, descriptive analysis in SPSS 27. The frequency procedure was used to analyze the descriptive characteristics of the study sample. Absolute numbers as well as percentages were tabulated stratified for the outcome variable "admission to a nursing home" or "admission to another place."

In order to take the hierarchical structure of the data into account, a multilevel analysis with 60,209 patients at level 1 nested in 199 hospitals at level 2 was applied. For the multilevel logistic regression analysis we used MlwiN, Version 3.01 from the Center for Multilevel Modeling, University of Bristol. The association between the independent social variables and the likelihood of discharge to a nursing home, adjusted for covariates and clustering effect on hospital-level, was analyzed entering the covariates and predictors in five blocks (see **Table 1**).

To estimate the parameters we used a quasi-likelihood approach based on Taylor series expansion as approximation to linearize the nonlinear function. Second order Taylor approximation or penalized quasi-likelihood (PQL) has proved to be a generally better estimation method than marginal quasi-likelihood (MQL) and first order Taylor approximation, especially if groups at lowest level are small and random effects are large (50). As statistic test Wald test is recommended, since it is a quasi-likelihood method and AIC, BIC as well as comparing deviances are not very accurate (51). As a condition for the application of a logistic regression analysis to avoid overfitting, Hosmer and Lemeshow state that the number of individuals in the outcome category with smaller n must be at least ten times the number of all variables included in the model. This condition is given in our analysis with 16 variables with a total of 50 dummy-coded categories in the full model and 4,691 individuals in the smaller outcome category. To test for possible collinearity between the independent categorial social variables education level, hospital insurance class and household structure, we used Cramer's V, providing the best balance between Type I error control and power (52). The results showed no critical association among the variables.

RESULTS

Table 2 describes the characteristics of the study sample. 7.8% or 4,691 of the total of 60,209 patients in the study sample were admitted directly to a nursing home after hospital discharge. In bivariate comparison, the rate of admission to a nursing home was higher for women, older patients, Swiss nationals, patients with a low education level, patients with no supplementary hospital insurance, and those living alone. The most important single characteristic is an indicator of health status: 39.9 percent of the patients with the main diagnosis of dementia are admitted to a nursing home, followed by 28.6 percent of patients with a dementia-related comorbidity and 22.9 percent of patients with mental disorder as the principal diagnosis.

TABLE 2 | Overview of the multilevel logistic regression model building process.

Model	Variables included
A	Model with random intercept Including social predictors, adjusted for age, gender, nationality and year of hospitalization
B	Model A complemented by variables assessing the health status as covariates
C	Model B complemented by interaction terms between the social predictor variables
D	Model C complemented by main effect of language region of hospital
E	Model D complemented by interaction terms between the social predictor variables and language region of hospital.

[3]Office Federal of Statistics, Household Budget Survey 2015-2017, Table T20.02.01.02.12.

TABLE 3 | Results of the multilevel logistic regression models A, B and D with random intercepts; Estimations for social predictors, health covariates and regional variables (p, odds ratio and 95% confidence interval for single predictors; joint Chi2 test (df), p and ICC (intra-class-variance); Models adjusted for gender, age group, nationality, year of hospitalization and number of hospitalizations before index-hospitalization.

	Model A				Model B				Model D			
		95% CI				95% CI				95% CI		
	OR	Lower	Upper	Sig.	OR	Lower	Upper	Sig.	OR	Lower	Upper	Sig.
Individual level												
Education level (ref.: tertiary)	1.00				1.00				1.00			
Upper-secondary	1.13	1.01	1.26	*	1.09	0.98	1.22		1.09	0.97	1.22	
Compulsory	1.22	1.09	1.37	***	1.15	1.03	1.30	*	1.16	1.03	1.30	*
Insurance class (Ref.: private)	1.00				1.00				1.00			
Semi-private	0.95	0.83	1.09		0.98	0.86	1.13		0.98	0.85	1.13	
Compulsory	1.19	1.06	1.35	**	1.24	1.09	1.41	**	1.24	1.09	1.41	**
Household (ref.: living with others)	1.00				1.00				1.00			
Single household	1.55	1.45	1.67	***	1.64	1.52	1.76	***	1.64	1.53	1.76	***
Principal diagnosis (ref.: other)					1.00				1.00			
Malignant neoplasms					1.80	1.62	2.00	***	1.80	1.62	2.01	***
Cardiovascular diseases					0.81	0.74	0.89	***	0.81	0.74	0.89	***
Chronic respiratory diseases					1.04	0.84	1.28		1.04	0.84	1.28	
Diabetes					1.24	0.91	1.70		1.24	0.91	1.70	
Musculoskeletal diseases					0.85	0.76	0.95	**	0.85	0.76	0.95	**
Mental disorders					4.67	4.01	5.44	***	4.73	4.06	5.50	***
Dementia-related disorders					11.75	9.91	13.93	***	11.95	10.07	14.17	***
Nr. of somatic comorbidities (ref. none)			1.00				1.00					
One					1.36	1.21	1.54	***	1.36	1.20	1.53	***
Two					1.91	1.69	2.15	***	1.90	1.68	2.14	***
Three to four					2.75	2.45	3.09	***	2.74	2.44	3.07	***
Five and more					4.27	3.72	4.90	***	4.25	3.70	4.88	***
Mental comorbidity (ref.: none)					2.39	2.16	2.65	***	2.39	2.16	2.65	***
Dementia-related comorbidity (ref.: none)					5.14	4.60	5.75	***	5.17	4.62	5.78	***
Hospital-level												
Language region (ref.: German-speaking)								1.00				
French-speaking region									0.54	0.37	0.80	**
Italian-speaking region									0.70	0.37	1.31	
Joint Chi2 (df), *p*	1,949.5 (16), $p < 0.001$				4,002 (32), $p < 0.001$				3,987.9 (34), $p < 0.001$			
ICC	34.4%				21.3%				20.0%			

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

In **Table 3**, we report the crucial parameter estimates from the different logistic regression models A, B and D; for details of all models see **Supplementary Additional Tables 2**, **3**.

The parameter estimates of **Model A** show significant associations between the three social predictors and the odds of being admitted to a nursing home, controlling for gender, age, nationality, year of hospitalization and hospital-level variance. Compared to individuals with tertiary education, those with compulsory (OR = 1.22) or with upper secondary education (OR = 1.13) have higher odds of moving to a nursing home after hospital discharge. The same applies to individuals without supplementary hospital insurance (OR = 1.19) compared to individuals with private insurance, the highest insurance class, whereas individuals with semi-private insurance do not differ from those with the private insurance class. The highest odds show individuals living alone compared to those living with others in a household (OR = 1.55). The between-hospital variance (ICC) of Model A is high with a proportion of 34.4% of the total variance. **Model B** includes the variables describing the health status of patients. Very strong and significant predictors for admission to a nursing home are the principal diagnosis of a mental disorder (OR = 4.67) and even more pronounced, a dementia-related disorder (OR = 11.75). Further, a high number of somatic comorbidities and mental and dementia-related comorbidities are strong predictors of nursing home admission. After controlling for these health-related covariates, the effects of the social variables remain significant, though reduced for education level, while the effect of insurance class and living alone vs. living with other persons becomes slightly more pronounced. The included parameters reduce the between-hospital variance markedly to 21.3%. In **Model C**, none of the tested interaction terms showed a significant effect, thus none of these terms

were included for further model development (see the detailed results in the **Supplementary Additional Table 3**). Including the language regions in **Model D** showed a significant difference between the language regions of Switzerland: Taking into account the effect of social variables, health status and demography as well as the variance between the hospitals, the patients hospitalized in the French-speaking region had markedly lower odds of discharge to a nursing home (OR = 0.54) compared to the patients in the German- or Italian-speaking regions. Including the language regions as parameters in the model did merely reduce the level 2 variance. Finally, **Model E** tested the hypothesis that there is an interaction between the social predictors and the three main language regions that may explain a significant part of the variance of hospital admission. We found a relevant interaction effect between the different categories of insurance class and the language regions and therefore stratified Model B by language region (see **Figure 3** and details in the **Supplementary Additional Table 5**).

The stratified analysis revealed that both socio-economic variables—educational attainment and insurance class—are moderated by the regional context, but not the effect of living alone. For the German-speaking region of Switzerland, the associations between all three social variables and the odds of admission to a nursing home remain significant. A low education level, having no private insurance and living alone are all associated with higher risks of moving to a nursing after hospital discharge. The result for the French-speaking part of Switzerland shows a different picture: living alone is a significant predictor of admission to a nursing home, but neither education level nor insurance class. In the Italian speaking part, living alone and insurance class are significant predictors of the outcome, but education level is not.

DISCUSSION

In this paper we have examined whether there are social inequalities in the likelihood of admission to nursing homes after an acute hospital stay in the older population with chronic conditions in Switzerland. Of the total of 60,209 patients in our study sample 7.8% or 4,691 were admitted directly to a nursing home after hospital discharge. We found significant effects of education, insurance class and living alone in a model adjusted for age, gender, nationality and year of hospitalization. Patients with the lowest education level had a 22% higher likelihood of being admitted to a nursing home compared to patients with the highest education level. Patients without supplementary insurance had a 19% higher likelihood of new institutionalization compared to patients with the highest insurance class (private). For individuals living alone this likelihood was 55% higher compared to older people living with others. Taking into account the health status of the patients, we found somewhat weaker but persisting effects of education level and stable effects of insurance class and living alone. This result is in line with our first hypothesis. Regarding the effect of the insurance class, our findings strengthen the evidence that financial resources are an important predictor of institutionalization in developed countries (10). Regarding the effect of education level the interpretation of our results are more complex. Including the different indicators of morbidity and comorbidity in our model reduces the effect of education on the odds of nursing home admission. We assume that this result is related to the fact that low educational resources increase the risk of developing chronic health conditions and also the risk of an exacerbation of these diseases. The stronger effect of education level found in model A would therefore be caused partly by the poorer health status of the individuals low in education. The complex and reciprocal relationship between lower education, higher risk of morbidity or multimorbidity and probability of a nursing home admission in old age may explain the somewhat inconclusive results concerning the effect of education in review studies (10). An other analysis based on the SIHOS database showed that patients with low education level hospitalized due to a chronic health condition more often are diagnosed with multimorbidity (53). This points to the multiple burden on this population group and the necessity of sufficient support during and after hospitalization. The result of a persistent and strong effect of living alone to predict new institutionalization after acute hospital discharge is consistent with the results found by Agosti et al. (30) in Italy and Harrison et al. (2) in Scotland. This similarity of the findings provides further support for a stable and consistent relationship between living alone and a higher admission rate to nursing homes rate independent of medical needs or SES like education or income. This result could stimulate the discussion about new forms of housing for older people (e.g., co-living arrangements).

In accordance with our second hypothesis (model D) we found a main effect of the language regions that were interpreted as indicators for the regional infrastructure and old age policies: In the French-speaking region the odds of being admitted to a nursing home after hospital discharge are 46% lower than in the German-speaking regions of Switzerland. This result is consistent with studies observing disparity in old age health care policies and infrastructure between the cantons and language regions in Switzerland (39, 54, 55). The interaction analysis between regions and socio-economic parameters revealed a significant effect for insurance class, but not for education level nor living alone (model E). To analyze this effect in more detail, the sample was stratified by language region and the models were calculated separately for each region. We found that our third hypothesis was only partially supported by our results:

The effect of the insurance class as proxy for income is clearly moderated by the regional context, the effect of education level is somewhat weaker moderated, whereas the effect of living alone is comparable in all three language regions. Individuals with fewer education-related and financial resources seem to be better off in the French-speaking part of Switzerland, where the older individuals with a lot or with few resources did not significantly differ as far as the question at stake is concerned. This may be explained by the stronger implementation of the ambulant care and the intermediate infrastructure (e.g., SPITEX and assistant living) and the accessibility of these services for the whole population in this region. Based on Beckfield's institutional theory of

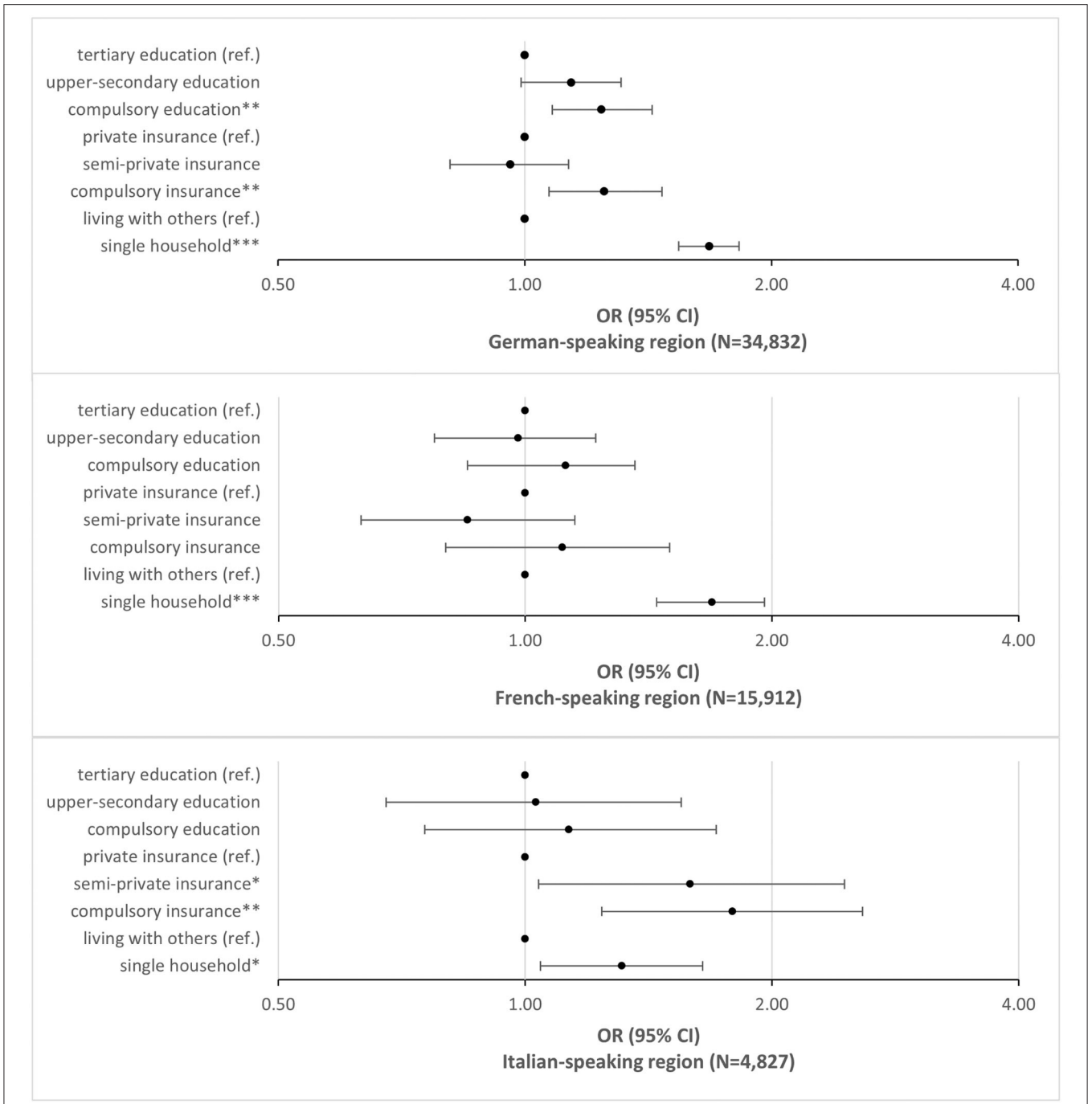

FIGURE 3 | Social determinants and nursing home admissions in the language regions. Odds of admission to a nursing home after hospital discharge; logistic regression model B stratified for the three language regions in Switzerland controlled for gender, age group, nationality, health status and year of hospital admission: OR, CI 95%, $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

welfare states, we could therefore presume that the language regions in Switzerland are characterized by different meso-level arrangements that influence the social inequality in health and health care in their populations (22). However, this does not seem to be true for the aspect of the availability of social support at home: Living alone remains a stable risk factor for institutionalization in our study that is not mitigated by regional aspects.

Strength and Limitations

One of the unique strengths of this study is the ability to link individual census data to medical inpatient data of all acute

hospitals in Switzerland. Therefore the study sample provides a nearly representative sample of the older population treated as inpatient in an acute hospital. In comparison to many other studies the sample is not restricted to a specific fraction of health problems or a specific fraction of the hospital care.

The limitations are mainly related to the implications of routinely collected data not created to answer the study questions. As a consequence of this, we must assume the existence of unmeasured confounding. First of all, in order to conduct a comprehensive analysis of our hypothesis, we would have preferred to include information about the hospital discharge management at the hospital-level. Information on the involvement of social work in the preparation of hospital discharge and support for social disadvantaged patients would have been of particular interest. However, taking into account the hospital-level-variance did not change the main effects we found in our study. Second, we were unable to include information about the access to health and social care at the community or cantonal level because these geographical information were not included in the SIHOS-database. Unmeasured confounding is also possible in the assessment of the health status in our study. The medical data assessed in the hospitals records only health problems with a relevance for the medical care during the hospital stay. A further potential limitation of this study includes the use of one-time survey data to measure risk factors for a nursing home admission. Given the length of the follow-up time (in extreme cases, six years of difference), it is possible that these may have changed over time and thus produce a time-varying measurement bias. This problem concerns only the predictor variable 'living alone'. We assume that education level will hardly change in old age and the insurance class was assessed as part of the medical record at the time of the hospitalization. The bias concerning the predictor 'living alone' would result in a bias toward the null, therefore the observed effect size found in our study could be slightly underestimated.

Our outcome variable discharge to nursing home or to other places may include the problem of a misclassification bias concerning two specific patient paths: (a) patients being discharged to a rehabilitation ward and not returning home after discharge from rehabilitation, but instead moving to a nursing home. In the SIHOS database this specific patient path is rare (3.6% of all records of patients 75 years and older); most patients who are discharged from rehabilitation ward after an acute hospital stay return home. The second patient path of interest (b) includes patients using acute transition care (ATC) in a nursing home but returning home after a short time. Because ATC and short time stays of nursing home care were rarely used in Switzerland during the observation time of this study (ATC: 0.3% of all beds; Short time stays: 1.9% of all beds), we assume that misclassification bias is not a serious problem discharge (56).

Conclusion

To conclude, the results of our study point to three aspects that are especially important for the promotion of social equality in health care for older people in Switzerland:

- Acute hospital discharge in older persons is a critical moment of transient dependency, in which social inequality affects the chance of living independently in one's own home.
- The effect of social determinants on nursing home admission after hospital discharge may be mitigated by the regional policy and health care.
- Future research should address the question which housing solutions, community services and primary health care interventions are effective in reducing the risk that socially disadvantaged older people will enter a nursing home without medical need.
- "Aging in place" as a key element of the quality of life and social integration should be accessible for all people regardless of income and place of living.

DATA AVAILABILITY STATEMENT

These data are the property of the Swiss Federal Statistical Office (SFSO) and can only be made available by legal agreements with the SFSO. The data that support the findings of the present analysis are used under license for the SIHOS study and are not publicly available due to the data protection restrictions. However, they are available after signing a data protection contract with the Swiss Federal Statistical Office (SFSO) Sektion Gesundheitsversorgung, Espace de l'Europe10, CH-2010 Neuchâtel, Switzerland Email: gesundheit@bfs.admin.ch.

AUTHOR CONTRIBUTIONS

NB participated in the development of the conceptualization and methodology and the acquisition of the funding of the SIHOS-study, designed and performed the analyses, interpreted the results, wrote the original draft of this paper, and edited the manuscript. AZ and LB-O participated in the development of the conceptualization and methodology and the acquisition of the funding of the SIHOS-study, interpreted the results, and edited the manuscript. All authors have read and approved the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.871778/full#supplementary-material

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Multimorbidity Among Urban Poor in India: Findings From LASI, Wave-1

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Background: Multimorbidity has become a norm in low-and middle-income countries such as India requiring notable health system improvements to combat. Urban population is a heterogeneous group where poor are at a risk of facing inequity in accessing healthcare services which can jeopardize our efforts to attain universal health coverage (UHC). We aimed to estimate the prevalence, assess correlates and patterns of multimorbidity among urban poor. Further, we assessed the outcomes of multimorbidity such as healthcare utilization, expenditure and self-rated health.

Methods: Longitudinal Aging Study in India (LASI), wave-1 is a nationally representative survey conducted amongst participants aged ≥45 years in 2017–18. We included 9,327 participants residing in urban areas, categorized as poor based on monthly per capita expenditure. Descriptive statistics computed prevalence with 95% uncertainty interval. Multivariable logistic regression was executed to assess the association between multimorbidity and various correlates, expressed as adjusted odds ratio. An ordinal regression model was run between self-rated health and number of chronic conditions.

Results: The prevalence of multimorbidity was 45.26% among the urban poor. Hypertension and oral morbidities were the most commonly observed dyad. Respondents who were poorer [AOR: 1.27 (1.06–1.51)] had higher chances of having multimorbidity than the poorest. Respondents with a health insurance [AOR: 1.40 (1.14–1.70)] had a higher risk of having multimorbidity. In-patient admission was significantly higher among participants having multimorbidity. Out of pocket expenditure increased while self-rated health deteriorated with each additional morbid condition.

Conclusion: Multimorbidity is found to be increasingly prevalent among urban poor and individuals having health insurance which demonstrates the need to expand healthcare insurance schemes such as Ayushman Bharat for urban poor to achieve UHC.

Keywords: multimorbidity, LASI, India, inequity, urban poor, UHC

INTRODUCTION

Multimorbidity, the co-occurrence of two or more chronic conditions being related or not, in an individual is evidently rising among aging population (1, 2). It has emerged as a significant global health issue that necessitates a comprehensive care strategy and notable healthcare system advancements to combat. The burden of multimorbidity is not limited to the high income countries alone, rather is equally observed in the low-and middle-income countries (LMICs) owing to the

changing lifestyle and cultural behaviors, urbanization, and changes in environmental exposures (3). Our previous systematic review estimated the prevalence of multimorbidity in South Asia to range from 4.5% to 83% across different age groups (4). Multimorbidity is often associated with an increased healthcare utilization, compromised physical functioning and quality of life, and psychological distress among patients and families (5). Additionally, polypharmacy has been detrimental to patient adherence and health (6).

The increasing burden of multimorbidity has a significant impact on the ability to achieve universal health coverage (UHC) (7). Although, healthcare facilities in urban areas are developing quicker than rural but, due to growing urbanization and migration, urban population has become a heterogeneous group where poor are compelled to face disparities in accessing sanitation, water, housing, and healthcare services (8). Many urban households face a threat of impoverishment due to increased out of pocket expenditure while seeking healthcare and loss of income due to illness (9, 10). They often spend 70% of total out of pocket expenditure on medicine purchases in India (10). Additionally, evidence suggests the onset of multimorbidity tends to occur 10–15 years earlier among people residing in the most deprived areas than those in the most affluent posing a challenge for this vulnerable group (11, 12).

Usually, in the areas of high socio-economic deprivation such as urban poor, the difficulties associated with multimorbid patients are exacerbated by the so-called 'inverse care law,' which states that the rising requirements and demands result in decreased healthcare access, fewer consultations, decreased patient enablement, and increased physician stress (13). As a result of the increasing treatment burden and lower capacity to cope, mental health problems such as depression and anxiety are exacerbated (14). Due to the limited access to healthcare, poor population have a combined burden of infectious and chronic diseases and poor health and quality of life outcomes (15). A study on multimorbidity in extreme poverty estimated the prevalence of two or more chronic illnesses at 22.8 % (16).

The growing burden of multimorbidity may severely impact the achievement of UHC, particularly among older adults and urban poor (17). Inadequately integrated and disease-specific care management programs such as National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases and Stroke (NPCDCS) may accentuate these issues, impeding the provision of quality care. Hence, there is a significant unmet need for accessible, egalitarian, and responsive primary healthcare services among vulnerable groups such as urban poor. Recent programmes such as Ayushman Bharat envisage to provide continuum of care for vulnerable sections through health insurance which further needs evidence based guidance to inform decisions about service provision and resource allocation**.** Hence, we aimed to estimate the prevalence, assess correlates and frequently occurring patterns of multimorbidity among poor residing in urban areas. Further, we aimed to assess the patient outcomes of multimorbidity such as healthcare utilization, expenditure and self-rated health.

Abbreviations: LMICs, Low-and-middle income countries; UHC, Universal Health Coverage; HWCs, Health and Wellness Centers; NCDs, Non-communicable diseases; SRH, Self-rated health; OOPE, Out of pocket expenditure; NPCDCS, National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases and Stroke; LASI, Longitudinal Aging Study in India; MPCE, Monthly per capita income; OPD, Out-patient department; IPD, In-patient department; HRQoL, Health related quality of life; CI, Confidence Interval; OR, Odds ratio; AOR, Adjusted Odds Ratio; INR, Indian National Rupees.

METHODS

Study Design and Participants

We conducted a population-based, cross-sectional analysis using data from the Longitudinal Aging Study in India (LASI), wave 1. LASI is a biennial national survey conducted during April 2017–December 2018, to provide estimates on the indicators of the health, economics, and social behaviors of aging population in India. LASI adopted a multistage stratified area probability cluster sampling design to arrive at a nationally representative sample of 72,250 individuals aged ≥45 years and their spouses (irrespective of age). LASI conducted face to face participant interviews using a pre-validated questionnaire in the local language of the respective states. LASI did not include persons living in collective arrangements such as nursing homes, jails, army camps, care homes etc. Individual response rate to LASI, wave 1 was 87.3%. To ensure standardization, LASI followed comprehensive manuals for field protocol, procedures, quality control and control of non-sampling errors. At national level, training was provided to trainers followed by state level training of investigators, The detailed description of methodology can be referred from LASI wave-1, India report (18).

Procedures

For this study, we included data from 9,327 participants aged ≥45 years clubbed from "poorer" and "poorest" quintiles based on MPCE (monthly per capita expenditure), residing in urban areas termed as urban poor. The sample size of 9,327 (12.91 % of total participants) was reached after excluding a total 62,923 participants who were either below 45 years of age, resided in rural areas or did not belong to the poorer or poorest MPCE quintile. A brief explanation on inclusion criteria for this study is provided in **Figure 1**.

Variables

Socio-Demographic and Socio-Economic Characteristics

Various socio-demographic characteristics such as sex (male and female), region (East, West, North, South, North-east & Central) and social groups (scheduled tribe, scheduled caste, other backward class and others) were included in the analysis. Age was categorized into three groups viz., 45–59 years, 60–74 years, and ≥75 years. Education was derived from the self-reported highest level of education and was regrouped as "no formal education", "up to primary", "middle school to higher secondary and diploma", and "graduation and above". Occupation was predicated from past work engagement for at least three consecutive months in the lifetime and current working status; categorized into three groups "never worked", "currently working", and "currently not working". Further,

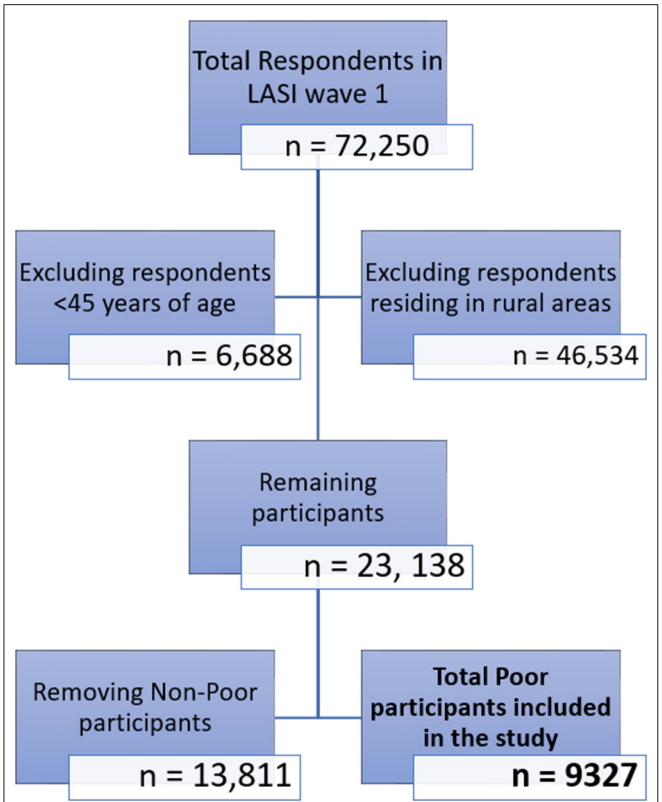


FIGURE 1 | Sample size derivation.

depending on the living arrangements with participant's partner, we grouped them as "with partner" and "without partner".

Healthcare cost incurred which includes healthcare provider fess, medicines, diagnostic tests, hospitalization charges, transportation, and other expenses due to hospital visit were elicited from respondents in Indian Rupees (₹). Healthcare utilization was assessed through the number of hospitalizations and out-patient visits in the past 12 months from the date of interview. Based on the total number of visits they were classified as "never" or "at least once". To estimate the healthcare access by the participants LASI, enquired about the type of facility visited and healthcare providers available during their visits. Further, self-rated health was used as a proxy indicator for health-related quality of life (HRQoL) computed on the basis of five-point Likert scale ("very good", "good", "fair", "poor", and "very poor") administered for subjective assessment of health status.

Outcome

The primary outcome of our study was multimorbidity, defined as the co-occurrence of two or more chronic conditions within an individual, without defining an index disease. We considered 17 self-reported chronic conditions (hypertension, diabetes, cancer, chronic lung disease, chronic heart disease, stroke, arthritis or bone/joint conditions, psychological or neurological conditions, hypercholesterolemia, thyroid disorder, gastrointestinal problems, skin disease, chronic kidney disease, urine incontinence, oral morbidities, visual impairment, and hearing impairment) to attain the outcome variable. Number of morbidities was scored as one in presence of one chronic condition, and sum of these scores was generated for each observation. As defined above, individuals scoring at least two or more were identified as having multimorbidity.

Statistical Analysis

The analysis was done using STATA statistical software version 17.0 for Windows (Stata Corp, College Station, TX, US). We used descriptive statistics (frequency & percentage) to describe the characteristics of study population. They were further used to describe the healthcare utilization & access. Prevalence of multimorbidity across various attributes was determined along with 95% confidence intervals (CI) as a measure of uncertainty for weighted proportions. We computed crude odds ratio (OR) to assess association between individual characteristics and multimorbidity followed by a multivariable logistic regression model to assess the potential risk factors associated with multimorbidity, reported as adjusted odds ratio (AOR) with 95% CI. Patterns (dyads and triads) of co-occurring conditions were assessed through a simple matrix approach which employed a comprehensive analysis of all possible and exhaustive combinations of chronic conditions with frequency of more than 0.5% (19). Next, median healthcare cost incurred by these patterns were estimated for those who spent on health. Further, an ordinal regression was computed between self-rated health with number of morbid conditions and adjusted for other covariates. Survey weights were considered during analysis to compensate for complex survey designs.

Ethical Considerations

This study is based on anonymous data obtained from LASI. The original LASI study was approved by the human ethics committee of Indian Council of Medical Research, New Delhi and International Institute of Population Sciences, Mumbai. Informed written consent was obtained from all participants prior to participation.

RESULTS

Description of the Study Population

Our study is based on a total of 9,327 participants. The mean age of respondents was 59.6 ± 10.4 years. Women comprised 55.7% of the study population. We observed 40.63% of the participants had no formal education while only 16.30% of the participants had health insurance. The detailed description of sample characteristics is provided in **Table 1**.

Profile and Distribution of Morbidity

The overall prevalence of multimorbidity in the study population was estimated to be 45.26%. Multimorbidity was more common among participants aged ≥75 years, females, who lived without partner and had a health insurance. Multimorbidity was found to be more prevalent among the non-working group such as 53.84% amongst participants who never worked and 51.84% among participants who are currently not working. Southern

TABLE 1 | Weighted socio-demographic characteristics of the study population and prevalence of multimorbidity across various socio-demographic attributes.

Attributes	Categories	*n* (%)	Multimorbidity present *n*, % (95% CI)
Age group (years)	45–59	4,775 (51.20)	1,616, 33.83 (32.50–35.21)
	60–74	3,545 (38.01)	1,893, 53.41 (51.74–55.05)
	≥75	1,007 (10.79)	646, 64.14 (61.10–67.12)
Gender	Male	4,131 (44.29)	1,696, 41.06 (39.55–42.57)
	Female	5,196 (55.71)	2,458, 47.31 (45.94–48.67)
Caste	Scheduled caste	1,487 (16.13)	640, 43.07 (40.51–45.60)
	Scheduled tribe	370 (4.01)	141, 38.16 (33.14–43.27)
	Other backward class	4,561 (49.49)	1,975, 43.30 (41.86–44.75)
	Others	2,799 (30.37)	1,352, 48.30 (46.44–50.17)
Region	East	1,560 (16.73)	822, 52.68 (50.18–55.19)
	West	2,417 (25.91)	936, 38.73 (36.78–40.70)
	North	675 (7.24)	329, 48.71 (44.91–52.58)
	South	2,516 (26.97)	1,218, 48.42 (46.44–50.38)
	North east	186 (2.00)	74, 39.53 (32.70–47.20)
	Central	1,973 (21.15)	776, 39.34 (37.17–41.53)
Education	No formal education	3,789 (40.63)	1,720, 45.39 (43.80–47.00)
	Primary completed	2,585 (27.71)	1,252, 48.43 (46.49–50.38)
	Up to matriculation	1,987 (21.31)	831, 41.85 (39.64–44.03)
	Higher secondary and diploma	464 (4.98)	170, 36.54 (32.24–41.20)
	Graduate and above	501 (5.37)	181, 36.16 (31.91–40.51)
Working status	Never worked	2,943 (31.57)	1,584, 53.84 (52.00–55.64)
	Currently working	3,624 (38.87)	1,141, 31.48 (29.97–33.02)
	Currently not working	2,755 (29.56)	1,428, 51.84 (49.95–53.71)
Partner	With partner	6,614 (70.92)	2,795, 42.26 (41.07–43.47)
	Without partner	2,712 (29.08)	1,359, 50.12 (48.21–52.01)
MPCE quintiles	Poorer	4,831 (51.79)	2,002, 41.44 (40.05–42.85)
	Poorest	4,496 (48.21)	2,153, 47.88 (46.42–49.36)
Health insurance	Yes	1,498 (16.30)	760, 50.70 (48.17–53.30)
	No	7,691 (83.70)	3,333, 43.34 (42.23–44.45)

region accounted for the highest prevalence of multimorbidity while more than half of the Eastern region had multimorbidity. Amongst the urban poor, poorest had the higher prevalence of multimorbidity (47.88%) as compared to the poorer (41.44%). The detailed description of prevalence of multimorbidity across various socio-demographic variables is presented in **Table 1**.

We observed hypertension and oral morbidities s (3.4%) were the most commonly occurring dyads followed by hypertension and diabetes (2.07%) while hypertension, diabetes and oral morbidities (1.04%) formed the most commonly presenting triad (**Table 2**).

Correlates of Multimorbidity

The crude odds ratio showed a significant association between age, gender, primary education and no work with multimorbidity. The findings from multivariable analysis suggested the likelihood of having multimorbidity increased with aging as the participants aged 60–75 years had [AOR: 2.01 (1.67–2.43)] which increased to [AOR: 2.76 (2.02–3.75)] among respondents aged ≥75 years. Respondents from eastern part of the country had the highest chances of having multimorbidity [AOR: 2.05 (1.44–2.92)] followed by south [AOR: 1.74 (1.20–2.54)]. We observed the risk of multimorbidity to be highest among participants who had never worked in their lifetime for at least three consecutive months with an AOR of 2.16 (1.70–2.76). Respondents who had health insurance coverage had a higher risk of having multimorbidity [AOR; 1.40 (1.14–1.70)] as compared to the others. The univariable analysis revealed a protective association for multimorbidity but after adjusting for other covariates, multivariable regression depicted multimorbidity to be significantly common [AOR: 1.27 (1.06–1.51)] amongst poorer as compared to the poorest group (**Table 3**).

Patient Outcomes of Multimorbidity

Trends in Healthcare Utilization and Expenditure

We observed a significantly higher in-patient (IPD) admission among those with multimorbidity (10.94% vs. 5.81%) as compared to those without multimorbidity while visit to the out-patient department (OPD) was almost similar. Participants with (53.69%) or without multimorbidity (37.53%) preferred private hospitals over public facilities. Majority of the participants

TABLE 2 | Frequently occurring multimorbid patterns (frequency > 0.5%).

Sl. No	Patterns	Frequency	Percentage
1	Hypertension + Oral Conditions	321	3.44
2	Hypertension + Diabetes	193	2.07
3	Gastrointestinal disease + Oral Conditions	179	1.92
4	Arthritis and other bone/joint diseases + Oral Conditions	154	1.65
5	Hypertension + Diabetes + Oral Conditions	97	1.04
6	Hypertension + arthritis and other bone/joint diseases	89	0.96
7	Hypertension + Gastrointestinal disease	86	0.92
8	Hypertension + gastrointestinal disease + Oral Conditions	77	0.82
9	Diabetes + Oral Conditions	75	0.81
10	Hypertension + Arthritis and other bone/joint diseases + Oral Conditions	73	0.78
11	Arthritis and other bone/joint diseases + Gastrointestinal disease	71	0.76
12	Hypertension + Visual impairment	57	0.61
13	Chronic Lung disease + Oral Conditions	49	0.53
14	Hearing impairment + Oral Conditions	48	0.51
15	Hypertension + Skin diseases	47	0.5

TABLE 3 | Logistic regression showing association between multimorbidity and its correlates.

Attributes	Categories	OR (95% CI)	*p*-values	AOR (95% CI)	*p*-value
Age groups (years)	45– 60	Reference		Reference	
	60–75	2.24 (1.87–2.68)	0.000	2.01 (1.67–2.43)	0.000
	≥75	3.50 (2.63–4.64)	0.000	2.76 (2.02–3.75)	0.000
Gender	Male	Reference		Reference	
	Female	1.29 (1.09–1.53)	0.004	0.94 (0.73–1.20)	0.598
Caste	Scheduled caste	0.99 (0.78–1.26)	0.939	1.05 (0.84–1.31)	0.681
	Scheduled tribe	0.81 (0.58–1.13)	0.208	1.05 (0.73–1.50)	0.805
	Other backward class	Reference		Reference	
	Others	1.22 (1.01–1.48)	0.040	1.17 (0.97–1.41)	0.096
Region	East	1.70 (1.23–2.36)	0.001	2.05 (1.44–2.92)	0.000
	West	0.97 (0.70–1.34)	0.839	1.05 (0.74–1.49)	0.777
	North	1.45 (1.05–2.00)	0.023	1.72 (1.20–2.47)	0.003
	South	1.44 (0.98–2.09)	0.059	1.74 (1.20–2.54)	0.004
	North east	Reference		Reference	
	Central	0.99 (0.72–1.36)	0.962	1.14 (0.81–1.62)	0.449
Education	No formal education	1.47 (0.95–2.28)	0.087	1.17 (0.75–1.84)	0.492
	Primary completed	1.66 (1.07–2.58)	0.025	1.37 (0.88–2.14)	0.169
	Up to matriculation	1.27 (0.81–2.00)	0.300	1.15 (0.74–1.78)	0.536
	Higher secondary and diploma	1.02 (0.58–1.78)	0.954	1.01 (0.59–1.71)	0.984
	Graduate and above	Reference		Reference	
Working status	Never worked	2.54 (2.08–3.10)	0.000	2.16 (1.70–2.76)	0.000
	Currently working	Reference		Reference	
	Currently not working	2.34 (1.88–2.91)	0.000	1.75 (1.38–2.23)	0.000
Partner	With partner	Reference		Reference	
	Without partner	1.37 (1.13–1.67)	0.002	0.92 (0.75–1.12)	0.393
Healthcare insurance	Yes	1.34 (1.13–1.61)	0.001	1.40 (1.14–1.70)	0.001
	No	Reference		Reference	
MPCE quintile	Poorer	0.77 (0.65–0.91)	0.003	1.27 (1.06–1.51)	0.010
	Poorest	Reference		Reference	

TABLE 4 | Trends of health care utilization among urban poor.

Healthcare access	Multimorbidity present		
	Absent *n*, % (95% CI)	Present *n*, % (95% CI)	*p*-value
OPD visits in last 12 months (*n* = 5,941)			
Never	579 20.77 (19.28–22.32)	579 18.35 (17.02–19.75)	0.000
At least once	2,208 79.23 (77.67–80.72)	2,575 81.65 (80.25–82.98)	
IPD visits in last 12 months (*n* = 6,034)			
Never	2,667 94.19(93.25–95.00)	2,852 89.06 (87.94–90.13)	0.000
At least once	165 5.81 (4.99–6.75)	350 10.94 (9.87–12.06)	
Type of health care facility (*n* = 9,182)			
Public	689 13.53 (12.60–14.50)	742 18.14 (16.98–19.36)	0.000
Private	1,911 37.53 (36.19–38.87)	2,196 53.69 (52.14–55.22)	
Others	416 8.17 (7.43–8.95)	495 12.11 (11.12–13.14)	
None	2,076 40.77 (39.41–42.13)	657 16.06 (14.95–17.23)	
Healthcare provider (*n* = 9,190)			
Doctors	2,340 45.93 (17.74–20.16)	2,797 68.31 (66.85–69.73)	0.000
Nurses	9 0.17 (0.08–0.34)	11 0.27 (0.13–0.48)	
Paramedics	449 8.81 (8.05–9.62)	393 9.60 (8.71–10.54)	
Traditional	70 1.37 (1.07–1.73)	77 1.88 (1.49–2.34)	
Others	57 1.13 (0.84–1.45)	42 1.02 (0.74–1.38)	
None	2,170 42.60 (41.23–43.96)	775 18.92 (17.74–20.16)	
Health insurance (*n* = 9,189)			
Yes	738 14.49 (13.53–15.48)	760 18.56 (17.39–19.79)	0.022
No	4,358 85.51 (84.52–86.65)	3,333 81.44 (80.21–82.61)	
Source of health insurance (*n* = 1,695)			
Central govt.	225 27.08 (24.11–30.27)	257 29.99 (26.94–33.18)	0.700
State govt.	494 59.5 (56.09–62.88)	503 58.76 (55.31–62.01)	
Private	60 7.27 (5.56–9.21)	64 7.48 (5.80–9.44)	
Others	51 6.10 (4.61–8.00)	32 3.77 (2.57–5.23)	

uniformly had access to the doctors. We found less than one fifth of the study population were insured under any healthcare insurance scheme which was mostly funded by state government (**Table 4**).

We plotted the patterns of commonly occurring chronic conditions with the healthcare cost incurred for them. It depicted that the participants spent a maximum of around INR 1,200 for the triad of hypertension, diabetes and oral morbidities followed by INR 1,000 for dyad of chronic lung condition and oral morbidities (**Figure 2**). We observed an increase in out of pocket expenditure (OOPE) for each additional long term condition. The total median healthcare expenses (in INR) among participants with no morbid condition was 350 which increased to 600 and 1,080 for two and four or more chronic conditions respectively (**Figure 3**).

Self-Rated Health

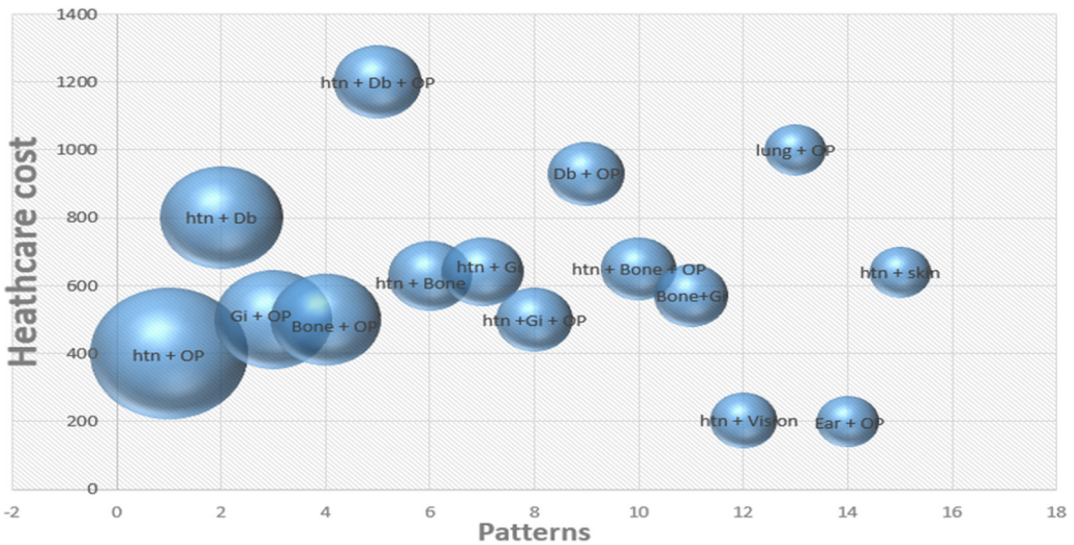
Our findings from ordinal regression model suggested, self-rated health deteriorated with an increase in each additional chronic condition (**Table 5**). After adjusting for various attributes such as age, gender, and health insurance etc.; we found a significant per unit deterioration of self-rated health as the number of morbid conditions increased with highest among those with four or more morbid conditions [AOR:9.75 (7.34–12.96)].

DISCUSSION

Universal health coverage aims to provide accessible and affordable quality health services for every person everywhere (20). The Sustainable Development Goal 3 calls on to prioritize health for all by 2,030 where vulnerable populations such as poor need special attention (21). Estimates suggest, around 90% of the world's poorest billion live in sub-Saharan Africa or South Asia (22). In India, a South Asian country urban population is projected to rise from 31% in 2011 to 46% by 2030 out of which 30%–40% people reside in slums or areas of deprivation (23). Additionally, the healthcare system is primarily oriented toward management of infectious diseases along with maternal and child health (22) whereas multimorbidity requires long term support where continuity of care plays an important role (24). We estimated the magnitude and assessed patient outcomes of multimorbidity among urban poor to orient evidence based resources for this group.

Our study elicited a high prevalence of multimorbidity among poor population residing in urban areas. Multivariable regression revealed a higher chance of having multimorbidity among poorer group than the poorest; and participants having healthcare insurance. Healthcare expenditure increased with each additional condition and was highest for the most commonly occurring triad. A significantly higher healthcare utilization such as IPD visit was observed among participants having multimorbidity. Self-rated health deteriorated with each additional chronic condition.

We observed an overall prevalence of multimorbidity to be around 45% which is consistent with the findings of our previous community based study which reported 41% prevalence among participants aged ≥18 years in urban areas of Odisha, India (25). We obtained a slight higher prevalence in the present study which may be due to the aging population considered here. Moreover, a study from China reported that the impact of multimorbidity on work productivity loss was found lesser among rural residents than the urban group (26). Additionally, a study conducted among urban residents of Spain found almost 50% of the residents



Foot Notes: Bone- Arthritis and other bone/joint diseases; Db- Diabetes; Ear- Hearing impairment; Gi- Gastrointestinal diseases; htn- Hypertension; lung- Chronic lung disease; Vision- Visual impairment; skin- Skin disease; OP- Oral conditions

FIGURE 2 | Healthcare expenditure across commonly occurring patterns of multimorbidity.

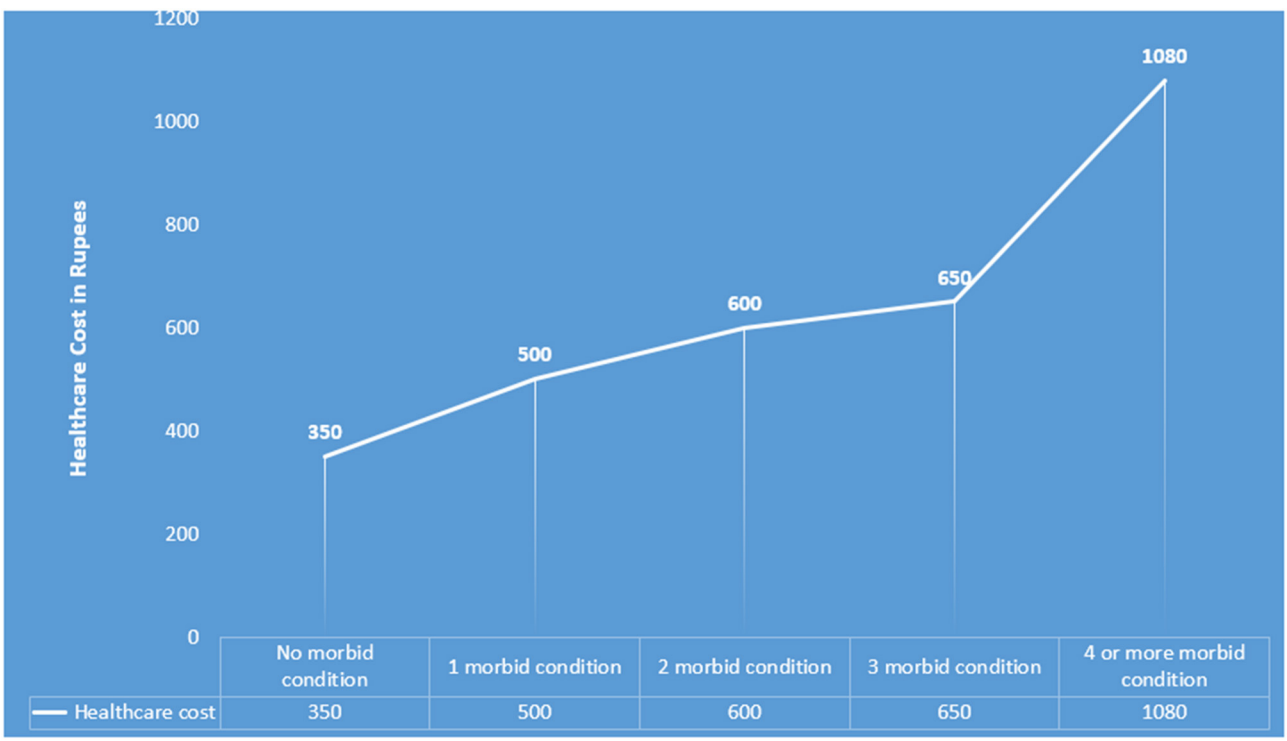


FIGURE 3 | Trends of healthcare expenditure with number of morbid conditions among urban poor (median INR).

TABLE 5 | Ordered logistic regression showing association between self-rated health with number of morbid conditions.

Attributes	Categories	AOR, 95% CI	*p*-value
Number of morbid conditions	No morbid conditions	Reference	
	One morbid condition	1.68 (1.33–2.11)	0.000
	Two morbid conditions	2.66 (2.10–3.37)	0.000
	Three morbid conditions	4.92 (3.63–6.66)	0.000
	Four or more morbid conditions	9.75 (7.34–12.96)	0.000

**Adjusted for age, gender, caste, region, education, working status, partner, MPCE quintiles, and health insurance.*

had multimorbidity (27). These findings are almost similar to our findings however, there is a paucity of literature on multimorbidity among urban poor in LMICs such as India which makes it challenging to compare our results with similar studies (28).

After adjusting for other variables, we found a higher risk of multimorbidity among poorer group than the poorest. This points toward the heterogeneity within urban poor in accessing healthcare facilities. A probable explanation for this could be that the urban poor are mostly migrants coming for employment opportunities to big cities where neo-migrants often lack access to healthcare facilities or are often not covered in the local list of frontline workers such as ASHA which devoid them from obtaining primary care facilities (29, 30). Additionally, a systematic review suggested higher odds of multimorbidity among urban residents (31). Nonetheless, lack of healthcare insurance is another factor for under diagnosis of multimorbidity among the poor group as elucidated by our study. We observed multimorbidity to be more common amongst respondents who had a healthcare insurance which clearly elucidates better prospects of receiving healthcare facilities among people with insurance. This is similar to the findings of our previous study which also revealed participants without insurance had a negative association with multimorbidity (32). Here, it is worth noting that implementing equitable and egalitarian health insurance schemes such as Ayushman Bharat needs special attention for inclusion of this group.

Furthermore, we found an increase in healthcare expenditure with each additional condition which is consistent with the findings of a previous study which showed mean out of pocket expenditure for OPD visit increased from INR 262.2 for participants with no NCD to INR 431 amongst those who had multimorbidity. Here, it is worth noting that higher OOPE implies a need to pay directly from pocket for utilizing healthcare facilities which gets hampered by the inability to pay as in the case of urban poor (33). Multimorbidity requires long term use of multiple drugs, periodic investigations and visits to doctor (34) which is easy for poorer group, an explanation for easy access to healthcare and hence, better diagnosis and continuity of care among this group than the poorest. Additionally, older adults are often dependent on their children for finances which compels them to underutilize healthcare services (35).

Previous studies document an increased hospital admission and emergency visits among patients with multimorbidity (32). We also observed a significantly higher IPD visit among multimorbid individuals which further needs attention for multimorbidity management especially amongst urban poor who face disparity in healthcare utilization and expenditure. With the change in disease epidemiology, it is imperative to prioritize quality health services through infrastructure development and capacity building of human resources with an aim to reduce OOPE. Additionally, reinforcing trust in public health system is necessary to align with the global discourse of attaining UHC. Furthermore, self-rated health (SRH), a proxy indicator for quality of life was found to deteriorate with each additional chronic condition which is in harmony with the findings of previous studies which revealed patients with multimorbidity have inferior self-rated health (36).

Implications for Policy and Practice

Multimorbidity is found to be increasingly prevalent among urban poor and those who are not working which points toward an unmet need for multimorbidity care among this marginalized group. The existing Ayushman Bharat scheme envisage to provide free healthcare services to poor, but its frame needs to be broadened to cover urban poor specially the migrating population. It is imperative to have Health and Wellness Centers (HWCs) in the vicinity of urban slums so as to have easy access to health services thus reducing OOPE. A focus on older adults and people living in eastern region is necessary. Additionally, risk factors of multimorbidity such as dietary control, abstaining from tobacco, alcohol and physical activities should be targeted at an early state to prevent or delay the disease onset. Screening should be expanded in current programs such as the National Programme for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases, and Stroke (NPCDCS). There is an urgent need to create awareness regarding oral hygiene from childhood. Information, education and communication activities should aim at motivating people to equally prioritize oral health in order to improve oral hygiene. Also, coordinated quality care for both physical and oral health should preferably be provided under one umbrella. A holistic care approach for women's overall well-being is required as women have been identified to be at higher risk of having multimorbidity. Integration of current programs such as NPCDCS and RMNCH+A will be useful for continued support to women's health. Digital literacy to avail e-services is required especially among women and older adults as these groups may face challenges in accessing healthcare due to inadequate digital literacy. Further, cohort studies are warranted to understand the heterogeneity in healthcare needs within urban poor.

Strengths and Limitations

This study used a national level data to extrapolate the differences in multimorbidity prevalence and its outcomes among urban poor, a vulnerable group which needs special attention for healthcare to achieve UHC. We used 16 chronic conditions to assess multimorbidity which is another strength of this study, but these conditions were self-reported which might undermine

the true population estimates. Evidence suggests self-reported conditions leads to misclassification bias which under-represents the issue being studied (37, 38). However, previous studies have also suggested a high agreement between self-reported conditions and clinical assessed conditions (39). Nonetheless, self-reported conditions majorly limit our study. Furthermore, this study was based on cross-sectional data which could not establish causality.

CONCLUSION

Our findings elicit inequalities in the magnitude and distribution of multimorbidity within urban poor. Participants having health insurance had higher chances of having multimorbidity which can be due to better healthcare access in this group. Additionally, poorer SRH and higher OOPE with each additional long term condition cannot be overlooked. This points toward expanding coverage of healthcare insurance schemes such as Ayushman Bharat along with setting HWCs for urban poor to achieve UHC.

DECLARATION

All methods were carried out in accordance with relevant guidelines and regulations.

DATA AVAILABILITY STATEMENT

Publicly available datasets were analyzed in this study. This data can be found here: https://iipsindia.ac.in/content/lasi-wave-i.

ETHICS STATEMENT

As the present study utilizes de-identified data from a secondary source available in public domain, it doesn't require ethical review and approval. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

SP: concept and design. AS, SKe, and SG: acquisition, statistical analysis, or interpretation of data. AS, SKe, and SG: drafting of the manuscript. SP and SKa: monitored analysis and critical revision of the manuscript for important intellectual content. SP and SKa: administrative and technical support. SP: supervision. All authors reviewed the manuscript. All authors contributed to the article and approved the submitted version.

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Gender Disparity and the Association Between Socioeconomic Status, Mental Health, and the Need for Long-Term Services and Support Among the Older Koreans

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Background: Population aging—the inevitable increase in the percentage of older adults—is occurring all around the world as the fertility rate declines and life expectancy rises. This study examined the relationship between socioeconomic status (SES), mental health, and the need for long-term services and support (LTSS) among Korean older adults. It also aimed to provide evidence-based information for South Korea's long-term support services and programs.

Methods: This study used the data on older adults aged over 60 years from the 2018 Korean Longitudinal Study of Aging (KLoSA). Ultimately, 5,527 older adults were included in the database (42.6% men, 57.4% women). To clarify the association between SES, mental health, and the need for LTSS among older Korean men and women, chi-squared test, *t*-test, and structural equation modeling (SEM) were performed.

Results: The SEM analysis showed that a significant, negative association was observed between SES and the need for LTSS among these older adults—the higher SES groups would generally have less need for LTSS. Mental health had a strong, negative impact on the need for LTSS—better mental health status of the older individuals would indicate a lower need for LTSS, and the effect was stronger among older men. Meanwhile, the positive relationship between SES and mental health was verified—the higher the SES of these older adults the better their mental health.

Conclusions: Gender- and social class-sensitive impacts of mental health on the need for LTSS were observed in this study. These findings could provide an evidence-based reference for interventions targeting different genders and social classes in Korea's long-term care system, such as the enhancement of social welfare and mental health status of the older adults.

Keywords: socioeconomic status, mental health, need for long-term services and support, older Korean adults, gender disparities, structural equation modeling

INTRODUCTION

Driven by decreasing levels of mortality and increasing life expectancy, the world continues to witness unprecedented, sustained changes in the age structure of the global population. People live longer, and the overall population has rapidly increased, with a greater proportion of older people. All regions worldwide will experience increasing elderly populations from 2020 to 2050, as the percentage of this population aged 65 years or older could grow from 9.3 to 16.0% during that time (1). South Korea officially became an aged society in 2017, with over 14% of its people aged 65 years or older (2). As of 2020, South Korea is the country with the world's lowest total fertility rate (0.84) and first reported more deaths than births (3, 4). In South Korea, the proportion of people aged 65 years or older is estimated to rise from 15.9% in 2020 and reach 40.1% by 2060 (5, 6). Thus, South Korea's aging population has become a serious concern.

Compared with other groups, older adults exhibit "frailty"—they are physically unhealthy and mentally weaker (7). As aging progresses, their decreasing cognitive ability of them will compel them to find available care services (8). The United Kingdom, Australia, Japan, and other welfare states have become aging societies and have responded by providing community-based sustainable health-promotion services; these are integrated with healthcare and welfare based on cooperation with central and local governments (9, 10). As a super-aged society, South Korea has placed the older people as a target for various supports and services in terms of economic aspects, such as long-term care insurance and the Framework Act on Social Security laws (11). Series of long-term care-related programs and facilities have been established for older adults to assist in their daily lives to improve their quality of life since 2008, and the services providers also rapidly expanded (12).

Long-term services and supports (LTSS) comprise day-to-day help needed by people with long-term conditions, disabilities, and frailty (13). This could include self-care (e.g., bathing, dressing, and toileting), help with household tasks such as meals, transportation, bills, and complex health care (medications, wound care), and other ongoing social services (14). Older people in Korea have the highest poverty and suicide rates and medical costs among the OECD countries; however, the aging response index that measures the level of preparedness for aging is the lowest (15). Because the majority (70–80%) of the long-term care services providers and institutions are private (16), issues of concern include criticized quality, insufficient mutual cooperation, and communication that prevents sustainable services from being provided (17); further, the perception of the services and supports used is significantly lower than in other welfare countries (18). In Korea, older people accounted for about 23.5% of one-person households in 2015 and the proportion of seniors living alone increased to 33.5% in 2016 (19, 20). Moreover, from 2008 to 2016, family structure and attitudes about older people's care have changed significantly. The proportion of parents who live with their children declined from 38.0 to 29.2%; surveys indicate that the increasing Korean population thought that parental support should not only be in the family and need support from the government and society (21). However, their use and eligibility for benefits face challenges and are more limited in home-based (68%) care and support (22).

Existing research supports the widely held conclusion that the need for LTSS (informal or home care) disparities could result from socioeconomic status (SES) (23, 24). SES is a significant factor that affects older adults' LTSS preferences in the care of type (25). Earlier studies have discovered that older people with higher educational attainment and household income were less functionally affected and had more predictive attitudes and planning of LTSS (26, 27). SES most commonly encompasses income and the attainment of education and occupational prestige, which is typically the social position or class of a person or group (28, 29). As educational achievement is typically determined early in life, education is considered a sign of the first choice. Income or related working occupation characteristics might be chosen widely to investigate the links between SES and health (30). In Korea, compression of morbidity and health care utilization were more common among those with a high SES (16). Furthermore, a cross-sectional study reported that women were more likely than men to plan to need specialized LTSS, such as homecare (31).

Mental health has long been a primary topic in many research fields, especially in terms of aging and healthcare support. Meanwhile, owing to the functional decline, the need for LTSS among older adults is impacted by biomedical causes and psychological disorders (32, 33). The literature has reported that elderly people who perceive high levels of isolation or loneliness show low levels of physiological functioning' repair and maintenance (34). The increased use of medical services and frequency of physician visits are influenced by depression among the elderly in primary care practices (35, 36). Additionally, older adults who had lower life quality ratings were inclined to increase the risk of complex medical needs (37). Research on Japanese and Chinese elderly (38–40) also indicated that mental health negatively affects the need for LTSS—better mental health status corresponds to a lower need for LTSS; however, the strength of such effects also varies depending on gender and age. It has been recognized that a person's mental health and the family's wellbeing should be emphasized across healthcare and LTSS systems (41).

Previous studies have also observed a relationship between mental health and socioeconomic status (SES). These studies have consistently indicated that lower SES is linked to an increased incidence of psychiatric disorders and more persistent patterns of depression (42–44). For example, adults living in the low-income group reported an increased risk of mental health problems than individuals who live in the high-income group (45, 46). Moreover, older, less-educated individuals with longer working times are most likely to experience mental disorders and suicidal ideations in Korea (47–49). A study about the Japanese aged 65 years and older mentioned working (full-time or part-time job) played a positive role in slowing the deterioration of mental health (50). Therefore, changes in SES could lead to subsequent changes in mental health status with the impact of individual and contextual determinants (51).

Understanding the connections between socioeconomic status and older adults' wellbeing is especially critical in the

pledge of the United Nations' 2030 Agenda for Sustainable Development. Its Sustainable Development Goals include an emphasis on the most disadvantaged, including elderly adults, and can be accomplished in all sectors and levels of society (52). Therefore, the associations between SES, mental health, and the need for LTSS for older people have become an increasingly important policy concern, especially in countries with populations in advanced stages of aging.

Some previous studies have mostly explored the relationship between SES and the need for LTSS, mental health, and the need for LTSS, SES, and mental health. Seldom analysis included all the three variables, let alone among older Korean adults. Traditional modeling methods that merely demonstrate correlations between variables were mainly used. Structural equation modeling (SEM) is a useful analytical method for testing and estimating associations by combining statistical data with qualitative assumptions while simultaneously accounting for measurement error (53). The paths in modeling indicate the hypothesized relationships between variables that can work as both predictors and responses simultaneously and serve as mediators between explanatory and response variables (54). Hence, to fill the research gap, this study aimed to identify the relationships between SES, mental health, and the need for LTSS among older Koreans using excessive sample data by employing SEM and further explain whether a gender disparity exists in the relationship.

METHODS

Study Design and Data

The study used cross-sectional data from the Korean Longitudinal Study of Aging (KLoSA) Wave 7 (2018) in this study. The KLoSA was launched in 2006 and includes a nationally representative sample of Koreans aged 45 years or older obtained through multistage stratified probability sampling based on geographical area (55). The KLoSA is the first nationwide study of South Korea and was founded by the Ministry of Labor, which tests depressive symptoms and is open to the public. In interdisciplinary research on the social, economic, physical, and psychological issues related to aging, the KLoSA has also been developed to gather the basic data needed to devise and implement effective social and economic policies to address the trends that emerge as the population ages. Data were collected using computer-assisted personal interviewing with a good response rate. A total of 6,940 samples were collected in Wave 7, and the final number of the people aged over 60 years old included in this study after the screening was 5,527 (2,353 men and 3,174 women).

Measurements

Assessment of SES

SES is a multidimensional concept affecting health through various components including income, education, and occupation, one of which may have different impacts on the health status and healthcare usage (56, 57). This study evaluated the educational level by asking the participants the question "Which level of education did you complete?" with five options: (1) elementary school and below, (2) middle school, (3) high school, or (4) college/university or higher. Income is closely related to employment, and household income could be a good alternative to assess the older individuals' SES (30). Annual household income (unit: KRW: 10,000 won) was discretized based on quartile: (1) Q1: $\leq$ 1,000 (USD 8,500), (2) Q2: 1,001–2,000 (USD 17,000), (3) Q3: 2,001–3,500 (USD 29,750); (4) Q4: >3,500. According to the concept of productive aging, working at a later age is a healthy approach to maintaining one's health (50). More questions were asked to these older adults, such as "current work or not". The answers including (1) "yes" or (2) "no" were included in this study.

Assessment of Mental Health

Many interdisciplinary studies have recognized and researched the concept of mental health as a primary component of wellbeing (58). This study assessed the mental health of older adults by 3 dimensions (40, 59) and asked them three questions (1) "How satisfied are you with your health status?" (subjective health); (2) "How satisfied are you with your overall quality of life?" (life satisfaction); (3) "How about your feelings and behaviors during the past week?" (past week mental health: reversal of past week depression). Responses for the first two questions range from 0 ("absolutely no") to 100 ("absolutely certain"), and responses were classified into two categories: good (scores $>$ 50) and bad (scores $\leq$ 50). The third question was measured by the Center for Epidemiologic Studies Depression Scale, a 10-item Likert scale questionnaire assessing depressive symptoms in the past week (60). Options for each item range from "most of all of the time" (score of 3) to "rarely or none of the time" (score of 0). The total scores ranged from 0 to 30. Higher scores suggest a greater severity of symptoms (past week depression). The Cronbach's alpha coefficient of the scale in this study was 0.863. The Kaiser-Meyer-Olkin measure of sampling adequacy was 0.904, with a result for Bartlett's test of sphericity of $<$0.001.

Assessment of Need for LTSS

In South Korea, the eligibility for using the long-term care related service and supports for older adults to assist in their daily lives is divided by a set of government-issued criteria and checklists, including the fundamental assessment of activities of daily life disabilities and functional limitations (61). The need for care could be reflected in the phases of the caregiving trajectory by episodic status or events such as pains and hospitalization (14). In this study, the assessment of the need for LTSS by four variables. (1) "total ADL/IADL": Activities of daily living (ADL) and Instrumental Ability of Daily Life (IADL)were measured in this survey using 17 questions, with 3-level answers (1 = do not need help, 3 = need help in every respect). (2) Activity limitation by health (1 = not at all, 4 = very much); (3) hospitalization times in the past 2 years; (4) the number of body pains (head, shoulder, arm, fingers, etc., 13 pains in total).

TABLE 1 | Participants' descriptive characteristics.

Variables	Men	Women	Total
	n (%)/mean ± S.D.	*n* (%)/mean ± S.D.	*n* (%)/mean ± S.D.
Participants	2,353 (42.6%)	3,174 (57.4%)	5,527 (100%)
Age	72.17 ± 8.26	73.28 ± 8.73	72.80 ± 8.55
Marital status			
Married/living with a partner	2,124 (90.3%)	1,848 (62.0%)	3,972 (71.9%)
Separated/divorced	60 (2.5%)	74 (2.3%)	134 (2.4%)
Widowed/missing (dispersed family)	153 (6.5%)	1,240 (39.1%)	1,393 (25.2%)
Never married	16 (0.7%)	12 (0.4%)	28 (0.5%)
Households composition			
Single household	377 (16.0%)	1,001 (31.5%)	1,378 (24.9%)
Couple household/one generation	1,279 (54.4%)	1,177 (37.1%)	2,456 (44.4%)
Two generation	586 (24.9%)	712 (22.4%)	1,298 (23.5%)
Three generation or more/others	111 (4.7%)	284 (9.0%)	395 (7.2%)
Awareness of supports and services			
Yes	1,618 (68.8%)	2,157 (68.0%)	3,775 (68.3%)
No	735 (31.2%)	1,017 (32.0%)	1,752 (31.7%)
Current using supports and services			
Yes	45 (1.9%)	93 (2.9%)	138 (2.5%)
No	2,308 (98.1%)	3,081 (97.1%)	5,389 (97.5%)

Statistical Analysis Approach

Descriptive statistics were collected to describe the participants' demographic characteristics. The gender disparity in social-demographic characteristics, SES, mental health indicators, and the need for LTSS indicators were measured using a chi-squared test. A p-value of <0.001 denotes statistical significance, and all the analyses were performed using the Statistical Package for Social Science (SPSS) software suite, version 24.0.

SEM was performed to investigate the relationship between SES, mental health, and the need for LTSS in older Koreans. SEM is expressed by path diagrams, which allow the researcher to diagram the hypothesized set of relationships in the model. Factors have two or more indicators called latent variables, which are represented using circles or ovals in path diagrams. The model in the SEM consists of two types of latent variables: exogenous variables (determined outside the model) and endogenous variables (determined by the model).

In the study, the exogenous variable was SES, and the endogenous variables were mental health and the need for LTSS. Lines indicate relations between variables; A line with one arrow represents a hypothesized direct relationship between two variables. The direction of the arrows connecting each exogenous variable to its' indicators (pointing to the indicators): the latent variable is measured by indicators. SES was measured by three variables: education level, household income, and current work. Mental health was measured based on respondents' health satisfaction, life satisfaction, and past week mental health. The need for LTSS was measured by four variables: total ADL/IADL, activity limitations, hospitalization times, and the number of pains.

The maximum-likelihood estimation to predict the best-fitting model was used in this study. The parameters were estimated in the model. To interpret and compare, regression coefficients between variables were focused on standardized regression coefficients shown in the diagrams. The AMOS version 21 statistical software package for Windows was used to perform the SEM, measure the model's fitness indexes, and obtain the maximum-likelihood estimates of model parameters.

RESULTS

Sample Characteristics

Table 1 illustrates the basic descriptive demographic characteristics of older adults. Of the 5,527 participants involved in our analysis, 2,353 (42.6%) were men, and relatively fewer were women (3,174, or 57.4%), with an average age of 72.80 ± 8.55 years in 2018. Men and women showed different proportions of marital status. The percentage of older men who were married or living with a partner was higher than that of older women, while older women showed a higher proportion in the widowed/missing group. The older persons who lived alone or living with a spouse in one generation accounted for the majority, while there were differences in the proportions between male and female groups (16.0 vs. 31.5%; 54.4 vs. 37.1%). In addition, almost 70% of them were aware of the existence of long-term care services and supports, including the institutional/home care services, activity support services, etc. However, the proportion of those using in 2018 shared only 2.5% among these older Koreans.

Table 2 displays information regarding the descriptive characteristics for the selected variables by gender. Regarding age, older men and women participants shared similar proportions in the three groups, with the biggest number in the range 60–69 years old. In terms of education, more older males had high

TABLE 2 | Descriptive SES, mental health, and need for LTSS characteristics of participants by gender.

Variables	Gender						χ^2-Test (*p*)
	Men (*n* = 2,353)		Women (*n* = 3,174)		Total (*n* = 5,527)		
	n	%	*n*	%	*n*	%	
Age							
60–69	993	42.2%	1,221	38.5%	2,214	40.1%	14.27 (0.001)
70–79	857	36.4%	1,145	36.1%	2,002	36.2%	
≥80	503	21.4%	808	25.5%	1,311	23.7%	
Education level							
Elementary school and below	668	28.4%	1,928	60.7%	2,596	47.0%	711.804 (<0.001)
Middle school	441	18.7%	532	16.8%	973	17.6%	
High school	851	36.2%	601	18.9%	1,452	26.3%	
College/University or higher	393	16.7%	113	3.6%	506	9.2%	
Annual household income (per 10,000 Korean won)							
Q1	537	22.8%	1,106	34.8%	1,643	29.7%	118.814 (<0.001)
Q2	545	23.2%	754	23.8%	1,299	23.5%	
Q3	561	23.8%	647	20.4%	1,208	21.9%	
Q4	710	30.2%	667	21.0%	1,377	24.9%	
Current work							
No	1,364	58.0%	2,525	79.6%	3,889	70.4%	301.879 (<0.001)
Yes	989	42.0%	649	20.4%	1,638	29.6%	
Subjective health							
Bad	900	38.2%	1,556	49.0%	2,456	44.4%	63.531 (<0.001)
Good	1,453	61.8%	1,618	51.0%	2,178	55.6%	
Life satisfaction							
Dissatisfied	655	27.8%	1,129	35.6%	1,784	32.3%	36.970 (<0.001)
Satisfied	1,698	72.2%	2,045	64.4%	3,743	67.7%	
Past week depression							
Mean ± S.D.[a]	6.24 ± 5.433		7.13 ± 5.633		6.75 ± 6.00		−5.938 (<0.001)
Activity limitation							
Not at all	327	13.9%	305	9.6%	632	11.4%	43.876 (<0.001)
Not much	1,145	48.7%	1,449	45.7%	2,594	46.9%	
Some degree	686	29.2%	1,066	33.6%	1,752	31.7%	
Very much	195	8.3%	354	11.2%	549	9.9%	
Hospitalization times							
0	2,129	90.5%	2,785	87.7%	4,914	88.9%	13.429 (0.004)
1	168	7.1%	304	9.6%	472	8.5%	
2	36	1.5%	65	2.0%	101	1.8%	
≥3	20	0.8%	20	0.6%	40	0.7%	
Number of pains							
0	1,011	43.0%	666	21.0%	1,677	30.3%	388.824 (<0.001)
1	508	21.6%	645	20.3%	1,153	20.9%	
2	449	19.1%	805	25.4%	1,254	22.7%	
≥3	385	16.4%	1,058	33.3%	1,443	26.1%	
Total ADL/IADL							
17	2,002	85.1%	2,735	86.2%	4,737	85.7%	1.301 (0.254)
≥18	351	14.9%	439	13.8%	790	14.3%	

[a]*t-test.*

school education while more females achieved elementary school education. Regarding annual household income, the older men were distributed more in high-level income, and the older women were more opposite in the low-level income. Around 70% of them did not work currently, and that was more in the women group. Additionally, significant differences in age,

TABLE 3 | Model invariance test using multiple-group analysis.

Model	χ^2	df	χ^2/df	GFI	AGFI	CFI	RMSEA	ΔCFI	ΔRMSEA
M_1	592.516***	64	9.258	0.979	0.964	0.933	0.039	-	-
M_2	592.516***	64	9.258	0.979	0.964	0.933	0.039	0	0
M_3	592.516***	64	9.258	0.979	0.964	0.933	0.039	0	0
M_4	627.658***	71	8.840	0.978	0.965	0.929	0.038	0.004	0.001
M_5	662.528***	74	8.953	0.977	0.965	0.925	0.038	0.004	-
M_6	680.044***	75	9.067	0.976	0.965	0.923	0.038	0.002	-
M_7	672.459***	77	8.977	0.976	0.959	0.922	0.038	0.001	-

M_1, elderly men; M_2, elderly women; M_3, unconstrained; M_4, measurement weights; M_5, structural weights; M_6, structural covariances; M_7, structural residuals.
****$p < 0.001$.*
df, degrees of freedom; AGFI, adjusted goodness of fit index; RMSEA, root-mean-square error of approximation.

TABLE 4 | Standardized effects between SES, mental health, and need for LTSS by gender.

Items	Direct		Indirect		Total	
	Men	Women	Men	Women	Men	Women
SES → Need for LTSS	−0.334***	−0.347***	−0.245***	−0.255***	−0.579***	−0.601***
Mental health → Need for LTSS	−0.479***	−0.433***	-	-	−0.479***	−0.433***
SES → Mental health	−0.512***	0.588***	-	-	0.512***	0.588***

SES, socioeconomic status; need for LTSS, need for long-term services and support.
****$p < 0.001$.*

education, annual household income, and current work were also reported between the older men and women group.

Most of the older people rated their health status as "good" and were satisfied with their quality of life. There were significant differences in subjective health and life satisfaction between older men and women. Additionally, the mental health scores of the two groups showed different levels, with higher scores in women (men: 6.24 ± 5.433, women: 7.13 ± 5.633). Concerning the activity limitation, not much limitation was reported in older men and women, and there was a high proportion of older women who reported some degree of activity limitation. Regarding hospitalization time, most of them had not used inpatient services during the past 2 years. Concerning the number of body pains, the men group showed a higher proportion of those with no pain, whereas the women group showed a higher proportion of those with multiple pains. However, there was no significant difference between men and women in the ADL/IADL scores.

Structural Model

Measurement Invariance Across Gender

Table 3 illustrates the results of the selected fitness indicators regarding the measurement invariance across gender and the fitness indexes in the seven different models. The fitness indexes between the male and female elderly were first compared to demonstrate whether the gender variable is suitable for this group comparison.

This study introduced the goodness of fit index (GFI), adjusted goodness of fit index (AGFI), and root mean square error of approximation (RMSEA) as the model fitness indexes. When the size of the samples used is sufficiently large, as in this study, a non-significant chi-squared value is rare (62, 63), which demonstrates this test's usefulness given the sample-size dependency (64). **Table 4** reveals that the fitness indices of older Korean men and women were the same (or GFI = 0.979, AGFI = 0.964, CFI = 0.933, RMSA = 0.039 in both M_1 and M_2). The GFI, AGFI, and CFI values surpassed 0.90, and the RMSA values were <0.05, indicating that the measurement invariances between the two groups could be further explored for the other models.

We used the ΔCFI and ΔRMSEA between M_3 (the unconstrained model), M_4 (measurement weights model), M_5 (structural weights model), M_6 (structural covariance), and M_7 (structural residuals) to evaluate the measurement invariance in this study. M_3 does not restrict the model coefficient, while M_4 implies that the indicator loadings for the corresponding construct are equal for each group. M_5 constrains both the indicator loadings for the corresponding construct and structural coefficients across the groups. Conversely, the indicator loadings for the corresponding construct and the structural coefficients of each group were assumed to be equal in the M_6. Moreover, M_7 supposes that the indicator loadings, structural coefficients, endogenous variables' covariance, and variance of the exogenous variable across the groups are equal.

The ΔCFI between M_4 and M_3, M_5 and M_4, M_6 and M_5, and M_7 and M_6, are 0.004, 0.001, 0.002, and 0.001, respectively; ΔRMSEA is 0.001 between M4 and M3, and 0 betweenM_5 and M_4, M_6 and M_5, and M_7 and M_6. Previous literature states that a change of <0.010 in the CFI (ΔCFI) signifies that a measurement invariance has formed across groups (65). Regarding the ΔRMSEA, changes of <0.015 in the RMSEA

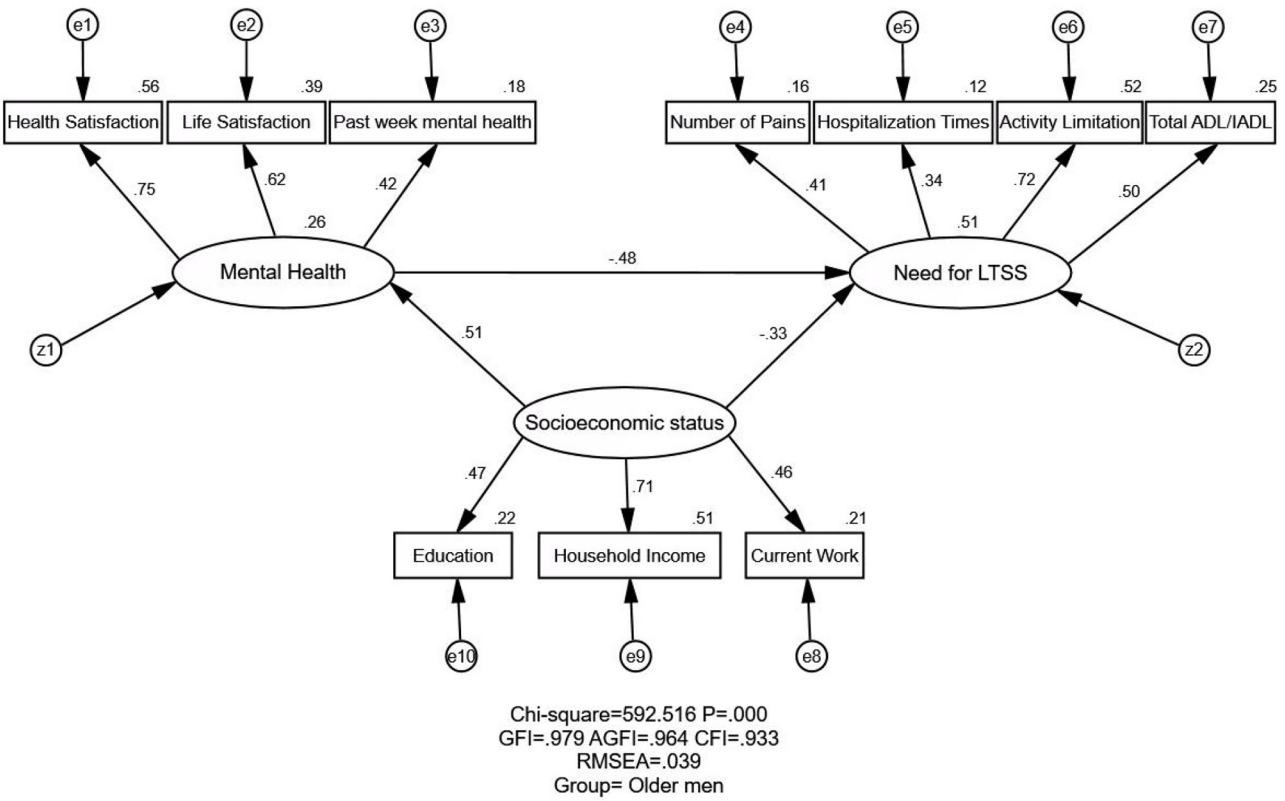

FIGURE 1 | Structural equation modeling analysis of the association between SES, mental health, and the need for LTSS among South Korea's older men (n = 2,353). The data were employed to analyze the association between SES, mental health, and the need for LTSS. The arrows indicate the associations and directions between variables. All parameter estimates were statistically significant ($p < 0.001$). χ^2, chi-square value; GFI, goodness of fit index; AGFI, adjusted goodness of fit index; RMSEA, root-mean-square error of approximation; SES, socioeconomic status; Need for LTSS, need for long-term services and support; CMIN, the chi-square value as noted in AMOS.

(ΔRMSEA) are accepted when establishing the measurement invariance if the sample size is more than 300 (66). As all ΔCFI values in this study were <0.010 and all ΔRMSEA values were <0.015, the measurement invariance was established between the M_1, M_2, M_3, M_4, M_5, M_6, and M_7 models across both the older men and women groups in this study.

Model Fitness Indices

Figures 1, **2** illustrate the proposed (unconstrained) model for the older men and women groups, respectively. The estimates of model fitness were the same for the two groups: GFI = 0.979 > 0.90, AGFI = 0.964 > 0.90, CFI = 0.933 > 0.90, and RMSEA = 0.039 < 0.05. Therefore, the proposed model fits the empirical data well for both groups. However, the CMIN value (the chi-squared value in AMOS) was significant ($p < 0.001$; **Table 3**). As this value is sensitive to sample size, it was not used to appraise the fitness index in our study, as in prior research.

Relationship Between SES, Mental Health, and Need for LTSS Using SEM

Table 4 and **Figures 1**, **2** illustrate the association and standardized effects between SES, mental health, and the need for LTSS. As mentioned in the Methods, the standardized effect is the standardized estimate path coefficients in equivalent units (range: 0–1). The total effects in the path mode can be divided into two parts: direct and indirect. The direct effect is the direct empirical association of an independent variable on a dependent variable, while the indirect effect is the indirect empirical association of an independent variable on a dependent variable through other mediators. As shown in **Figure 1** or **Figure 2** of the manuscript, SES → need for LTSS shows the direct effect from SES to the need for LTSS. While SES → Mental health → need for LTSS illustrates the indirect effect of SES on the need for LTSS through Mental health.

Relationship Between SES and Need for LTSS

The relationship between SES and the need for LTSS has been reported as negative, direct, and indirect (through mental health). The negative and direct effects of SES on need for LTSS were observed in both older men (standardized direct effects = −0.334) and women (standardized direct effects = −0.347). Meanwhile, SES negatively and indirectly affected the need for LTSS through mental health (standardized indirect effects = −0.245 for older men and −0.255 for older women). Ultimately, SES exerted a stronger negative effect on the need for LTSS for older women (standardized total effects = −0.601 for men and

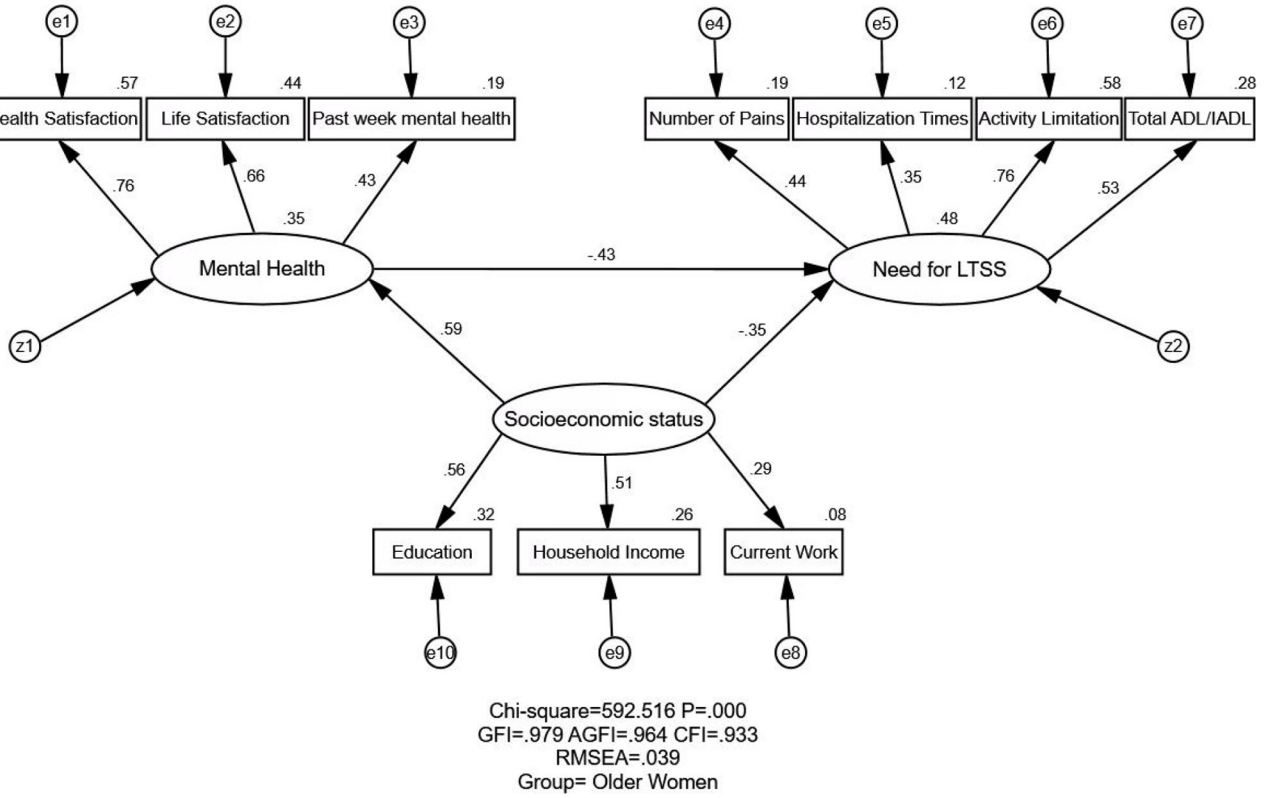

FIGURE 2 | Structural equation modeling analysis of the association between SES, mental health, and the need for LTSS among South Korea's older women (n = 3,174). The data were employed to analyze the association between SES, mental health, and the need for LTSS. The arrows indicate the associations and directions between variables. All parameter estimates were statistically significant ($p < 0.001$). χ^2, chi-square value; GFI, goodness of fit index; AGFI, adjusted goodness of fit index; RMSEA, root-mean-square error of approximation; SES, socioeconomic status; Need for LTSS, need for long-term services and support; CMIN, the chi-square value as noted in AMOS.

−0.579 for women), indicating that older women with higher SES generally have less need for LTSS.

Relationship Between Mental Health and Need for LTSS

A direct negative relationship was observed between mental health and the need for LTSS among the two groups. The better the mental health, the less the need for LTSS, indicating that improving mental health among the elderly would reduce the need for LTSS. Additionally, the relationship between mental health and the need for LTSS was higher for older men (standardized direct/total effect = −0.479) than older women (standardized direct/total effect = −0.433).

Relationship Between SES and Mental Health

The SES's direct and positive effects on mental health were shown among the men and women groups. Therefore, the higher the level of SES among these older adults, the fewer mental disorders, and the better their mental health. Each group exhibited statistical significance, and the coefficient was stronger in older women (standardized direct/total effect = 0.588 for older women and 0.512 for older men).

DISCUSSIONS

Summary of the Findings

SES and Need for LTSS

This research has noted the negative effect of SES on the need for LTSS in both Korean older men and women. Similar findings have been observed in elderly populations in Canada (67), Vietnam (68), Japan (38), and China (40). These studies have identified that socioeconomic factors, such as education, household income, and work status, are related to the need for LTSS. This finding may explain why earlier research has demonstrated that people who live in the most disadvantaged regions report higher levels of unsatisfactory long-term care needs (69). Notably, although the association between SES and the need for LTSS was found among both men and women, SES exerted a slightly stronger effect on the need for LTSS for older women than for men. This result was in line with a previous study on Chinese older adults, which stated that socioeconomic factors were stronger among women for the use of LTSS (40). This may be due to the women's older average age and a greater proportion of living alone, resulting in a higher level of dependence on socioeconomic and care support (70). Additionally, as for the SES indicators in the model, education, income, and work showed

different effects in the men and women groups. In the 1960s and 1980s, women were gradually integrated into the labor and educational system (71). Thus, household income and work had stronger effects in the men group, while the effect of education in the women group was stronger. It may be inferred that the Korean women who need care could receive more help from their spouses and children (72).

Mental Health and Need for LTSS

The results of this study demonstrated the negative relationship between mental health status and the demand for LTSS in gender groups. This parallels the results of previous research conducted on senior citizens in Japan and China (38–40). The older men got lower scores on the depression scale and had a better level of mental health (men: 6.24 ± 5.433; women: 7.13 ± 5.633). However, the men's dysfunctional coping strategies for mental distress, such as overusing alcohol and reducing social connectedness, expose them to various undesirable physical or mental outcomes that rely more on help from their spouse or family and get more effect from mental health fluctuations on the need for LTSS (73). From the standpoint of healthcare professionals, older persons with mental disorders could suffer exhaustion and distancing; simultaneously, there is the inference of a possibility of blaming even abandonment (74). According to the previous study (39), older individuals in Japan who were more socially isolated did not prefer getting care services at their own or relatives' homes even when they required care. Therefore, recognizing the role of such emotional and mental health problems such as depression—in the case of older people—in reducing people's ability and motivation to manage their health is critical to avoiding unmet LTSS (75, 76).

SES and Mental Health

The strong positive association between SES and mental health is compatible with previous research: (1) the population with lower SES appears to have more mental health issues (44), and (2) those with higher SES states are typically better off (77, 78). The positive relationship between SES and mental health observed in this study differed by gender, which was stronger in older women. Previous studies have reported the differential effects of sub-indicators on mental health. Income and work status could lead to stronger relationships with SES in older men than women, while education is more strongly related to SES in women than in men (79). Women who own less SES would matter less, that it would be more dependent on their spouses' SES, and older women's social status might be more reliably measured by their educational history (80, 81). Additionally, when facing dynamic economic status changes, older women were reported more likely to have a continuously high level of depression than older men (82). This could support the hypothesis that SES indicators are differently associated with mental health in men and women.

SES, Mental Health, and Need for LTSS

This study explored the relationship between SES, mental health, and the need for LTSS using SEM among older Korean adults. A significant negative association was observed between SES and the need for LTSS among older adults. Mental health had strong negative impacts on the need for LTSS in both gender groups, with a higher level in older males. Meanwhile, SES was also significantly and positively associated with mental health for both genders, and this was a little stronger among older females.

SES inequality could contribute to different levels of mortality, behavioral risk factors, and psychological stress (83, 84). In examining previous studies (38, 40), the current findings can be well explained as follows. South Korea's older adults from different SES levels live in different communities with different environments—the disparity in SES could imply a different level of access to health services. These environmental community factors also lead to different mental outcomes among older persons; when their mental health deteriorates, the need for LTSS progressively appears and rises. Therefore, there were different effects of SES indicators on mental health and the need for LTSS.

Numerous studies have already examined the relationship between SES and health to reveal significant associations consistently in this relationship. Typically, this has suggested that SES was associated with health outcomes in different races and the treatment choice in healthcare (85, 86), Although gender-based discrimination in employment and education has somewhat changed throughout South Korea's economic development process (87), women in South Korea still have a lower SES than men and a higher prevalence of depression and chronic diseases even today (88), Moreover, in the traditional family model, men are expected to be primarily responsible for economically supporting the household, while women are expected to leave the labor force and care for children at home as families form and grow. Notably, this seems to have more profoundly influenced Korean family characteristics with fewer satisfactory marriages and less egalitarian divisions of housework between spouses (89), Therefore, older men may experience high levels of life dependence on their spouse with more negative mental responses over a long duration (90). Conversely, older women seem to have a higher level of need for LTSS related to chronic diseases and functional limitations.

Limitations and Future Research

This study had several limitations. First, only one-wave data from the KLoSA survey were used in this study although it was a relatively large sample size, which could limit the generalizability of the results. The cross-sectional nature of data restricted the examination of cause-effect relationships among these factors. So, it would be planning to use the multiple waves data to explore the changes in the need for LTSS associated with SES and mental health.

Second, limited indicators for each latent variable (such as SES, the need for LTSS) are available in the SEM hypothesis model because of the questionnaire's simplified content design, and its consequent responses. Since only the gender difference of the hypothesized model was explored in this study, more research focusing on the difference in employment status, rural and urban, etc. are worthy of conducted in the future. The health of status of people at different SES levels may be impacted by multiple determinants, such as the existed physical limitation level, actual support, subjective/official assessment of the need for LTSS, or the reverse causality relationship. Meanwhile, the need for LTSS affected by age and the differences in marital status is also important for further subanalyses. Thus, further studies

should consider more comprehensively the relationship between SES and health status.

Third, this study's indicators of mental health include "subjective health," "life satisfaction," and "prior week's depression". These questions primarily focused on cognition and finished with self-judgment, ignoring the effects of other stressors. Subjective health may be misunderstood as the physical health-related questions by older adults. Additionally, women tend to be less optimistic about their ADL functional limitations. Therefore, a future study is planned to clarify the association between SES, mental health, and the need for LTSS using more SEM indicators.

CONCLUSIONS AND IMPLICATIONS

Despite some limitations, gender- and class-sensitive impacts of mental health on the need for long-term care services and support were emphasized in this study. These findings may provide an evidence-based reference for interventions targeting different genders in Korea's long-term care system.

The critical impact of SES on mental health and the need for LTSS suggests that social and political measures to improve the SES of older adults are needed, particularly in the welfare areas of the labor market and social security. Public policy that promotes early intervention and prevention for vulnerable older adults and their families should also be encouraged, as this may advance their SES and minimize SES inequality in a more effective way.

It is essential to accommodate the diversity of older people and enhance care options with personalized care arrangements. In South Korea, policy and clinical decision-making could aim to augment special care according to the severity of the disease, chronic pain, or comorbidities' effects on the health and functional status of older female patients (91). Additionally, older Korean men who have negative coping strategies for mental distress and highly depend on spouses in daily life (69) may require considerably more access to life support and mental health response. Therefore, considering the target population's characteristics and setting the priority on universal LTSS accessibility should be more focused in the future (16).

DATA AVAILABILITY STATEMENT

The data for this study were taken from the Korean Longitudinal Study of Aging (https://survey.keis.or.kr/eng/klosa/klosa01.jsp) and analyzed here. Data are available in the public domain.

ETHICS STATEMENT

This was a secondary analysis of the KLoSA study which involved human participants. Participants provided their written informed consent to participate in this study. Participants approved by the KLoSA data were anonymized. This study has been approved by the Yonsei University Institutional Review Committee (Task No. 1041849-202104-SB-068-01).

AUTHOR CONTRIBUTIONS

BZ: conceptualization, methodology, formal analysis, writing—original draft, review, and editing. FK and EN: conceptualization, methodology, review, and editing. DS: review and editing. All authors contributed to the article and approved the submitted version.

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Starting Time of Presbyopic Eyeglasses Wear and Lifestyle

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Purpose: Presbyopia is a serious burden in the aged population, however, the factors affecting its progression have not been fully determined. The aim of this study was to explore the association between the time of starting to wear presbyopic eyeglasses and lifestyle, in participants aged from 40 to 59 years.

Methods: We selected the sample to be representative of sex and age for the age group 40 to 59 *years*. Participants completed a web-based survey on presbyopia-related questions, symptomatic dry eye, sleep habits, Pittsburgh Sleep Quality Index, subjective happiness scale (SHS), and other lifestyle-related questions including marital status, income, screen time, sun exposure, family history of myopia, and the frequency of regular visits to medical services.

Results: We found 529 participants (26.5%) used near correction, with a mean age for first near correction of 47.8±4.8 years. An earlier commencement of near correction correlated with hyperopia ($P = 0.013$), late wake-up time ($P = 0.010$), a poor subjective sleep quality score ($P = 0.019$), and a low annual income score ($P = 0.025$), after adjusting for age and sex. Stratification by income demonstrated the low-income group exhibited more dry eye, later wake-up time, longer sleep latency, longer sleep duration, worse sleep efficacy, lower SHS score, and a higher prevalence of living alone compared with the high-income group. The usage of corrective devices did not differ between the two groups.

Conclusions: The current study suggests a healthy sleep habit may delay the need for near correction, in addition to myopia. Shift work and circadian rhythm disruption might exacerbate presbyopia progression.

Keywords: presbyopia, near correction, accommodation, lifestyle, sleep, circadian rhythm, shift work, income

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INTRODUCTION

Presbyopia is a presentation of near vision focusing difficulty while under full correction of distance vision, and it is a global burden for health and the economy in super-aging societies (1–4). Recent investigations found presbyopia was associated with subjective happiness, sleep quality (5), quality of life (6) and visual disability. Presbyopia is a consequence of aging and should inevitably progress alongside other aging events. Among the various lifestyle contributors, sleep and circadian rhythm are most closely correlated with aging and longevity (7, 8). In addition to conventional experiments for aging and longevity performed in insects, studies in animals and humans also

suggest circadian disruption or desynchronization of circadian oscillators increases disease risk and appears to accelerate aging, resulting in poor longevity (9–13). Collectively, lifestyle has been repeatedly described as a significant contributor to the aging process.

Ocular disorders are also closely associated with lifestyle (14–21), specifically, allergic conjunctivitis and pets (14), dry eye and physical activity (15), meibomian gland dysfunction and metabolic syndrome (16), myopia and outdoor activity (17), central serous chorioretinopathy and stress (18), age-related macular degeneration and high-fat diet (19), glaucoma and sleep apnea (20), and diabetic retinopathy and sleep apnea (21). Accommodative function is mainly driven by the major intraocular structures of the lens and ciliary body. Lifestyle may potentially alter the progression of presbyopia, as shown in animal experiments, where unfavorable lifestyle habits such as smoking worsened presbyopia (22). As such, it could be hypothesized that lifestyle may be associated with presbyopia progression, however, to the best of our knowledge, this has not been explored.

The aim of this study was to investigate the association between presbyopia progression and lifestyle-related variables. A web-based survey was conducted to ask 2000 participants their age of first using near correction, as well as their sleep habit, annual income and other lifestyle items.

MATERIALS AND METHODS

Ethics Approval and Participant Recruitment

The web-based survey was approved by the Institutional Review Board and Ethics Committee of the Haneginomori Eye Clinic (approved 3 April 2017, permission number 17-007) and was carried out in accordance with the Declaration of Helsinki. We selected the sample to be representative of sex and age for the age group 40 to 59 years. Ipsos Incorporated (Tokyo, Japan), a company certified in the protection of personal information, was in charge of the survey. All subjects aged 40 to 59 years who used the web survey panel (Research Panel Incorporated, Tokyo, Japan) were asked to participate in this study. Entry requirements for the survey were age and sex, with potential presbyopia at the age of 40–59. Among 1,000,000 panels from the general public in Japan, age-matched participants were randomly selected, and invitation mails were sent without introducing the aim of the study. The first 2,000 participants who satisfied requirements were enrolled. The study took place from 7 to 13 April 2017. Participants received no money, but reward points (approximately one dollar value) that could be used on the panel website as compensation.

Consent was waived by the ethics committee for this opt-out study. Instead, the first screen of the app stated that this was a research app and all data obtained would be used for the study. It was also clearly stated that participation was voluntary and could be withdrawn anytime, and the anonymity of participants would be preserved. Only after participants clicked the agree button at the bottom of the screen, could they proceed to the next screen of the app. Participants were also provided with contact information for the study and an inquiry form from the app.

Abbreviations: PSQI, Pittsburg Sleep Quality Index; SHS, subjective happiness score.

Questionnaires

Participants were asked to complete two questionnaires on major indices for quality of life: happiness and sleep quality. Happiness was evaluated with the validated Japanese version of the subjective happiness scale (SHS) (23) and sleep quality was measured with a validated Japanese version of the Pittsburgh Sleep Quality Index (PSQI) (24). The SHS is a four-item questionnaire of subjective global happiness where each item requires patients to rate the statements on a 7-point Likert scale and higher values correspond to higher subjective happiness. The PSQI is comprised of seven subscales that evaluate sleep quality, including subjective sleep quality, daytime dysfunction, sleep latency, sleep duration, habitual sleep efficacy, sleep disturbances, and use of sleep medications. Scores for each subscale were calculated using separate algorithms, with each component scored on a scale of 0 to 3, where three was the worst score. The highest possible global score was 21, with the normal range on the PSQI being <6.

Questions on presbyopia included awareness and impact of focusing difficulties, age they first became aware of focusing difficulty, and age they commenced using aids for near vision (including reading glasses, progressive spectacle lenses, monovision contact lenses, and multifocal contact lenses). In regards to awareness and impact of focusing difficulties, awareness was defined as the sensation of focusing difficulties without any significant concern, while awareness and impact was defined as the sensation of focusing difficulties that affected daily life. The severity of visual burden was surveyed for near, middle-distance and far vision (1: No burden without blurred vision, 2: No burden with blurred vision, 3: Burden with blurred vision). A short dry eye questionnaire (25) was used to detect symptomatic dry eye with three questions that are widely used in epidemiological studies: (1) How often do your eyes feel dry (not wet enough)? (2) How often do your eyes feel irritated? and (3) Have you ever been diagnosed (by a clinician) as having dry eye syndrome?

Questions on lifestyle included annual income (graded 1 [3 million yen] to 11 [highest] with one million yen per step), living with no-one or anyone, frequency of regular visits to a medical service (graded from 1 [every week] to 7 [none] for frequency), screen time (h), sun exposure time (h), and number of myopic parents. Questions on sleep habit were included in the PSQI.

Statistical Analysis

Where appropriate, data are given as mean ± standard deviation since the obtained data were normally distributed using the Kolmogorov-Smirnov test. Correlations were evaluated using a standardized partial regression coefficient. Regression analysis was performed to identify the factors affecting the age of first near correction by simple correlation adjusted for age and sex. Multiple regression analysis was then performed to determine

TABLE 1 | Comparison of parameters between corrected and uncorrected presbyopia groups.

	Corrected (*N* = 529)	Uncorrected (*N* = 1,471)	*P*-value[a]
Age (y)	53.2 ± 4.4	47.4 ± 5.3	<0.001*
Sex (% men)	50.0	50.0	0.912
Myopia (%)	55.4	64.4	<0.001*
Hyperopia (%)	27.0	8.9	<0.001*
No correction for distance vision (%)	25.5	25.1	0.843
Burden for near vision score[b]	1.93 ± 0.91	1.41 ± 0.74	<0.001*
Burden for middle-distance vision score[b]	1.54 ± 0.79	1.35 ± 0.68	<0.001*
Burden for far vision score[b]	1.42 ± 0.73	1.51 ±0.78	0.021*
Symptomatic dry eye (%)	32.7	36.5	0.075
Screen time (h)	4.56 ± 3.15	4.83 ± 3.31	0.110
Sun exposure per week (h)	7.59 ± 11.36	7.66 ± 11.45	0.903
Number of myopic parents	0.52 ± 0.66	0.66 ± 0.72	<0.001*
Wake-up time	6:39 ± 2 h 7 m	6:32 ± 1 h 45 m	0.409
Bedtime	23:41 ± 1 h 41 m	23:50 ± 1 h 40 m	0.139
Sleep latency	18.0 ± 18.0 m	19.0 ± 18.0 m	0.370
Sleep duration	6 h 13 m ± 1 h 04 m	6 h 32 m ± 1 h 45 m	0.146
Sleep efficacy (%)	95.00 ± 5.77	94.90 ± 5.82	0.761
Sleep medicine score[b]	0.30 ± 0.84	0.27 ± 0.80	0.559
Daytime alertness score[b]	0.36 ± 0.73	0.34 ± 0.71	0.628
Subjective sleep quality score[b]	1.35 ± 0.63	1.34 ± 0.68	0.701
Sleep quality index (PSQI global score)[c]	5.54 ± 2.82	5.33 ± 2.93	0.157
Subjective happiness score[d]	4.36 ± 1.05	4.24 ± 1.06	0.020*
Regular visit to medical service score[e]	5.28 ± 2.01	5.88 ± 1.77	<0.001*
Living alone (%)	13.0	17.1	0.032*
Annual income score[f]	6.52 ± 3.95	6.03 ± 3.90	0.014*

P < 0.05, [a]t-test or chi square test as appropriate.*
[b]Scored 1–3 (most severe) for severity.
[c]Global score of Pittsburg Sleep Quality Index implicating poor sleep quality in high score.
[d]Subjective Happiness Scale implicating happiness in high score.
[e]1 (every week) to 7 (none) for frequency.
[f]Scored 1–11 (highest) for each one-million-yen step in annual income.

the predictors of the age of first near correction and possible predictors (income, wake-up time, and hyperopia).

The difference of optical parameters and responses between corrected and uncorrected presbyopia groups, between high-income (≧7 million yen) and low-income (<7 million yen) groups, and between waking-up in the morning and afternoon groups, were analyzed using unpaired *t*-tests and chi-squared tests, as appropriate. One-way ANOVA was performed to determine the difference in age of first near correction among stratified wake-up time groups.

All analyses were performed using StatFlex (Atech, Osaka, Japan) with p <0.05 considered significant.

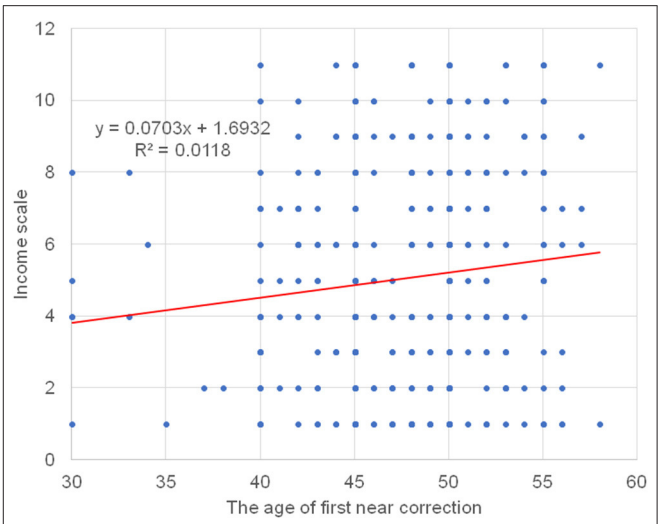

FIGURE 1 | Scatter plots of the age of first near correction and annual income scale. There is a correlation between the age of first near correction and annual income with the age of first near correction occurring earlier in the lower income group (beta = 0.123, *P* = 0.004). Note, many data points overlap leading to the appearance of a smaller number than in the graph.

RESULTS

Mean age was 49.0 ± 5.9 y and 50.3% were men. A total of 529 participants (26.5%) used near correction. A comparison of parameters in corrected and uncorrected groups is shown in **Table 1**. There was a significant difference in age, prevalence of myopia and hyperopia, number of myopic parents, SHS, frequency of regular visits to a medical service score, prevalence of living alone, and annual income score between uncorrected and corrected groups.

The mean age of first near correction was 47.8 ± 4.8 y in the corrected group and it correlated with the presence of hyperopia, wake-up time, subjective sleep quality score, and annual income score, adjusted for age and sex (**Figure 1** and **Table 2**). Multiple regression analysis revealed income, wake-up time, and the presence of hyperopia were independently correlated with the age of first near correction. One way ANOVA also indicated the age of first near correction correlated with wake-up time ($P = 0.045$) (**Figure 2**).

Next, a comparison of parameters between subgroups was performed to explore other contributory factors in late wake-up and low-income subgroups (**Tables 3**, **4**). The age of first near correction was significantly lower in low-income (<7 million) and afternoon wake up groups. First near correction occurred 1.4 years and 4.7 years earlier in low-income (<7 million) and afternoon wake up groups, respectively, compared with high-income (≥7 million) and morning wake-up groups, respectively. Comparison between two groups stratified by wake-up time revealed the afternoon wake-up group exhibited poor PSQI, longer sleep latency and lower sleep efficacy compared with the morning wake-up group. Comparison between two groups stratified by income revealed the low-income group exhibited

TABLE 2 | Correlation between the age of first near correction and parameters.

	Linear regression		Adjusted for age and sex	
	Beta	***P*-value[a]**	**Beta**	***P*-value[a]**
Age	0.590	<0.001*	0.588	<0.001*
Sex	−0.080	0.066	−0.059	0.089
Myopia	0.086	0.047*	0.067	0.055
Hyperopia	−0.107	0.013*	−0.086	0.013*
No correction for distance vision	0.006	0.889	−0.000	0.990
Burden for near vision	−0.058	0.182	−0.072	0.038*
Burden for middle–distance vision	−0.097	0.024*	−0.099	0.004*
Burden for far vision	−0.014	0.738	0.020	0.570
The age of first corrective eyeglasses for near	0.093	0.032*	0.013	0.708
Symptomatic dry eye	0.062	0.153	0.036	0.316
Screen time	−0.057	0.188	0.007	0.848
Sun exposure per week	−0.059	0.171	−0.016	0.651
Number of myopic patients	0.016	0.747	0.055	0.172
Wake–up time	−0.102	0.017*	−0.089	0.010*
Bedtime	−0.039	0.369	−0.067	0.055
Sleep latency	−0.055	0.201	−0.016	0.641
Sleep duration	0.069	0.108	0.054	0.119
Sleep efficacy	0.069	0.109	0.030	0.390
Sleep medicine	−0.024	0.569	−0.026	0.447
Daytime alertness	0.009	0.830	−0.007	0.841
Subjective sleep quality	−0.113	0.008*	−0.082	0.019*
Sleep quality index score	−0.058	0.180	−0.048	0.165
Subjective happiness	0.071	0.098	0.051	0.144
Regular visit to medical service	0.019	0.649	0.046	0.188
Living alone	−0.045	0.295	−0.051	0.144
Annual income	0.123	0.004*	0.078	0.025*
Multiple regression	**Non–adjusted**		**Adjusted for age and sex**	
Wake-up time	−0.097	0.023*	−0.086	0.013*
Annual income	0.120	0.005*	0.076	0.028*
Hyperopia	−0.110	0.010*	−0.088	0.010*

P <0.05, [a]Standardized partial regression coefficient.*

later wake-up time, longer sleep latency, longer sleep duration, worse sleep efficacy, lower SHS score, higher prevalence of living alone, and more myopic parents compared with the high-income group. Usage of corrective devices was not different between the compared groups.

DISCUSSION

The current study reveals lifestyle may be associated with the age of first near correction. The essential pathology of presbyopia however, that is, lens hardening and deteriorated ciliary mobility, were not determined. In particular, this study suggests a relationship between sleep habit and presbyopia. This

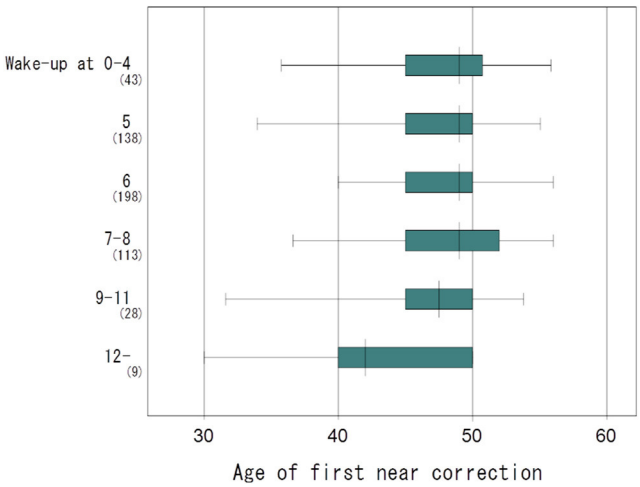

FIGURE 2 | Box plots showing the distribution of the age of first near correction and wake-up time. The age of first near correction was early in the later wake-up time group, reaching statistical significance (one-way ANOVA, $P = 0.045$). The vertical line in each diagram indicates the median scores. The width, positive error bar, and negative error bar of each box indicate the 25th−75th percentiles, maximum values, and minimum values, respectively.

is notable considering it has been well documented that circadian rhythm disorders and sleep disorders may lead to severe diseases including cancer, metabolic disorders, cardiovascular disorders, neuropsychiatric disorders, and short life span (26, 27). Like in other organs, the ordinary aging process in the eyes suffers detriments from a desynchronized sleep habit and disturbed circadian rhythm due to late wake-up times.

The current study found low annual income was associated with early need for near correction whilst usage of near corrective devices was the same between high- and low-income groups. The difference in lifestyle between high- and low-income groups may contribute to the first age of near correction in Japan, rather than the affordability of eyeglasses. We speculate that the high-income group has more favorable sleep habits and circadian rhythms, which could be linked to a later age of first near correction than in the low-income group. They are more likely to live with a spouse or other family, which may promote a more support for healthy sleep habits. In contrast, poor sleep quality and a high prevalence of living alone in the low-income group may lead to poor subjective happiness measured with SHS, as demonstrated in the current survey.

In regards to refraction, myopia was inversely associated with subjective and objective presbyopia, as suggested in prior studies (28). Myopia, early wake-up time, and high income were independently correlated with slow presbyopia progression. In relation to presbyopia progression, appropriate near correction (especially in hyperopic subjects) and healthy sleep habit are recommended.

The current study has several limitations. This is a web-based study and lack of objective data including measurement of accommodation and refraction is a considerable limitation that should be ameliorated in a subsequent study. Accommodation

TABLE 3 | Comparison of parameters between groups classified by wake-up time.

Stratification and parameters	Wake-up time		
	Morning (*N* = 520)	Afternoon (*N* = 9)	*P*-value*[a]
Age (y)	53.2 ± 4.3	51.7 ± 6.4	0.317
Sex (% of men)	49.8	66.6	0.513
Myopia (%)	55.9	22.2	0.094
Hyperopia (%)	26.9	33.3	0.959
No correction for distance vision (%)	25.5	22.2	0.844
Near correction with monofocal eyeglasses (%)	55.0	66.6	0.691
Near correction with bifocal eyeglasses (%)	46.3	55.5	0.818
Near correction with soft contact lenses (%)	5.0	0	0.933
Burden for near vision score[b]	1.93 ± 0.90	2.11 ± 1.05	0.554
Burden for middle-distance vision score[b]	1.53 ± 0.78	2.00 ± 0.87	0.076
Burden for far vision score[b]	1.42 ± 0.73	1.44 ± 0.88	0.919
The age of first near correction (y)	47.9 ± 4.7	43.2 ± 6.5	0.004*
Symptomatic dry eye (%)	32.5	44.4	0.693
Screen time (hour)	4.57 ± 3.17	4.11 ± 2.15	0.666
Sun exposure time per week (hour)	7.52 ± 11.00	11.78 ± 25.66	0.266
Number of myopic parents	0.52 ± 0.66	0.33 ± 0.52	0.488
Wake-up time	6:15 ± 1 h 22 m	18:05 ± 4 h 24 m	<0.001*
Bedtime	23:42 ± 1 h 34 m	0:05 ± 5 h 14 m	0.501
Sleep latency (m)	17.4 ± 17.4	37.8 ± 37.2	0.001*
Sleep duration	6 h 14 m ± 1 h 4 m	6 h 4 m ± 1 h 13 m	0.609
Sleep efficacy (%)	95.11 ± 5.41	87.94 ± 15.39	<0.001*
Sleep medicine score[c]	0.30 ± 0.83	0.44 ± 1.01	0.598
Daytime alertness score[c]	0.36 ± 0.73	0.33 ± 0.71	0.927
Subjective sleep quality score[c]	1.35 ± 0.63	1.44 ± 0.53	0.657
Sleep quality index[d]	5.49 ± 2.77	8.67 ± 3.67	0.001*
Subjective happiness score[e]	4.36 ± 1.05	4.14 ± 0.94	0.522
Regular visit to medical service score[f]	5.28 ± 2.02	5.44 ± 2.01	0.803
Living alone (%)	12.7	33.3	0.202
Annual income score[g]	5.07 ± 3.08	3.00 ± 1.91	0.077

P < 0.05, [a]t test or chi square test as appropriate.*
[b]Scored 1–3 (most severe) for severity.
[c]Scored 0–3 (most severe) for severity.
[d]Global score of Pittsburg Sleep Quality Index implicating poor sleep quality with high score.
[e]Subjective Happiness Scale implicating happiness with high score.
[f]1 (every week) – 7 (none) for frequency.
[g]Scored 1–11 (highest) for each one-million-yen step in annual income.

TABLE 4 | Comparison of parameters between groups classified by income.

Stratification and parameters	Income[h]		
	High (*N* = 183)	Low (*N* = 231)	*P*-value*[a]
Age (y)	53.5 ± 4.1	52.8 ± 4.6	0.053
Sex (% of men)	49.2	51.3	0.735
Myopia (%)	55.9	54.7	0.956
Hyperopia (%)	26.9	27.2	0.941
No correction for distance vision (%)	26.6	24.1	0.498
Near correction with monofocal eyeglasses (%)	54.5	56.0	0.798
Near correction with bifocal eyeglasses (%)	47.8	44.8	0.915
Near correction with soft contact lenses (%)	4.7	5.1	0.921
Burden for near vision score[b]	1.87 ± 0.89	2.02 ± 0.91	0.120
Burden for middle-distance vision score[b]	1.49 ± 0.76	1.60 ± 0.82	0.119
Burden for far vision score[b]	1.39 ± 0.71	1.46 ± 0.76	0.301
The age of first near correction (y)	48.4 ± 4.5	47.0 ± 4.9	0.002*
Symptomatic dry eye (%)	28.6	37.9	0.061
Screen time (hour)	4.97 ± 3.12	4.35 ± 3.18	0.051
Sun exposure time per week (hour)	8.34 ± 10.67	7.84 ± 12.21	0.665
Number of myopic parents	0.39 ± 0.64	0.60 ± 0.68	0.006*
Wake-up time	6:07 ± 1 h 45 m	6:40 ± 2 h 29 m	0.006*
Bedtime	23:36 ± 1 h 31 m	23:27 ± 1 h 53 m	0.635
Sleep latency (m)	14.3 ± 14.3	21.0 ± 21.0	<0.001*
Sleep duration	6 h 6 m ± 59 m	6 h 22 m ± 1 h 8 m	0.013*
Sleep efficacy (%)	95.71 ± 4.53	94.06 ± 6.95	0.002*
Sleep medicine score[c]	0.18 ± 0.75	0.37 ± 0.93	0.021*
Daytime alertness score[c]	0.33 ± 0.70	0.39 ± 0.77	0.365
Subjective sleep quality score[c]	1.34 ± 0.60	1.37 ± 0.66	0.540
Sleep quality index[d]	5.38 ± 2.62	5.75 ± 3.04	0.139
Subjective happiness score[e]	4.49 ± 0.98	4.20 ± 1.11	<0.001*
Regular visit to medical service score[f]	5.40 ± 1.97	5.12 ± 2.06	0.103
Living alone (%)	6.4	21.6	<0.001*
Annual income score[g]	8.03 ± 1.64	2.66 ± 1.41	<0.001*

P < 0.05, [a]t-test or chi square test as appropriate.*
[b]Scored 1–3 (most severe) for severity.
[c]Scored 0–3 (most severe) for severity.
[d]Global score of Pittsburg Sleep Quality Index implicating poor sleep quality with high score.
[e]Subjective Happiness Scale implicating happiness with high score.
[f]1 (every week) – 7 (none) for frequency.
[g]Scored 1–11 (highest) for each one-million-yen step in annual income.
[h]Participants were classified as in a high income (≧7 million yen annual income) or low income (<7 million yen annual income) group.

is associated with pupillary diameter, corneal aberration, and refraction (29–32) and each element should be further confirmed. Another limitation of this internet survey comes from the fact that internet users do not accurately represent the general population, sampling frame and volunteer sample. Future studies may benefit from using narrow or specific sub-groups, such as specific occupational groups, or focus on specific factors related with nature and the type of

working, such as office work vs. outdoor work. Additional information about physical and mental health as well as family history may also help explain sleep quality. Furthermore, a detailed questionnaire on lifestyle including smoking, drinking, exercise, diabetes (33) and hypertension, would be necessary to conclusively evaluate the interaction of lifestyle and presbyopia.

In conclusion, the current study suggests a healthy sleep habit may contribute to delaying the need for near correction, in addition to myopia. shift work and circadian rhythm disruption might exacerbate presbyopia progression.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Institutional Review Board and Ethics Committee of the Haneginomori Eye Clinic (approved 3 April 2017, permission number 17-007). Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

KN and MA designed the study and wrote the manuscript. MA collected and analyzed the data. KN, MK, KT, and MA critically read the draft manuscript. All authors approved the final version of the manuscript.

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Does Retirement Make People Happier?-Evidence From China

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To investigate whether people's happiness will increase after retirement, this paper empirically investigates 2012, 2015, and 2017 China General Social Survey (CGSS) data using Ordinary Least Squares, Binary logit, and Fuzzy regression discontinuity Design. The results all show that retirement will significantly increase the happiness of men in urban China. The paper also validates these findings by testing the continuity of the reference and covariates at the cut–off point, changing the model settings, and using a more rigorous sample classification method. In addition, the article further analyzes the heterogeneity of the study and finds that retirement brings more happiness to those who have a college degree or less and have multiple children. The better the health status, the smaller the effect of retirement on happiness. The more social interactions, the smaller the effect of retirement on happiness. The policy implication of this paper is that when implementing a delayed retirement policy, special care should be taken for groups with greater welfare impairment, and it needs to be introduced together with other supporting measures to reduce people's worries. This paper analyzes the relationship between retirement and happiness in China and makes suggestions for the implementation of a delayed retirement policy, enriching the theoretical and empirical work on the effects of retirement on people's happiness and contributing to the world's response to aging and welfare policies for the older person.

Keywords: retirement, RD, happiness, policy, role

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INTRODUCTION

With the generational change in population, the baby boomers born in the 1950s and 1960s in China will gradually exit the labor market and enter retirement. Retirement is an important turning point in life, the end of labor, and the beginning of retirement. It implies changes in work, life, and psychology, and therefore, changes in happiness before and after retirement have attracted the attention of more and more scholars.

On the one hand, compared with before retirement, the elderly after retirement may reduce unhealthy, high–risk, harmful, and stressful jobs, and have more time to participate in entertainment–oriented activities to promote brain activities, enhance relationships with their families and protect mental health, thus increasing the happiness of the older person (1–4), especially for voluntary retirees (5, 6). On the other hand, retirement changes individuals' daily routines, physical and mental activities, reduces income levels, and at the same time brings individuals a sense of loneliness, low value, thus reducing people's happiness (7, 8).

Research on the impact of retirement on the happiness of the older person in China, the extent of the impact, and the channels of the impact will provide important inspiration for China's upcoming retirement policy and will also provide important implications for the world's response to aging and the improvement of the welfare of the older person. At the same time, it has enriched the theoretical and empirical work on the impact of retirement on happiness. In particular, it should be noted that the happiness studied in this paper is a proxy for subjective well–being in a broad sense. The rural residents' pension insurance system started late and the level of protection is very low. Basically, after retirement, they still engage in agricultural production, and retirement or not has no impact on their lives. Since female workers are mostly affected by their spouses' work status and family conditions, their retirement situation is more complicated. and men in China's urban areas are more compliant with the work and retirement system. Therefore, in this paper, only the impact of retirement on the happiness of urban men is studied.

At present, empirical research on the impact of retirement on happiness has mixed conclusions. Some research found that retirement had a negative effect on happiness, while others believed that the effect was positive. Early research on the relationship between retirement and happiness is derived from psychology, and mainly describes the relationship between retirement and happiness. These studies concluded that retirement is associated with lower life satisfaction, depression, and lower happiness (9, 10). Some scholars have explained the reason for the decline in happiness after retirement. First, the decline in individual happiness after retirement is mainly due to the reduction of personal income and other key resources. Second, retirement will deprive individuals of their social role in the social division of labor and have an adverse impact on their sense of social identity, thus easily triggering negative emotions, and reducing the quality of life (11, 12); from the perspective of family relations, concluded that no matter who the spouse retired first, the right to speak in the family would be reduced, which in turn would reduce their satisfaction with life (13). This indicates that retirement will reduce the happiness of married people. Some Chinese scholars have found that environmental information, regulation, and governance have a significant impact on happiness (14–18).

Some scholars have argued that retirement will significantly improve the happiness of residents. For example, Some research studied data from multiple US public opinion surveys and found that retirement will make the older person feel more satisfied with their quality of life, and the impact on men is significantly greater than that on women (19). Jokela et al. further supported the above views, and believed that retirement will increase the individual's leisure time and reduce their pressure from work and competition, and therefore help increase their happiness (20); some studies have also confirmed that retirement will significantly increase people's happiness (21).

At the same time, some scholars argue that the effect of retirement on happiness is not significant. The empirical research of Beck shows that retirement has no obvious effect on changes in happiness. This is mainly due to the advantages and disadvantages of retirement for individuals, and it is a neutral event in the life course (7). According to role theory, retirement may have a negative or positive effect on the happiness of an individual, it depends on the individual's perspective on the role, so if we only focus on the ultimate effect of retirement on life satisfaction, it is difficult to draw significant conclusions.

Existing research discusses the negative or positive effects of retirement on happiness, but it lacks effective treatment of endogeneity and cannot get rid of the mutual causality between retirement and happiness. Researchers tried to clarify the relationship between retirement and happiness through pension rules, but the results are still uncertain (22). At the same time, the existing research lacks the corresponding mechanism analysis of the impact of retirement on happiness. Considering the particularities of China's pension system, such as involuntary retirement, and the internal validity issues in the study of the Chinese sample, whether the empirical findings of other countries in the world are applicable to China requires further empirical analysis of China's samples with more precise methods.

Based on the deficiencies of previous research, such as less attention to the Chinese sample, the internal validity of the research on the Chinese sample, and the insufficient research on the internal mechanism, this paper uses the Chinese urban household registration population in the CGSS data in 2012, 2015 and 2017 as the research object, and adopts the fuzzy regression discontinuity design to more accurately identify the causal relationship of the impact of retirement on happiness and examine the group differences in the impact of retirement on happiness and the ways in which retirement affects happiness. This article enriches the empirical research on the impact of retirement on happiness and provides empirical material for further theoretical work on the impact of retirement on happiness. In addition, the research has important inspiration for China's upcoming retirement policy and is of great significance to the world's policy formulation in response to aging and improving the welfare of the older person. In particular, it provides a certain reference significance for the formulation of retirement policies in developing countries. At the same time, it has enriched the theoretical and empirical work on the impact of retirement on happiness.

Our research has found that reaching the national pension granting age will cause a large proportion of Chinese people to retire. Retirement greatly improves personal happiness, and its impact is significant and robust. Second, we found that retirement brings more happiness to those who have a college degree or less and have multiple children. The better the health status, the smaller the effect of retirement on happiness. The more social interactions, the smaller the effect of retirement on happiness. The method used in this paper provides a clear framework for the research on how retirement affects happiness.

The structure of the article is as follows: The second part is the theoretical basis, and the third part mainly includes the data sources, the setting of the variables and their basis, descriptive statistics, and its analysis; The fourth part is the empirical results, it mainly elaborates the regression results of the three models of Ordinary Least Squares (OLS), binary Logit and Fuzzy Breakpoint Regression (FRD); The fifth part is a further

discussion on the continuity of the reference variable and the covariate at the breakpoint, the test of the regression results of different sample intervals, and the analysis of heterogeneity. The sixth part is the conclusion and policy implication.

THEORETICAL BASIS

Role theory suggests that society is made up of people with different statuses, positions, occupations, and personalities. When a person expresses views and opinions consistent with his or her personality, performs the duties and work of a position, or fulfills the rights and obligations of his or her social status, we can assume that the person is playing a certain role. Each person is playing multiple roles at the same time.

Retirement means that the older person no longer plays the role in the frontline job position and returns to the family and the life which is unfamiliar and far away from work to play the role that society and life require him to play. In this process, role changes and conflicts will occur. Work is a source of self–esteem and self–identity and plays a central role in the lives of adults. Retirement ends this job role, and the retired individual will suffer psychologically because he/she can no longer see himself as a productive and contributing member of society. The theory holds that leisure roles during retirement cannot replace work roles as a source of self–esteem (2).

Some scholars argue that individuals play multiple roles, such as family roles and friend roles. These roles are continuous, and individuals tend to maintain their original state after retirement. Retirement will not change people much (23, 24). The job role is not necessarily their core role. Retirement can provide an opportunity for them to spend more time on the important roles of friends and family, and the continuity of these roles after retirement will prevent overall negative consequences of retirement. The author further pointed out that retirement can alleviate the work pressure caused by performance requirements, which can actually improve mental health.

The theory of continuing socialization of old age believes that in old age, individuals still need to produce new values through continuous learning, such as proficient use of basic life skills, consciously abiding by social behavior norms, and gradually adjusting social relations; while constantly learning new knowledge, new skills, taking on new social roles and establishing new social relationships, in order to adapt to society and achieve self–improvement (25).

As shown in **Figure 1**, individuals will face retirement when they enter old age. After retirement, some of the roles of older adults are continuous, such as the role of family and the role of friends. Another part of roles changes as individuals move from work to non–work, and these transitions are mainly caused by changes in work status. For example, income will change after retirement (26, 27) and health will improve after retirement (28–32). Social interaction activities will be significantly reduced after retirement (29). Individuals also experience significant improvements in psychological mood as a result of retirement (30). The changes in income, health, social communication, and mood caused by the change of role will affect personal utility (33), and continued socialization in old age will in turn affect happiness. This paper hypothesizes that retirement will moderate

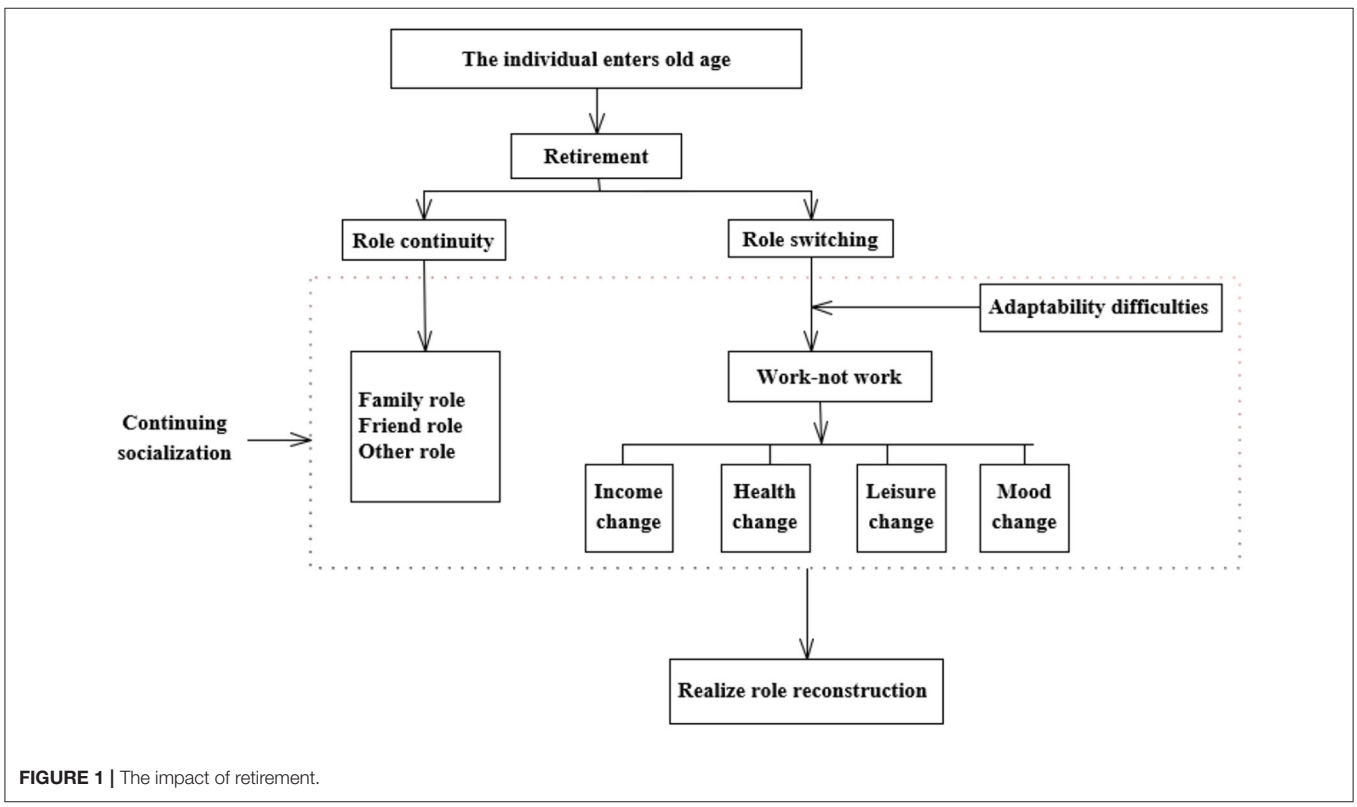

FIGURE 1 | The impact of retirement.

happiness through income, health, social interaction status, and mood changes to achieve role reconfiguration.

DATA

The data used in this paper comes from the data of the Chinese General Social Survey (CGSS), which started in 2003 and is China's earliest national, comprehensive, and continuous academic survey project. The CGSS system comprehensively collects data at multiple levels of society, communities, families, and individuals. After sorting out, it is found that the variables involved in this study exist in the CGSS data of 2012, 2015, and 2017, while they are missing in other years. Therefore, the survey data for these years are selected. In addition, the author has done the following processing on the selected data for 2012, 2015, and 2017: (1) In many countries in the world, women's retirement is affected by factors such as their husbands' retirement status and family characteristics, and their retirement behaviors are complex (34–36). The same is true of Chinese women's retirement behavior (37). In addition, China's retirement policy for female employees stipulates that the general female retirement age is 50 years old, the retirement age of female cadres is 55 years old, and female employees who are engaged in special types of work or are seriously ill can retire at 45 years old. In view of the complexity of women's retirement, China has formulated a retirement policy that is different from that of men, and this policy further enhances the choice of women's retirement. Some scholars have found that the complexity of Chinese women's retirement behavior does exist in reality, and many women apply for retirement before reaching the normal retirement age (38). Men have higher compliance with the mandatory policy of retirement at age 60, and are more suitable for research using the method of FRD. Therefore, this paper only retains male samples for the sake of scientific research and identification accuracy; (2). Due to historical reasons, in the 1950s, a retirement system was introduced to protect the right of urban workers. At that time, the only employer was either the government or state–owned enterprises and institutions. After economic reforms in the 1980s, the private sector and self–employed sectors entered the market. Retirement policies have been adjusted to cover urban workers in these "new" sectors, but still do not apply to rural China. As long as farmers are in good health, they usually continue to work. Therefore, in this study, we limit the analysis to urban residents (3). This paper eliminates the missing values of the main variables such as happiness, age, and retirement. At the same time, in order to better control sample selection bias and study the impact of retirement decisions on happiness, we exclude data for people older than 80 and younger than 40. Finally, 4,778 valid samples were selected, including 2876 non–retired samples and 1902 retired samples.

VARIABLE

Outcome Variable

The outcome variable of this research is happiness, which specifically refers to subjective happiness, that is, people's evaluation of their own lives, including emotional and cognitive aspects (39). In the individual questionnaire, the answer to the question "In general, do you think your life is happy?" is set into five categories: "very unhappy, relatively unhappy, not happy or unhappy, relatively happy, very happy", and they are respectively assigned a value of 1 to 5, in order to clearly distinguish whether an individual is happy or not, this study re–assigns the variables, the author defines the three categories of "very unhappy, relatively unhappy, and not happy or unhappy" as unhappiness, assigning a value of 0. Comparatively, the two categories of "relatively happy and very happy" are defined as happiness, with a value of 1.

Retirement

With reference to ZhangYi et al. we regard "retired" personnel and those who are no longer paid as retired personnel (26). The questionnaire asked, "Did you work for more than 1 h (including joining the army) in order to obtain income last week?" For this question, the option "not engaged in any work for the purpose of obtaining economic income" is assigned a value of 1 the option "paid leave, study, temporary suspension or seasonal closure, etc." is assigned a value of 2. "Unpaid leave, study, temporary suspension or seasonal closure, etc." is assigned a value of 3. "Yes, I work every week" is assigned a value of 4. This paper defines the three groups of people with a value of 2–4 as non–retired people and reassigned them a value of 0. Define "retirement" as retired population and assign a value of 1. Further, the questionnaire asked "What was the reason why you did not work last week?" and set 9 options of "study at school," "loss of workability," "non–working after graduation," "loss of original job due to reasons of employers," "loss of original job due to personal reasons," "expropriation of contracted land," "retirement," "housework," and "other reason." This article excludes the option "study at school" and "others" and defines the six types of "loss of labor," "non–working after graduation," "loss of original job due to reasons of employers," "loss of original job due to personal reasons," "expropriation of contracted land," and "housework" as the unretired population, and assigns a value of 0, This treatment is basically done in consideration of the fact that these six types of cases enjoy before and after reaching retirement age the treatment is different if the individual can enjoy disability benefits before reaching retirement age, there is no financial security for unemployment, but the annuity security from paying pension insurance will be legally enjoyed after retirement. In addition, the article removes the above six cases from the sample in the robustness test, defines unretirement more strictly, and tests the robustness of the effect of retirement on happiness.

Normalized Age

The driving variable in this article is the retirement age, and the legal retirement age for men in my country is 60 years old. With reference to Zhang Yi et al. we define the standardized age "a" as the actual age of men minus the legal retirement age of 60 years: a is calculated as follows: a = male's age−60 years (26). The questionnaire asked," What is your date of birth? (Record the year and month of the Gregorian calendar)." This article uses the year and month when the survey was conducted to subtract the year and month of the birth date to get the age of the respondent. and

TABLE 1 | Variable definition.

Variables	Variable definition
Happiness	Respondents' happiness: unhappiness = 0, happiness = 1
Retirement	Retirement status of respondents: not retired=0, retired=1
Age	Respondents' age
Belief	Religious beliefs of interviewees: Yes = 0, none = 1
Medicare	Respondent's medical insurance situation: not participating=0, participating = 1
Edu	Respondent's education level, unit: year
Child	Number of children the respondent has: 0 or 1 = 0, 2 or more = 1
Region	Region of the respondent: East = 1, Central = 2, West = 3
Income	Respondent's income, unit: ten thousand yuan
Health	Respondent's health status: 1–5, the larger the value, the healthier
Social_i	Respondents' social interactions: 1–5, the greater the value, the more frequent the interaction
Motion	Respondent's motion:1–10, the greater the value, the better the mood

TABLE 2 | Summary statistics.

Variables	ALL	Non–Retirement	Retirement
Happiness	0.791	0.762	0.835
Retire	0.398	0	1
Age	57.977	51.991	67.028
Age^2	3476.968	2774.542	4539.101
Belief	0.917	0.911	0.927
Medicare	0.939	0.922	0.965
Child	0.396	0.305	0.533
Social_i	2.684	2.743	2.595
Region	1.566	1.63	1.468
Edu	10.789	11.159	10.231
Income	4.579	5.107	3.781
Health	3.539	3.644	3.381
Motion	0.929	0.917	0.947
Observations	4778	2876	1902

then subtract 60 from the age of the respondent to get the value of "a".

Control Variables

Personal happiness is a composite indicator, which is also influenced by many other factors. According to the current research, it is mainly manifested in the following aspects. Factors such as faith status, education level, whether one participates in health insurance, the number of children, and the respondent's region can directly affect older people's evaluation of happiness (40, 41). In this paper, control variables are included to improve the reliability of the regression results. The specific variable selection and definitions are shown in **Table 1**.

Before setting up the model, this paper first conducts basic Summary statistics to show the statistical characteristics of variables. **Table 2** is the descriptive statistics of the research samples, which are divided into full samples, non–retired samples, and retired samples. Among them, happiness is the outcome variable, and the average value of the full sample is 0.791, the mean of the non–retired sample is 0.762, and the mean of the retired sample is 0.835, which indicates that the overall happiness of the surveyed group is high, and the average value of happiness after retirement has increased by 0.073 compared with the pre–retirement sample, indicating that retirement may have a positive effect on happiness, and further research will be carried out below. In this paper, age is the driving variable. The overall sample average is 57.977 years old; the retired sample average is 67.028 years old, and the non–retired sample average is 51.991 years old. Among the control variables, the average years of education of the retired sample are significantly lower than that of the non–retired sample, with a difference of about 1 year; in terms of the number of children, the number of children in the retired sample is significantly higher than that in the non–retired sample, which has an average of 2 more children. Among the mechanism variables, in terms of health status, the health level of the non–retired group is 0.263 higher than the average of the retired group; in terms of income, the average annual income of the retired group is 13,26 thousand yuan lower than that of the non–retired group.

EMPIRICAL STRATEGY

Our aim is to estimate the causal effect of retirement on happiness. We start with a linear model:

$$Happiness_i = \beta_1 Retire_i + \delta X_i + \varepsilon_i \quad (1)$$

$Happiness_i$ represents a sense of happiness, 0 represents unhappiness, 1 represents happiness; $Retire_i$ represents retirement, 0 represents not retired, 1 represents retired; X_i is other control variables that affect happiness; ε_i is the error term, which is an uncontrolled variable that affects happiness. β_1 is the parameter that the author focuses on, reflecting the way and extent of the impact of retirement on happiness.

Because the main explanatory variable retirement is a binary variable, this paper further uses the binary logit regression model for regression. The equation is as :

$$\ln\left(\frac{p_i}{1-p_i}\right) = \alpha + \sum_{j=1}^{k} \beta_{ij} x_{ij} + \varepsilon_i \quad (2)$$

Equation (2) is the binary logit regression model. The probability of whether the ith individual retires is p_i, where $p_i = (y_i = 1|x_{ij}).1–p_i$ represents the probability of not retiring. α is a constant term, β_{ij} is the coefficient of the independent variable, reflecting the way and degree of retirement's influence on happiness. The ratio of the probability of retirement to non–retirement, $p_i/(1 - p_i)$ is called the Odds ratio, abbreviated as "OR," which is positive and has no upper bound.

To identify the causal relationship between retirement and happiness, it is necessary to consider the estimation bias caused by possible reverse causality and missing variables. If happiness has an impact on retirement, reverse causality may play a role. For example, individuals with low happiness may tend to retire early; there may also be estimation biases caused by missing variables, such as unobserved influencing factors of personal life satisfaction. To deal with the above–mentioned endogenous problems and accurately identify the causal relationship between retirement and old age happiness, this article further adopts the method of Regression Discontinuity (RD) to identify causality. RD was first used by Thistlewaite and Campbell. It was not until the end of the 1990s that it attracted the attention of economists. RD can effectively identify the causal relationship between variables (42–44). The basic idea of the regression discontinuity (RD) method is that a cause variable (D) is completely determined by whether a reference variable (X) exceeds a certain breakpoint. If the reference variable (X) will affect the outcome variable (Y) at this point, then one can assume that the relationship between the two is continuous, and other factors that may affect the outcome are also continuous at the cutoff point, the jump of the result variable at the cutoff point can be said to be caused by the cause variable (D). Regression discontinuity (RD) methods are divided into two types: sharp regression dis– continuity (Sharp RD) and fuzzy regression discontinuity (Fuzzy RD). The characteristic of sharp regression discontinuity is that the probability of an individual being processed at the cutoff point $X = x0$ jumps from 0 to 1; but in many cases, the causal variable is often affected by factors that cannot be observed by researchers and are not completely determined by the reference variable. In this case, the fuzzy regression discontinuity method is more appropriate, that is, the probability of an individual being processed at the cutoff point $X = x_0$ jumps from a to b, where $0 < a < b < 1$.

China's retirement system fits exactly this feature. In principle, employees must retire at their statutory retirement age, but there may be special circumstances: (1) If employees' work is harmful to health, they are allowed to retire 5 years earlier than the statutory retirement age, or if the medical examination proves that they are seriously ill to continue working, they can retire early. (2) Among employees in the private sector, self–employed and temporary employees, the retirement age is not strictly enforced as in the public sector and state–owned enterprises. Therefore, people do not fully comply with the legal retirement age. A considerable number of people retire before reaching the retirement age, and a considerable number of people are still working for salaries after reaching the statutory retirement age. Therefore, it may not be directly from 0 to 1 at the breakpoint. As we will show later in this study, we do observe discontinuities in retirement rates in this age group. It can be seen from **Figure 2** that for male employees, the retirement probability has a big jump around the age of 60, from about 30% before retirement to about 60% after retirement. The retirement rate at the cutoff point x = 60 is indeed not a direct jump from 0 to 1, which is more in line with the characteristics of fuzzy regression discontinuity. Therefore, this paper uses fuzzy regression discontinuity (Fuzzy RD) to process the data.

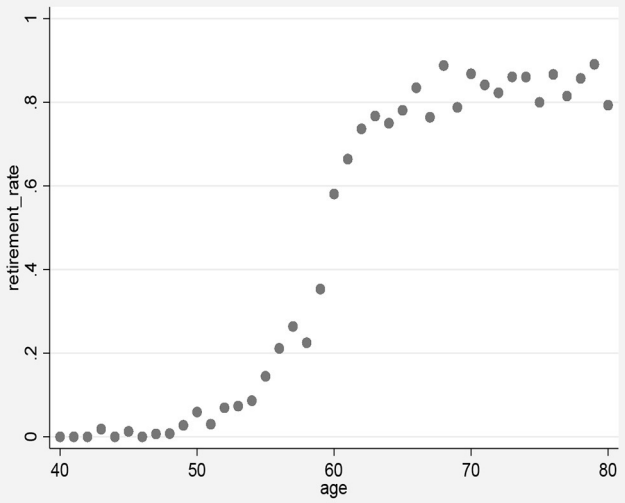

FIGURE 2 | The impact of retirement.

According to the theorem of Hahn et al. we can get the average treatment effect of retirement on personal happiness, the equation is as follows (45):

$$\mathrm{E}\left[\tau_i | X_i = x_0\right] = \frac{\lim\limits_{x \downarrow x_0} E\left[Y_i | X_i = x_0\right] - \lim\limits_{x \uparrow x_0} E\left[Y_i | X_i = x_0\right]}{\lim\limits_{x \downarrow x_0} E\left[D_i | X_i = x_0\right] - \lim\limits_{x \uparrow x_0} E\left[D_i | X_i = x_0\right]} \quad (3)$$

The variable X_i in this paper is the difference between the sample age and the cutoff point of 60 years old. The result variable is the happiness of the sample. The treatment variable *Di* is defined as whether to retire or not. If yes, then $D = 1$; if not, then $D = 0$. We estimate the difference in happiness between the retired sample and the non–retired sample based on formula (3), that is, the treatment effect.

To better identify the average treatment effect of retirement on happiness, this paper follows the idea of Hahn et al. adopts a parameter estimation method, using instrumental variables to estimate the effect of retirement on happiness (45). First, an equation for the effect of retirement on happiness is established:

$$Y_i = \beta_0 + \beta_1 R_i + \beta_2 f(S) + \beta_3 U_i + \varepsilon_i \quad (4)$$

In model (4), Y represents personal happiness; R_i represents whether to retire, a value of 1 represents retirement, 0 represents not retired; U_i is a control variable, including belief, edu, medicare, child, and region. β_1 represents the causal relationship between retirement and happiness, which is the average treatment effect of the FRD model ATE_{FRD}. S represents the difference between age and legal retirement age. f (S) represents a higher–order polynomial containing *S*. In this paper, high–order polynomials are added to construct non-linear relations for Fuzzy regression discontinuity to prevent the variable S from being correlated with the error term to cause errors. The order of the polynomials is judged using AIC (Akaike Information Criterion) (44).

Hank and Korbmacher pointed out that retirement *Ri* is affected by many factors such as family demographic structure (46). It is obviously related to the variables omitted in a model (4), and they are all included in the interference items. This will cause endogenous problems, so the direct use of the original variable *Ri* for OLS estimation is likely to lead to estimation bias, and the use of an exogenous variable can avoid this situation. Individual retirement is highly correlated with age, and there is no ambiguity in age, which has a strong exogenous nature. Using age–related instrumental variables can accurately estimate the retirement effect. Therefore, we adopt the two–stage least squares method, that is, to find the instrumental variables for retirement in the first stage and use the model (2) to perform regression calculation on the instrumental variables in the second stage to avoid endogeneity problems. The specific method is to use possible exogenous variables to regress *Ri* to obtain the estimator of *Ri*, which is used as an instrumental variable. For this purpose, the following model is established:

$$R_i = \alpha_0 + \alpha_1 D_i + \alpha_2 g(S) + \alpha_3 V_i + \delta_i \quad (5)$$

In this model, $g(S)$ is a high–order polynomial containing S. Here, we use the difference between the sample individual's age and the legal retirement age as an instrumental variable, namely D_i. When the age difference is >0, D_i takes the value 1, and these samples are the experimental group; When the age difference is <0, the value of D_i is 0, and these samples are the control group. Therefore, we can use the idea of instrumental variables combined with the breakpoint parameter estimation method (IV/RD) for analysis. The IV/RD parameter regression results in the subsequent empirical part of this article are all estimated using formula (4) and formula (5), that is, using two stage least square to obtain Fuzzy regression discontinuity estimates.

MAIN RESULTS

We first show the preliminary regression results using the linear model and the binary logit model, as shown in **Table 3**. Among them, models (1), (2), and (3) are linear regression results, models (4), (5), and (6) are binary logit regression results, models (1) and (3) are results without control variables, models (2) and (4) is the regression result after adding the control variables and age, and models (3) and (6) is the regression result after adding the control variables, age, and age^2.

After the estimation of the Fuzzy regression discontinuity model is completed, the model needs to be tested as follows to ensure the robustness of the estimation results. First of all, according to the research content of Lee and Lemieux, the breakpoint regression design needs to meet the local randomization assumption (29), that is, the reference variable can't be accurately controlled by individuals, otherwise the Fuzzy regression discontinuity will fail. Therefore, according to the test method proposed by McCrary, this article checks whether the sample age distribution is continuous at the cutoff point to test whether it meets the hypothesis of local randomization (47); Secondly, if the distribution of covariates also "jumps" at the cutoff point breakpoint, it cannot prove that the "jump" of the outcome variable at the cutoff point is due to the influence of the cause variable. The fuzzy regression discontinuity design will also lose its effect, so we need to test the continuity of the covariate at the cutoff point; Next, we will select different sample intervals for regression to further test the robustness of the results. Then, we do the analysis with income, health, social interaction, and mood as the mechanism variables. Finally, this paper tests the heterogeneity of changes in post–retirement happiness across groups with different education levels and number of children.

TABLE 3 | Main results.

	(1)	(2) OLS	(3)	(4)	(5) Logit	(6)
Retire	0.075***	0.041 **	0.039**	0.073***	0.040**	0.040**
	(0.012)	(0.017)	(0.016)	(0.012)	(0.016)	(0.016)
Age		0.002**	−0.011*		0.001*	−0.008
		(0.001)	(0.006)		(0.001)	(0.006)
Age^2			0.001**			0.000*
			(0.000)			(0.000)
Belief		−0.036	−0.035		−0.035*	−0.034*
		(0.022)	(0.022)		(0.020)	(0.020)
Edu		0.012***	0.012***		0.012***	0.012***
		(0.002)	(0.002)		(0.002)	(0.002)
Medicare		0.100***	0.101***		0.125***	0.126***
		(0.021)	(0.021)		(0.028)	(0.028)
Child		0.073***	0.067***		0.071***	0.067***
		(0.014)	(0.014)		(0.014)	(0.014)
Region		−0.005	−0.005		−0.006	−0.006
		(0.008)	(0.008)		(0.008)	(0.008)
N	4778	4778	4778	4778	4778	4778

****, **, * indicate significance at the level of 1, 5, and 10% respectively; the numbers in parentheses are the standard errors. The logit regression reports the marginal effect.*

Basic Regression Results

It can be seen from **Table 3** that the estimated results of OLS regression and binary logit regression are consistent in terms of significance, which shows that retirement significantly improves happiness. As far as the control variables are concerned, the higher the education level, the happier; Those who participated in medical insurance were significantly happier. Those with more children are significantly happier than those with fewer children. These variables are all significant at the 0.01 level. In addition, people without religious beliefs are happier after retirement. Geographically, the closer to the east, the happier but this is not statistically significant.

In order to make the estimation results more accurate and effective, we use Fuzzy regression discontinuity design to estimate again to solve the possible endogenous problems and sample selection bias problems. This paper refers to the research of some scholars and uses the rdbwselect method to estimate the optimal bandwidth 4, and the standardized age a and its square a^2 are respectively put into the model for regression (48–51). The specific regression results are shown in **Table 4**.

TABLE 4 | FRD estimation results.

	(1)	(2)
	bandwidth 4	
Retire	0.228***	0.225***
	(0.052)	(0.052)
a	0.086***	0.086***
	(0.005)	(0.005)
		−0.003
		(0.002)
Covariates	Yes	Yes
Observations	1290	1290

*** *indicate significance at the levels of 1%; in the parentheses are the standard errors.*

The research results in **Table 4** show that using Fuzzy regression discontinuity design can still draw conclusions that retirement improves happiness. When the driving variable of the model is only standardized age, the coefficient is 0.228, which is significant at the level of 0.01, which further validates the conclusions in **Table 3**. At the same time, in the first stage of regression, the driving variable a is significant at the level of 0.01, and the older the age the greater the possibility of retirement, which is consistent with the actual situation, indicating that the model settings are in line with reality. When the driving variable adds a^2, the coefficient is 0.225, which is significant at the level of 0.01, but a^2 is not significant, indicating that the image doesn't fit well, and the relationship between age and happiness is linear instead of an inverted U– shaped relationship. This is for reference only. This result is consistent with the study of Jokela et al. (20).

Specifications Checks

To ensure the credibility of the regression results, the control variables need to be tested, including belief, edu, medicine, child, and region. If the density distribution functions of these control variables also have "jumps" at the breakpoints, then the "jumps" of the outcome variables cannot be fully explained by the "jumps" of the processed variables, and the causal inference will lose its effectiveness. We use the idea of Fuzzy regression discontinuity to replace the original outcome variables with these covariates and obtain the change values of these control variables in **Table 5** before and after the cutoff point. From the results in the table, it can be seen that, except for medical insurance participation, these variables did not change significantly before and after the cut–off point, which further verified the credibility of the research conclusions. China's medical insurance system and retirement system are two independent systems retirement time is not affected by medical insurance participation status. When medical insurance participation changes significantly before and after the retirement threshold, controlling for medical insurance participation may lead to an underestimation of results, that is, retirement actually has a greater impact on well–being. It has no effect on our empirical conclusion. After the retirement age threshold, the participation rate of individual medical insurance increases significantly at the level of 5%, which may be due to the following reasons. On the one hand, urban and rural residents' medical insurance implements voluntary insurance, There must be an adverse selection problem in insurance. Only those who think it is cost–effective to participate in the insurance, otherwise they will not participate in the insurance. The older you are, the more health problems you may face and the need for medical insurance, so the older you are, the more likely you are to participate in the insurance. On the other hand, although the government has invested a lot of financial subsidies in medical insurance for urban and rural residents, for some urban and rural households, the cost of participating in the insurance is still a lot of expenses, and some families are unwilling to participate in the insurance. When the older person reach the retirement age, they can buy medical insurance if they get a pension. So there are more people participating in medical insurance after retirement than before retirement. In addition, in terms of the reimbursement ratio of medical insurance, some regions stipulate that the reimbursement standard for those who have reached the retirement age is higher than that for those who have not reached the retirement age. Some regions stipulate that the older the age, the higher the reimbursement rate. It may also lead to individuals being more likely to enroll in health insurance when they reach retirement age.

When performing Fuzzy regression discontinuity design, it is necessary to check whether there is endogenous grouping. If the individual knows the grouping rules in advance and can fully control the grouping variables through their own efforts, they can choose to enter the experimental group or the control group by themselves, resulting in endogenous grouping rather than random grouping near the cutoff point and causing the Fuzzy regression discontinuity design to fail. Based on the calculation method of McCrary, this paper examines whether there is precise control of the assigned variable by examining the continuity of the density function of the assigned variable at the cutoff point (47). **Figure 3** shows the density distribution diagram of the time between the age of the sample and the cutoff point. As can be seen in **Figure 1**, the density function curves all nearly overlap at the breakpoints without significant jumps. The density difference before and after the cutoff point is 0.084, and the standard error is 0.099, indicating that the age distribution of the sample individuals is continuous and smooth, that is, the individuals have not precisely manipulated the grouping variables.

Test of the "Jump" of the Explained Variable at the Cutoff Point

Figure 4A shows that there is indeed a significant jump in happiness around the age of 60. **Figures 4B,C** are the placebo tests on the assumption that the retirement age of the older person is 55 and 65 years old respectively. As can be seen from the figure, there is no significant change in happiness near the age of 55 and 65.

Robustness Check

To test the robustness of the results, this paper selects 50% and 200% of the optimal bandwidth, namely bandwidth 2 and bandwidth 8, to investigate the impact of retirement on

individual happiness. The results are shown in **Table 6**. As can be seen from the table, the coefficient gradually decreases with the increasing sample size. That's because the larger the sample range, the weaker the impact of retirement on happiness. This is determined by the intrinsic characteristics of the fuzzy regression discontinuous design model. The coefficient on retirement is significant at the 0.01 level, the standardized age term is always significant, and the standardized age–squared term is significant at broadband 8 insignificant at broadband 4. This indicates that the model is robust and less dependent on bandwidth.

In the previous sample, the non–retired sample included those who studied at school, lost the ability to work, did not work after graduation, lost their original job due to their employer, lost their original job due to personal reasons, did housework, and contracted land is expropriated. The above–mentioned samples are removed here, a more rigorous definition of retirement and non–retirement to do robustness tests. the optimal bandwidth 4 was estimated using the rdbwselect method, and the standardized age a and its square a^2 are respectively put into the model for regression. To test the robustness of the results, 50% and 200% of the optimal bandwidth, namely bandwidth 2 and bandwidth 8 were selected to investigate the impact of retirement on individual happiness. It is clear from the **Table 7** that retirement can still significantly improve happiness after adopting a stricter definition of retirement.

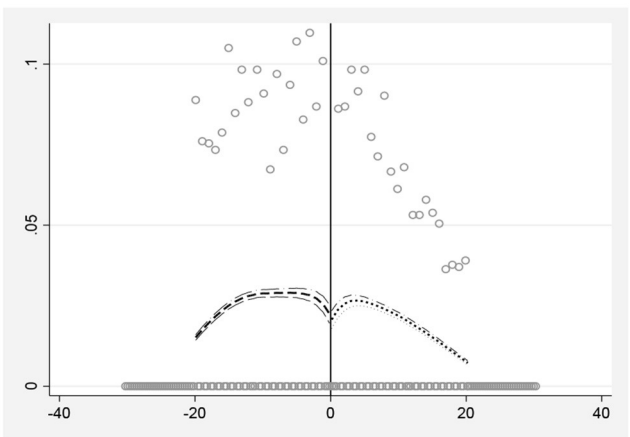

FIGURE 3 | The impact of retirement on happiness.

Alternative Estimation Methods

In order to test the robustness of the results of this paper, the sample whose age is exactly 60 years old is deleted in

TABLE 5 | Continuity test of control variables.

y	Coef.	Std.Err.	z	P>z	[95%Conf.	Interval]
Belief	−0.018	0.048	−0.380	0.704	−0.113	0.076
Edu	0.623	0.623	1.000	0.317	−0.598	1.845
Medicare	0.110	0.050	2.200	0.028	0.012	0.208
Child	0.096	0.087	1.100	0.272	−0.075	0.266
Region	−0.154	0.153	−1.010	0.312	−0.454	0.145
Lwald	−0.020	0.086	−0.230	0.817	−0.189	0.149

TABLE 6 | FRD estimation results using different bandwidth.

	(1)	(2)	(3)	(4)
	bandwidth 2		bandwidth 8	
Retire	0.175**	0.169*	0.149***	0.149***
	(0.087)	(0.087)	(0.030)	(0.030)
a	−0.022**	0.104***	0.062***	0.062***
	(0.010)	(0.007)	(0.002)	(0.002)
		0.004		−0.001**
		(0.005)		(0.000)
Covariates	Yes	Yes	Yes	Yes
Observations	722	722	2342	2342

****, **, * indicate significance at the levels of 1, 5, and 10% respectively; in the parentheses are the standard errors.*

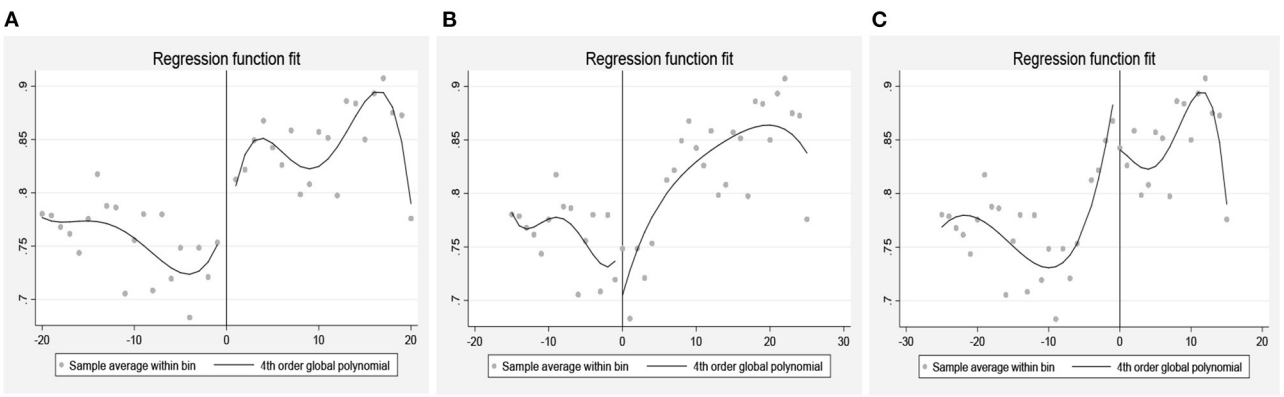

FIGURE 4 | (A) The effect of retirement on happiness when 60 is the retirement age. **(B)** The effect of retirement on happiness when 55 is the retirement age. **(C)** The effect of retirement on happiness when 65 is the retirement age.

TABLE 7 | The impact of retirement (redefined) on happiness.

	(1)	(2)	(3)	(4)	(5)	(6)
	bandwidth 4		bandwidth 2		bandwidth 8	
Retire	0.192***	0.187***	0.124	0.123	0.103***	0.105***
	(0.054)	(0.055)	(0.091)	(0.091)	(0.030)	(0.030)
a	0.085***	0.085***	0.135***	0.136***	0.063***	0.063***
	(0.005)	(0.005)	(0.013)	(0.013)	(0.002)	(0.002)
		−0.004*		−0.020*		−0.001***
		(0.002)		(0.011)		(0.000)
Covariates	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1152	1152	641	641	2092	2092

***, * *indicate significance at the levels of 1 and 10% respectively; in the parentheses are the standard errors.*

TABLE 8 | The impact of retirement on happiness.

	(1)	(2)	(3)
Retire	0.0516*	0.0657*	0.0596*
	(0.0169)	(0.0180)	(0.0217)
a	0.00431*	0.00629*	0.00603*
	(0.0009)	(0.0010)	(0.0020)
Retire x a	−0.00255	−0.00254	−0.00158
	(0.0016)	(0.0026)	(0.0032)
a^2		0.000218*	0.000230*
		(0.0001)	(0.0001)
Retire x a^2		−0.000354**	−0.000167
		(0.0002)	(0.0003)
a^3			0.00000135
			(0.0000)
retire x a^3			−0.0000141
			(0.0000)
Covariates	Yes	Yes	Yes
Observations	4592	4592	4592

**, * *indicate significance at the levels of 5 and 10% respectively; in the parentheses are the standard errors.*

this paper, the products of a, a^2, a^3 and retirement are put into the model separately, that is, using the method of local polynomial regression:

$$Y_i = f(a) + \beta_1 \times post60_i + f(a) \times post60_i + \varepsilon_i \quad (6)$$

As can be seen from **Table 8**, retirement still significantly improves happiness, and its impact on happiness is also Robust.

Mechanisms Analysis

How does retirement affect personal happiness? We try to identify the specific mechanisms of the impact of retirement on happiness to enrich empirical studies in China, as well as to find possible compensation options for future welfare losses resulting from the implementation of delayed retirement policies in China. Based on role theory and continuous socialization theory, we argue that retirement may cause different changes in happiness through changes in residents' income, health status, social interaction activities, and emotional status, so we test these four aspects. The empirical method used is:

$$happiness_i = \alpha_0 + \alpha_1 retire_i + \alpha_2 mediator_i + \alpha_3 retire_i \, x \, mediator_i + \alpha_4 X_i + \varepsilon_i \quad (7)$$

As shown in **Table 9**, health and social interactions affect the increase in happiness in retirement. The better the health status, the smaller the effect of retirement on happiness. The more social interactions, the smaller the effect of retirement on happiness. Income and emotional status do not affect the relationship between retirement and happiness.

TABLE 9 | Analysis of mediation effect.

	(1)		(2)		(3)		(4)
Retire	0.158***	retire	0.108***	retire	0.050***	retire	0.058
	(0.048)		(0.034)		(0.018)		(0.060)
Health	0.107***	social_i	0.044***	income	0.004***	motion	0.317***
	(0.008)		(0.007)		(0.001)		(0.033)
h x r	−0.036***	s x r	−0.026**	i x r	−0.002	m x r	−0.033
	(0.012)		(0.011)		(0.002)		(0.060)
Covariates	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	4778	4778	4778	4778	4778	4778	4778

***, ** *indicate significance at the levels of 1 and 5% respectively; in the parentheses are the standard errors.*

TABLE 10 | Analysis of the impact of retirement on the happiness of different groups.

	(1)	(2)	(3)	(4)
	edu		child	
	Below university	University and above	One	More than one
Retire	0.095***	0.028	0.042*	0.144***
	(0.023)	(0.032)	(0.025)	(0.029)
Empirical p–value	0.063	0.003		
Covariates	Yes	Yes	Yes	Yes
Observations	3630	1148	2888	1890

***, * *indicate significance at the levels of 1 and 10% respectively; in the parentheses are the standard errors.*

Heterogeneity Analysis

In order to find out how retirement affects personal happiness, and whether there is heterogeneity in the happiness of different groups after retirement, we will analyze the heterogeneity in groups based on education, and the number of children. Enrich China's experience and research, and at the same time find possible remedies for the loss of welfare equity caused by the implementation of the delayed retirement policy in China in the future.

From the columns (1)–(2) of **Table 10**, it can be seen that the happiness of the group with an education level below university is greater than that of the group with an education level and above, and there are significant differences between groups. It can be seen from the columns (3)–(4) of **Table 10** that a group with multiple children is happier after retirement than a group with a single child.

DISCUSSION

This paper explores whether and to what extent the retirement system affects the happiness of urban residents, and the results show that retirement will significantly improve the happiness of Chinese people. This is the same as some research conclusions in developed countries such as the United Kingdom, the United States, and Australia (19–21). The research in this paper further expands the boundaries of the impact of retirement on happiness, and has general reference significance for developing countries.

According to our model and empirical test results of the impact of retirement on happiness, the changes in happiness among groups are heterogeneous after retirement. Health and social interactions influence increases in retirement happiness. The better your health, the less impact retirement has on happiness. The more social interaction, the less impact retirement has on happiness. This may be due to the fact that retirement can free a person from social pressures at work, increase leisure time, develop hobbies, improve relationships with family members, enhance intimacy, and thus increase happiness. Jokela et al. (20) also found that came to the same conclusion (20). The implication for the policy is that the delayed retirement policy can be targeted to publicize different groups, and firstly publicize the groups whose welfare is less damaged, such as those with good health status and more social activities, so as to reduce the resistance of the policy.

The improvement of the post–retirement happiness of the group with the education level below the university is significantly greater than that of the group with the education level of the university and above. This may be because the positions in the group below the university are lower than those with a university degree, and the work is relatively boring and tiring. The family utility and leisure utility of middle–aged and older people are greater than the income utility brought by work, so they are happier after retirement. A group with multiple children experienced a greater increase in happiness after retirement than a group with one child. This may reflect the tradition of more children and more happiness. Older adults with more children have more family ties and are happier in retirement. The implication for the policy is that the delayed retirement policy may affect the existing group welfare status, causing greater welfare losses for groups with low education levels and many children, which may require the introduction of relevant supporting measures to narrow the group welfare gap.

It should be noted that a limitation of our research was the exclusion of female retirees. Because in traditional Chinese culture, men are in charge of the outside world and women are in charge of the home, women may give up work at any time due to family and other factors, and women's retirement behavior is more complicated. China's retirement policy for women has further enhanced the selectivity of women's retirement time. In traditional cultures, women are responsible for caring for grandchildren after retirement, complicating changes in women's post–retirement happiness. Further research is needed on the issue of Chinese women's retirement and the impact of Chinese women's retirement on happiness.

CONCLUSION

With the advent of the aging wave, people pay much attention to retirement policies. In order to enhance the sustainability of pensions and reduce financial pressure, the Chinese government wants to introduce a delayed retirement policy, which is bound to affect the welfare of the older person. In this context, this paper explores whether the retirement system will affect the happiness of residents and the specific extent of the impact, which is related to public decisions such as whether to launch delayed retirement, when to launch it, to whom, and how to launch it. Will retirement really make people happier? To answer the question of whether people's happiness will increase after retirement, this paper uses 2012, 2015, and 2017 China General Social Survey (CGSS) data to conduct empirical research through three methods: OLS, binary Logit, and Fuzzy regression discontinuity design. The results all show that retirement will significantly improve the happiness of people. By testing the continuity of reference variables and covariates at breakpoints and more rigorous sub–sample estimation results, the author found that the above conclusions are still robust. Retirement significantly increases the happiness of older adults, which is consistent with public opposition to delayed retirement. Some research also found that delaying retirement can harm the well–being of residents, such as affecting family care (52). Although delaying retirement can reduce the financial burden of China's pension system, it can have a negative impact on the happiness of the older person. The article further analyzes the heterogeneity of the research and found that retirement brings more happiness to people who have a college degree or less, and have multiple children. The better the health status, the smaller the effect of retirement on happiness. The more social interactions, the smaller the effect of retirement on happiness. It is important to stress that our findings apply only to male retirees, not all retirees.

In response to the empirical results obtained in this paper, this paper suggests that when implementing a delayed retirement policy, publicity should be strengthened for groups with greater welfare impairment and relevant welfare impairment compensation policy measures should be introduced. Considering the many reasons why people oppose the delayed retirement policy, such as the increase in family care needs, unfairness of the pension system, crowding out of employment, and pension wealth problems, the government needs to formulate reasonable supporting policies to solve people's worries in the process of implementing the delayed retirement.

DATA AVAILABILITY STATEMENT

Publicly available datasets were analyzed in this study. This data can be found here: http://cgss.ruc.edu.cn.

AUTHOR CONTRIBUTIONS

Material preparation, data collection, and analysis were performed by YZ and YT. The first draft of the manuscript was written by AZ. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript and contributed to the study conception and design.

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Research on older people's health information search behavior based on risk perception in social networks—A case study in China during COVID-19

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Objective: COVID-19 has caused great loss of human life and livelihoods. The dissemination of health information in online social networks increased during the pandemic's quarantine. Older people are the most vulnerable group in sudden public health emergencies, and they have the disadvantage of infection rates and online search for health information. This study explores the relationship between the health risk perception and health information search behavior of older people in social networks, to help them make better use of the positive role of social networks in public health emergencies.

Method: Based on the Risk Information Search and Processing model, and in the specific context of COVID-19, this study redefines health risk perception as a second-order construct of four first-order factors (perceived probability, perceived severity, perceived controllability, and perceived familiarity), and constructs a research model of the health risk perception and health information search behavior of older people. An online survey of people over 55 years old was conducted through convenience sampling in China from February 2020 to March 2020.

Results: A total of 646 older adults completed the survey. The structural equation model showed that health risk perception is a second-order factor (H1), that health risk perception has significant positive effects on health information search behavior (H2: $\beta = 0.470$, $T = 11.577$, $P < 0.001$), and that health risk perception has significant positive effects on affective response (H3: $\beta = 0.536$, $T = 17.356$, $P < 0.001$). In addition, affective response has a significant positive mediating effect on information sufficiency (H4: $\beta = 0.435$, $T = 12.231$, $P < 0.001$), and information sufficiency has a significant positive mediating effect on health information search behavior (H5: $\beta = 0.136$, $T = 3.081$, $P = 0.002$).

Conclusion: The study results indicate that the health risk perception of older people during the COVID-19 outbreak not only directly affected their

health information search behavior, but also had an indirect impact on their health information search behavior by affecting affective response and information sufficiency.

KEYWORDS

health information search behavior, health risk perception, COVID-19, social network, older people

Introduction

The worldwide spread of COVID-19 has caused immense loss of human lives and livelihoods (1). During the COVID-19 pandemic, governments in many countries such as China, Italy, and the United States tried to prevent further spread by isolating confirmed and suspected cases and restricting the movement of people (2, 3). When individuals cannot obtain sufficient information from traditional approaches, they often use social networks as an alternative source of information to meet their information needs (4). During the period of forced isolation, a large amount of information related to the pandemic spread rapidly through online social networks (5).

Online social networks play an important role in disseminating health information, shaping perceptions of health risk, and providing guidance on prevention behaviors. This role was seen with the Ebola outbreak in West Africa from 2014 to 2016 and the Middle East Respiratory Syndrome (MERS) outbreak in South Korea in 2015 (6, 7). The current media era has spawned more complex information dissemination routes, a larger volume of information, and more diversified information subjects and objects (8). Misinformation or disinformation (9) may harm people's health and trigger an "information epidemic" or an "infodemic." Information about the COVID-19 pandemic on social networks is mixed, and a large amount of unverified health information of various types has been continuously created and disseminated online during the pandemic, so that people often fail to identify scientifically valid health information (10).

The older people, as digital immigrants, are more vulnerable to information overload due to the deterioration of their physiological function, the limitations of their educational level, and their lack of network cognition (11). The World Health Organization showed that older people remain one of the most seriously affected groups during emergency situations (12) because they are not only physically vulnerable to infection, but also at a disadvantage when it comes to accessing health information. Meanwhile, the increasing health risk with age makes older people pay more attention to their health condition and health cognition level in general (13), and their desire for health information becomes more and more urgent. During the early phase of COVID-19 pandemic, it was critical for older people to obtain scientific and effective health information through social networks, which guide their lives and stabilize their mental state (14, 15).

Given this background, this study focused on 646 people over 55 years old during period of the COVID-19 outbreak in China (February 21, 2020–March 15, 2020). The study asked these questions:

(1) What was the risk perception of COVID-19 among older people during the outbreak?
(2) What was the health information search behavior of older people during the outbreak?
(3) What is the relationship between health risk perception and health information search behavior for older people?

Theoretical background

Online social networks

A social network is a relationship network formed by interactions between individuals or families and their relatives, friends, colleagues, neighbors, etc. (16). With the development of information technology and the emergence of social media, the online social network has become the mapping of users' interpersonal relationships in virtual space (17). These networks include those created with instant messaging software and dating software, blog or other online network platforms, media-sharing networks, and short videos (18). In recent years, diverse social networks have provided the most extensive channels for the generation, access, and sharing of health information (19).

Health risk perception

The term "health risk perception," which derives from "risk perception," has not achieved a unified definition in academic circles (20). Health risk perception is an important concept composed of health and risk transmission (21, 22) and has been confirmed to have a high correlation with health behavior, which plays an important role in health behavior theory (23, 24). Some scholars have paid attention to the public risk perception when new infectious diseases occur, such as MERS or H1N1 (25, 26), and some scholars have developed a public risk perception scale for public health emergency events (27). Other investigators

TABLE 1 Dimensions of health risk perception.

Dimensions	Object of study	Researcher
Severity, controllability	Radiation risk	(30)
Dread risk, risk, unknown risk	Heart disease	(24)
Likelihood, susceptibility, secondary predisposition	Cigarette smoking	(31)
Risk knowledge, personal control, environmental risk, optimistic bias	Diabetes	(32)
Perceived severity, perceived susceptibility	Sexually transmitted diseases	(33)
Possibility, severity, unpredictability, controllability	Public health emergencies	(27)
Consequences, likelihood	Influenza	(34)

have identified risk perceptions as being linked to information activities (28).

Risk perception is a multidimensional concept (29). Research on the dimensions of health risk cognition is still not unified or systematic. Table 1 shows various dimensions of health risk cognition used by some scholars in recent years.

In summary, in order to better understand the health risk perception of older people in the early stage of the COVID-19 outbreak, this study refers to the existing research conclusions to construct health risk perception variables from the four dimensions of perceived probability, perceived severity, perceived controllability, and perceived familiarity.

Health information search behavior

Health information search behavior derives from information search behavior. The definition of information searching behavior that is widely recognized by scholars is, "Information searching behavior refers to the information searching activities conducted by users to meet certain target needs," as proposed by Wilson (35). More recently, the development of user-centered online social networks has not only constructed a complex virtual interpersonal network for users, meeting their interaction and entertainment needs, but also formed a complex information base that greatly expands the health information search behaviors of users (36).

Many scholars have carried out numerous studies on the representation, content, influencing factors, search barriers, and other aspects of health information search behavior in online social networks, and drawn many scientific and effective conclusions (37). Both Manafo and Wong and Hutto et al. found that older adults do not have enough experience to construct effective online searches, that they search for information based only on their previous experience, lack the ability to evaluate the health information in social networks (38).

Therefore, we focus our research on older people and try to explore the relationship between older people's health risk perception and their health information search behavior.

Risk information search and processing model

Griffin et al. proposed the Risk Information Search and Processing (RISP) model in 1999 based on psychology and information communication theories: the Heuristic Systematic Model and the Theory of Planned Behavior (39). The RISP model's main variables are perceived hazard characteristics, affective response, information sufficiency, information subjective norm, perceived information-gathering capacity, and relevant channel beliefs (22).

"Perceived hazard characteristics" are individuals' assessment and prediction of risk status, including perceived probability, perceived severity, institutional trust, and personal control. "Affective response" in the RISP model refers to the uncertainty, worry, and fear generated by perceived risk characteristics. "Information sufficiency" is the central variable in the RISP model, and refers to the confidence in information an individual needs to deal with a risk event [i.e., the information sufficiency threshold (39)]. It is reflected in the individual's grasp of their own risk information in the face of risks, and represents the gap between the information the individual has available and the information necessary to effectively deal with the risk. "Information subjective norm" refers to the social pressure that an individual feels when taking a specific behavior. "Perceived information-gathering capacity" measures an individual's self-efficacy in information collection. "Relevant channel beliefs" reflect the trust level of social media (22, 39).

The RISP model proposes that an affective response generated by perceived risk characteristics will affect the confidence one wants to have in one's knowledge about the risk (information sufficiency threshold), and that one will be motivated to have more information-seeking behavior. The specific path of the model is shown in Figure 1.

Since the RISP model was proposed, the Griffin team and other scholars have used this model to carry out a number of studies: Griffin et al. verified the impact of risk perception, worry, and subjective norms on information sufficiency in drinking water safety risk perception and fish product consumption research (22). Hunnrne et al. conducted a comparative study of information search and processing behavior for public safety risks between American and Dutch citizens and found that the RISP model has applicability and effectiveness in different cultural backgrounds (40). Hovick et al. validated cancer risk information with the RISP model (41).

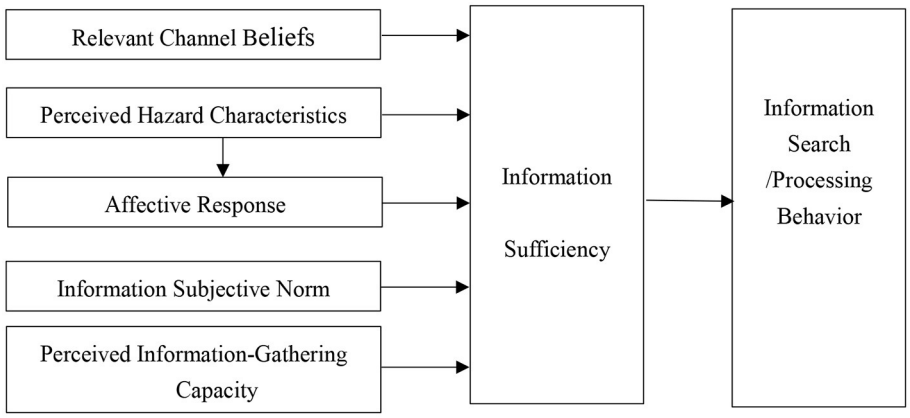

FIGURE 1
Risk information search and processing model.

Thus, the RISP model has good adaptability and should also be suitable for the study of health risk perception, providing a theoretical basis for the situational study of health information user behavior. However, some variables in the RISP model may not have a significant impact on this study and will need adjustment, as described in the following.

Considering the context of COVID-19, the study focuses on the characteristics of sudden public health events [e.g., high levels of attention to health information (15)], the impossibility of offline investigation under strict control measures (42), and the group characteristics of the older people (e.g., limited energy). Therefore, we deleted three variations: "information subjective norm," "relevant channel beliefs," and "perceived information-gathering capacity," and replaced "perceived hazard characteristics" with "health risk perception." The reasons for our changes are as follows: (1) With the RISP model, the "information subjective norm" is an important motivation to seek out and deal with non-personal risks (41). This study focuses on the risk perception of older people, which is directly related to individuals. Some studies did not consider the "information subjective norm" when they applied the RISP model to study health risk cognition, like Johnson (43). (2) Griffin et al. added media images into the RISP model and used "relevant channel beliefs" to reflect the trust level of social media (22). This study focuses on the relationship between risk perception and health information search behavior in older people facing COVID-19 and did not involve a differentiated study of various information channels. Therefore, "relevant channel beliefs" are not considered in this study. (3) Many studies have found that older people have ambiguous cognition of their own information collection ability (37). Other studies have found that self-efficacy is related to perceptions of the effectiveness of medications and confidence in self-knowledge (44), which is consistent with the "perceived familiarity" and "perceived controllability" of "health risk perception." Therefore, "perceived information-gathering capacity" is classified as "health risk perception" and will not be studied separately. We retained the variables of "affective response" and "information sufficiency," which will be discussed in Section Research model and hypotheses.

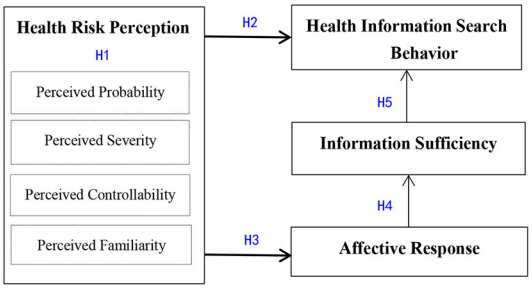

FIGURE 2
The health risk perception and health information search behavior research model.

Research model and hypotheses

Based on RISP theory, we propose a model of health risk perception and health information search behavior based on study of older people's online information searching behavior during the COVID-19 outbreak. Figure 2 provides a research framework for how health risk perception affects health information search behavior.

Health risk perception and health information search behavior

Risk is commonly defined as a multiplicative combination of the probability of a hazardous event occurring and the

severity of the resulting negative consequences (29). Dai et al. found that individuals have different perceptions of a risk and that their perceptions vary from one risk to another (27). Perceived severity of risk refers to an individual's assessment of the degree of harm associated with the risk (30). At the end of 2019, COVID-19 had the characteristics of being a highly unknown disease, highly contagious and having a high mortality rate. Severely ill patients were mostly older people and those with underlying diseases. Many older people began to pay attention to the risk of infection to themselves, their families, and the other people surrounding them, as well as the serious consequences after infection. Therefore, this study believes that perceived severity and perceived probability are very important parts of older people's assessment of the health risks caused by COVID-19.

In the objective result of risk, the greater the individual's ability to control the risk result, the more his risk perception will be inclined to the favorable side of the risk uncertainty result. Slovic proposed that the two dimensions of perceived possibility and risk severity (proposed in the psychometric paradigm of risk cognition) are not enough to fully reveal the characteristics of health risk cognition, and that risk controllability is also an important influencing variable (45). In their diabetes research, Walker et al. defined personal risk control as a means of behavior control taken by individuals to achieve health (32). In addition, public resources, especially medical resources provided by the government, public health funds, etc., affect the level of public health risk awareness (46). Since the outbreak of COVID-19, the Chinese government has continuously publicized a series of specific measures to prevent the spread of the virus, including wearing masks, reducing gatherings, etc. The media has continued to report on the progress of drug and vaccine research and development, and the current situation of the epidemic in various places. However, the home isolation measures taken by the government during the epidemic period made it difficult for older people to obtain information through offline information access channels, so as to assess the effectiveness of various prevention and control measures taken by the government and other public departments against the epidemic. Therefore, this study proposes that perceived risk controllability is also an important part of older people's evaluation of the health risk caused by COVID-19.

Risk familiarity is an important factor in risk assessment. Many scholars have found that risk perception is closely related to people's risk experience and knowledge of risk events (33). Slovic proposed in his risk cognition model that familiarity is an important factor affecting risk cognition, and defined familiarity as people's understanding or the visibility of risk events (45). The severity of the negative consequences that an infectious disease may cause, the possibility of contracting the infectious disease, and the ability to control its spread may all be relevant aspects of the public's assessment of the possible health risks of the infectious disease. COVID-19 was a sudden, new infectious disease. In the early days of the epidemic, the public had little knowledge of COVID-19. Limited by cognitive ability and the ability to search for information, the understanding of the infectious disease in older people was far below the average level. The familiarity of older people with COVID-19 directly affects their awareness of potential health risks.

Therefore, considering the reactions of older people during the COVID-19 outbreak as the context of this study, the first hypothesis of the study is developed:

> **H1.** Health risk perception is a second-order factor of perceived probability, perceived severity, perceived controllability, and perceived familiarity.

Risk perception has been confirmed to be associated with information search behavior (47). In the health field, Patel found that risk perception has an impact on health information search behaviors in cases of breast cancer (48). With the development of social networks, Guo et al. (49) found that risk perception significantly affects the health information behavior of social media users.

The public's perception of risk has an important impact on their information searching behavior in emergency situations (7). For example, Bish and Michie found that risk perception can promote protective motivation in public health emergency events, which increases preventive behavior during infectious disease outbreaks (50). In addition, the theory of planned behavior holds that the behavioral attitude and subjective norm affect individual behavioral intention, and behavioral intention leads to behavior (51), which is consistent with the logic that health risk perception affects health information search behavior. For older people, degenerative changes in human tissues and organs inevitably bring about a weakening of the function of the immune system, and the phenomenon of "survival with disease" is more common. Older people with various chronic and underlying diseases are at higher risk of death during public health emergency events (52). As a result, older people are more concerned about their health and life safety, and they are more active in searching for health information.

Therefore, this study makes the following hypothesis:

> **H2.** Health risk perception is associated with the health information search behavior of older people during public health emergency.

Health risk perception and affective response

The estimations and judgments made by individuals in the face of the same risk event are often different (22).

The RISP model divides the process of an individual facing risk information into three stages: cognition, emotion, and information search and processing (22). When individuals have differences in their perception of the possibility of risk, the severity of the consequences, the degree of trust in the risk management organization, and their own assessment of their ability to control the risk, their affective states will also be different (39). Health risk perception is the basis for the rational response of the public to public health emergency events (53). Previous studies have shown that people with different health risk perceptions differ in their negative emotions about infectious diseases (54). A positive correlation between Koreans' perception of the epidemic's severity and their negative emotions was confirmed by a study of the 2015 MERS outbreak (55).

Older people are more vulnerable to the public health crisis caused by COVID-19 because of their physical and social vulnerability (12). They tend to be less confident about their own immunity, to believe that they have a high possibility of infection and serious consequences of infection, to not be confident in epidemic control, and to not be familiar with COVID-19. Therefore, they not only have concerns about infection damaging their health, but also have concerns and fears about maintaining their personal lives and mental health. More importantly and universally, a public health crisis also weakens their social support network (12). Under these effects, older people are more likely to experience excessive worry, anxiety, and other negative emotions.

Therefore, this study makes the following hypothesis:

H3. Health risk perception is associated with the affective response of older people during public health emergency.

Affective response and information sufficiency

Affective response, as a negative affective state, will affect the information sufficiency threshold, that is, the confidence one wants to have in one's information about the risk (22). This point has been verified by subsequent studies by numerous scholars. For example, Hovick et al. found that negative emotions such as anxiety mediate the relationship between health risk perception and information sufficiency, in their study on cancer risk information searching behavior (41). During the outbreak of an infectious disease, the public's negative emotions related to the disease, such as anxiety or fear, tend to be more intense, especially on social networks (56). Moreover, the panic caused by such public health emergencies can easily spread quickly, an effect that is more prominent in the information age of big data (55). For older people, their ability to process social network information is not as good as that of other age groups (57), and a large amount of health information will cause confusion over the information and health concerns (9).

On the other hand, the perception of aging among older people is more sensitive than that of other groups, and with the decline of physical function and the increase of health troubles, the concern about health is inevitably stronger than in other groups (58). During the COVID-19 outbreak, older people knew little about the newly emerged novel coronavirus and they were not confident in their own immunity. As a result, they had stronger negative emotions, such as anxiety and fear of contracting the disease and the serious consequences of infection. Negative emotions made older people more likely to have a lower understanding of health information and a greater demand for health information (i.e., higher thresholds of information sufficiency). In addition, home quarantine measures during the epidemic further limited the access of older people to information.

Therefore, this study makes the following hypothesis:

H4. Affective response is associated with the information sufficiency of older people during public health emergency.

Information sufficiency and health information search behavior

The theory of RISP indicates that information sufficiency mediates the relationship between affective response and information search behavior. The threshold between the existing risk information and the information necessary to effectively respond to the risk gives individuals a strong need for information. It urges individuals to seek and process information more actively and systematically. Eventually, it affects the individual information search and processing methods (21, 22). Subsequent studies by many scholars have confirmed that individuals often meet their subjective information needs through more active information search behaviors. Public health information needs tend to increase significantly during public health emergency events, as confirmed by a survey by Tausczik et al. during the H1N1 epidemic (59). Considering the health inequalities of older adults (12), these adults show more intense health information needs and desire for understanding of health information than other groups. During the COVID-19 outbreak, traditional health information access routes (e.g., newspapers) were interrupted due to Chinese governments' home isolation measures; people had more free time and could rely more on social networks to obtain COVID-19 information. These conditions were more likely to trigger health information search behaviors on social networks.

Therefore, this study makes the following hypothesis:

H5. Information sufficiency is associated with the health information search behavior of older people during public health emergency.

Research methods

In this study, a questionnaire survey was used to empirically test the health risk perception and health information search behavior research model. All items on the questionnaire were pre-validated in the existing literature and modified in combination with the specific context of the COVID-19 outbreak as well as the characteristics of the elderly population. All items included in this study were measured on a five-point Likert scale.

Before the formal survey, the validity and reliability of the questionnaire was measured in the early stages with a pre-survey sent on January 15, 2020: 276 questionnaires were distributed through Wenjuanxing (www.wjx.cn, a platform providing questionnaire distribution functions), 250 valid questionnaires were returned, and then the questionnaire was revised according to the results. This sample was only used for questionnaire corrections.

Construct measurement

The main variables of the model in this study are health risk perception of COVID-19 (including perceived probability, perceived severity, perceived controllability, and perceived familiarity), affective response, information sufficiency, and information searching behavior related to COVID-19. The measurement indexes of the variables are shown in Table 2.

The questionnaire is composed of four parts. The first part gathers basic information, including age, gender, educational background, occupation, self-assessment of health status, and whether there are cases of infection in the region (city), which lays the foundation for subsequent research and analysis.

The second part is the investigation of the health risk perception of older people, which is mainly based on the studies of Slovicp et al. (20), Hayaki et al. (31), Chang (60), Dai et al. (27), Pask and Rawlins (54), Choi et al. (7), and so on. The measurement items required by this study are modified according to the actual situation. Health risk perception is divided into four dimensions in this study: possibility (individuals believe that the risk event could occur to themselves), severity (individuals perceive the severity of loss after the risk event), controllability (individuals take measures to avoid or reduce the degree of loss caused by the risk event), and familiarity (individuals' knowledge of the risk event). Each question was measured using a five-point Likert scale variable. To improve the quality of the questionnaire, PS3 and PC2 questions are set as reverse scoring questions.

The third part of the survey is about affective response and information sufficiency. Referring to the research of Griffin et al. (39), Hovick et al. (41), and Chew and Eysenbach (62), the affective response variables selected were anxiety, fear, and worry as the main affective factors; three questions measure the degree of anxiety, fear and future worry of older people about COVID-19. On a scale of 0–5, the higher the score, the higher the level of anxiety or fear or future concern. Information sufficiency uses Griffin et al. (22), Yang et al. (63), and other studies to set a total of two questions to measure the degree of understanding and demand of older adults for COVID-19 information. According to the 0–5 score, the higher the score, the higher the individual's understanding or demand for information on COVID-19. Question IS2 is set as a reverse scoring question.

The fourth part surveys the health information search behavior of older people. This part refers to the literature related to older people's health information search behavior, the Baidu index, the Weibo hot words list, the "COVID-19 Public Cognition and Information Communication Research Report" of the State Information Center and the Institute of Network Communication of Nanjing University, and the "COVID-19 Search Big Data Report" of Baidu. Health information search behavior was measured by the following four questions: "I often use social networks to seek health information," "During the outbreak, I was able to search on social networks for all the forms of information (text, video, pictures, etc.) I wanted about COVID-19," "During the outbreak, I could search in social networks for all kinds of information I wanted about COVID-19," and "During the outbreak, information related to COVID-19 on social networks could meet my needs."

Participants

The World Health Organization defines people aged 60–74 years as young elderly, people over 75 years as middle-age elderly, and people over 90 years as long-lived elderly (64), but some studies have set people over 50 years of age as old people; for example, from a psychological development viewpoint, psychologist Anders Ericsson believes that after the age of 50, people enter psychological "old age" (65). We also take into account that China's legal retirement age for enterprise employees is 60 years for men, 50 years for women, and 55 years for female civil servants (66). Therefore, we focused on adults aged 55 years and older. In addition, during the epidemic period, China's epidemic control policies, such as "home isolation," "one household with one person going out for shopping every 2 days," and "concentrated isolation" for key groups (such as those returning home from high-risk areas such as Hubei Province and foreign countries), made it inconvenient to conduct offline investigations. Therefore, we used instant messaging platforms such as WeChat and QQ to conduct an online survey. In

TABLE 2 The variables and questions.

Variable		Code	Question	References
Health risk perception (HRP)	Perceived probability (PP)	PP1	I may be infected by COVID-19.	(31, 54, 60)
		PP2	Someone close to me may be infected by COVID-19.	
		PP3	I think COVID-19 could happen at any time.	
	Perceived severity (PS)	PS1	I think COVID-19 is highly contagious.	(30, 60, 61)
		PS2	I think COVID-19 could kill me.	
		PS3	I don't think this COVID-19 outbreak is serious.	
	Perceived controllability (PC)	PC1	I think wearing a mask can effectively prevent infection with COVID-19.	(7, 27, 30)
		PC2	I don't think there are enough treatments for COVID-19 yet.	
		PC3	I think the spread and epidemic of COVID-19 are very difficult to control.	
	Perceived familiarity (PF)	PF1	I'm well aware of the latest developments of COVID-19.	(6, 20, 24)
		PF2	I'm well aware of the precautions against COVID-19.	
		PF3	I'm well aware of the difference between COVID-19 and a cold.	
Affective response (AR)		AR1	Your concern about COVID-19.	(22, 41, 62)
		AR2	Your fear of COVID-19.	
		AR3	Your concern about the future risks of COVID-19.	
Information sufficiency (IS)		IS1	How much do you know about COVID-19?	(22, 63)
		IS2	How much information do you need about COVID-19?	
Health information search behavior (HISB)			Please choose the option that best suits your situation according to the following statements: 1 = Very much does not match; 2 = Does not match; 3 = Average; 4 = Does match; 5 = Very much does match.	(7, 37, 38), Baidu (a search engine like Google); Baidu Index (a data sharing platform based on Baidu's massive data on netizens' behavior; www.index.baidu.com); Weibo hot word list (social media keyword search rankings).
		HISB1	I often use social networks to seek health information.	
		HISB2	During the outbreak, I was able to search on social networks for all the forms of information (text, video, pictures, etc.) I wanted about COVID-19.	
		HISB3	During the outbreak, I could search in social networks for all kinds of information I wanted about COVID-19 (source, signature, route of transmission, symptoms of infection, data on outbreaks, government measures, protective measures, research progress, supplies, people, etc.).	
		HISB4	During the outbreak, information related to COVID-19 on social networks could meet my needs.	

Social networking platforms include but are not limited to Wechat, QQ, Nail, Momo, Tantan, Weibo, blogs, Q & A platforms (Baidu Baike, Zhihu, Chunyu Doctor, Clove Garden, etc.), forum post bars (Tianya Community, Baidu Post Bar, etc.), Douban, news clients (Toutiao, Tencent News, Sina News, etc.), and video platforms (Youku, Iqiyi, Tencent Video, Watermelon Video, Kuaishou, Douyin, etc.).

addition, older people with experience using smartphones and without literacy disorders were selected in this study to ensure that participants could fill out the questionnaire independently or with assistance.

Data collection and procedure

In this study, the questionnaire was powered by www.wjx.cn and forwarded through WeChat and QQ. In addition, considering the physiological conditions, education, and smartphone proficiency of older people under isolation during the epidemic, the surveyor assisted participants in filling in the questionnaire, either through online assistance *via* WeChat or through the children of the respondents, working offline (i.e., the surveyor first informed the children of the respondents of the matters needing attention in filling out the questionnaire).

The formal survey, which started on 21 February 2020 and ended on 15 March 2020, collected 685 online questionnaires. In the process of data collection, 39 surveys were eliminated

TABLE 3 The demographics of the sample.

	Category	Number	%
Sex	Male	321	49.69%
	Female	**325**	**50.31%**
Age	55–59	72	11.16%
	60–69	198	30.65%
	70–79	**223**	**34.52%**
	≥80	153	23.68%
Educational background	Never went to school	89	13.78%
	Elementary school	113	17.49%
	Middle school	141	21.83%
	High school	**154**	**23.84%**
	College	133	20.59%
	Master's degree	16	2.48%
Professional	Civil servants	52	8.05%
	Public institution personnel	98	15.17%
	Employees of enterprises	126	19.50%
	Farmers (migrant workers)	**161**	**24.92%**
	Self-employed or private owners	62	9.60%
	Housewives	90	13.93%
	Soldiers	16	2.48%
	Retired/unemployed	41	6.35%
Health	Good	294	45.51%
	Not bad	**305**	**47.21%**
	Bad	47	7.28%
Infection in region	Yes	**347**	**53.71%**
	No	225	34.83%
	I don't know	74	11.46%

"Infection in region" refers to the judgment of respondents on whether there were cases of infection in their area (city or township). The bold values indicate the maximum value of the item.

because some participant responses were incomplete or true, so 646 complete surveys were obtained, with an efficiency rate of 94.31%.

The participants were over 55 years old, as shown in Table 3. In addition, all participants in this study have experience searching for health information on social networks.

Results

Measurement model

First, we measured how well the model fits. The results are shown in Table 4. As shown in Table 4, the result of SRMR is <0.8, and the values of d_ULS and d_G are both less than the corresponding value of 95% of the bootstrap quantile (HI95). Therefore, confirmatory composite analysis results show that the model has a good fit (67). The maximum variance expansion coefficient (VIF) was 5.440, much lower than the prescriptive diagnosis of 10.0 (67). This result shows that there is no multicollinearity problem in this model.

TABLE 4 Confirmatory composite analysis results.

Discrepancy	Value	HI95	Conclusion
SRMR	0.046	0.098	Supported
d_ULS	0.481	2.234	Supported
d_G	0.411	0.493	Supported

HI95, 95% of bootstrap quantile.

In this study, we used Harman's one-factor test to test the possible common method bias (67). The test results show that the largest factor accounts for 50.451, which is acceptable according to the recommendations of Fuller et al. (68). Therefore, the common method bias problem in this study is very small.

The sample data was analyzed by descriptive statistics, and the results are shown in Table 5. According to the analysis results, the average values of all variables in the model range from 3.506 to 3.987, and the standard deviation ranges from 1.089 to 1.330. In addition, the Cronbach's α of each latent variable is higher than the threshold value of 0.7, which indicates that the data reliability of each latent variable is high.

The validity of the questionnaire can be divided into convergent validity and discriminant validity (69). Convergent validity refers to the similarity of measurement results when different measurement methods are used to measure the same characteristics (70). Factor load, combined reliability (CR), and average variance extracted (AVE) are three effective indexes to test the convergent validity. The factor load of the observed variables exceeds the recommended value of 0.6, which indicates that the observed variables of the model are highly correlated with the structural variables (71). The data shows that the factor load of each observation variable exceeds the recommended value of 0.6. The CR describes the degree to which the observed variable determines the latent structure, and a value >0.7 can be considered as having a good internal consistency of the variable (71). As shown in Table 5, all CR values are >0.7. The AVE reflects the total difference of potential structure, and a value >0.5 indicates that the observed variables in this model explain each measurement dimension well. The AVE value in this study is >0.5 (72).

Discriminant validity is the extent to which a construct is truly distinct from other constructs by empirical standards. There are three main ways to evaluate discriminant validity: cross-loadings, the Fornell-Larcker criterion, and the heterotrait-monotrait (HTMT) ratio; *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)* (2nd edition) was used (73). Discriminant validity can be measured by the square root of each AVE observation variable. The square root of AVE observation variables is greater than the correlation

TABLE 5 Reliability, validity, and factor loading.

Latent variable		Item	Mean	SD	Loading	Alpha	CR	AVE
Health risk perception (HRP)	Perceived probability (PP)	PS1	3.653	1.250	0.910	0.859	0.914	0.780
		PS2	3.684	1.303	0.945			
		PS3	3.690	1.259	0.921			
	Perceived severity (PS)	PC1	3.617	1.168	0.853	0.868	0.919	0.792
		PC2	3.532	1.089	0.939			
		PC3	3.580	1.145	0.876			
	Perceived controllability (PC)	PP1	3.609	1.256	0.878	0.916	0.947	0.856
		PP2	3.551	1.174	0.896			
		PP3	3.659	1.141	0.875			
	Perceived familiarity (PF)	PF1	3.814	1.194	0.873	0.888	0.930	0.817
		PF2	3.688	1.283	0.938			
		PF3	3.569	1.297	0.900			
Affective response (AR)		AR1	3.945	1.310	0.917	0.912	0.945	0.851
		AR2	3.987	1.286	0.940			
		AR3	3.928	1.330	0.911			
Information sufficiency (IS)		IS1	3.648	1.186	0.893	0.783	0.902	0.821
		IS2	3.506	1.109	0.919			
Health information search behavior (HISB)		HISB1	3.608	1.210	0.821	0.897	0.929	0.767
		HISB4	3.625	1.258	0.891			
		HISB5	3.744	1.300	0.946			
		HISB6	3.702	1.238	0.840			

TABLE 6 Fornell-Larcker criterion.

	AR	HISB	IS	PC	PF	PP	PS
AR	0.922						
HISB	0.358	0.876					
IS	0.435	0.432	0.906				
PC	0.398	0.440	0.508	0.890			
PF	0.427	0.448	0.472	0.509	0.904		
PP	0.453	0.415	0.494	0.477	0.529	0.883	
PS	0.398	0.433	0.498	0.492	0.423	0.460	0.925

coefficient between AVE observation variables and other observation variables, which indicates that each observation variable has a higher discrimination degree (74). In this study, the square root of AVE observation variables is greater than the correlation coefficient between AVE observation variables and other observation variables. Table 6 shows the details. In summary, the questionnaire has good reliability and validity.

Structural model and discussion

Total effect analysis

We calculate the model path coefficients using SmartPLS 3.3.2. The results are shown in Figure 3 and Table 7.

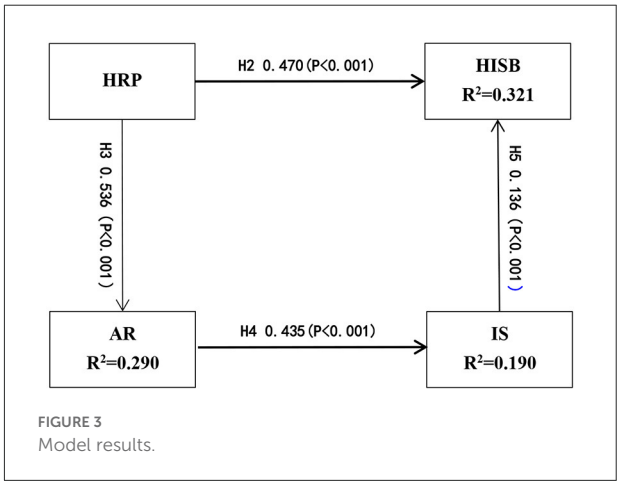

FIGURE 3
Model results.

The results show that H2, H3, H4, and H5 are supported. The model prediction ability of this study is evaluated by the internal model interpretation utility R^2. The greater the value of R^2, the stronger the explanatory ability of the measured variable to the latent variable. In this study, 32.1% of the model is explained by health information search behavior, 29.0% by affective response, and 19.0% by information sufficiency.

In addition, we use blindfolding to test the predictive correlation of the model. Q^2 is used to analyze the validity of

TABLE 7 The results of hypothesis testing.

Hypothetical path	β	T value	*P* value	Conclusion
H2: HRP -> HISB	0.470	11.577	<0.001	Support
H3: HRP -> AR	0.536	17.356	<0.001	Support
H4: AR -> IS	0.435	12.231	<0.001	Support
H5: IS -> HISB	0.136	3.081	0.002	Support

β is used to generate the best component score of the predictive effectiveness of the potential independent variable against the related potential dependent variable or the observed variable (75).

TABLE 8 The mediating effects of affective response and information sufficiency.

Path	β	T value	VAF	Conclusion
HRP -> AR -> IS	0.233	T = 8.085	33.86%	Partial mediation
AR -> IS -> HISB	0.148	T = 6.368	70.47%	Partial mediation

structural models; when the Q^2 value is greater than zero, the model has the ability to predict, and the greater the Q^2 value, the stronger the correlation of the model prediction (74). In this study, all of the Q^2 values (AR = 0.104, IS = 0.141, and HISB = 0.280) are greater than zero. In summary, the model has a good correlation of prediction.

Mediating effect analysis

We used the Bootstrapping function of SmartPLS 3.3.2 to verify the mediating effects of affective response on health risk perception and information sufficiency, and information sufficiency on affective response and health information search behavior (76). The sample size of bootstrapping is set at 5,000. The results of the mediating effect analysis showed that the total effect, direct effect, and indirect effect are significant ($P < 0.001$). The specific results are in Table 8.

According to a standard test of the mediating effect proposed by Hair et al. (77), the ratio of indirect effects to total effects (VAF) can be used to measure the strength of the mediating effect. It is generally considered that the ratio of indirect effects to total effects is >80% for complete mediation, 20–80% for partial mediation, and <20% for no mediation. The results show that the mediating effects of affective response between health risk perception and information sufficiency account for 33.86%, and the mediating effects of information sufficiency between affective response and health information search behavior account for 70.47%, both >20%. Therefore, affective response is partially mediated between health risk perception and information sufficiency, and information sufficiency is partially mediated between affective response and health information search behavior.

TABLE 9 Weights of first-order constructs on information quality second-order construct (examining H1).

Hypothetical path	β	T value	*P* value	Conclusion
PC -> AR	0.121	2.600	0.009	Support
PC -> HISB	0.144	3.127	0.002	Support
PF -> AR	0.177	3.634	<0.001	Support
PF -> HISB	0.184	3.796	<0.001	Support
PP -> AR	0.229	4.666	<0.001	Support
PP -> HISB	0.105	2.315	0.021	Support
PS -> AR	0.158	3.137	0.002	Support
PS -> HISB	0.169	3.539	<0.001	Support
AR -> IS	0.435	12.231	<0.001	Support
IS -> HISB	0.136	3.081	0.002	Support

Second-order analysis

In this study, health risk perception is a second-order factor divided into perceived probability, perceived severity, perceived controllability, and perceived familiarity. For hierarchical latent variable models, two approaches are commonly adopted to estimate the parameters by using PLS-SEM: the repeated indicator and two-stage approaches (78). In this study, the two-stage approach was used because the first-order model had four formative constructs. We estimated a repeated indicator model in the first stage and used the first-order construct scores in a separate second stage (79). The results of the second-order analysis are illustrated in Table 9. HRP is a second-order variable composed of four first-order potential structures: PC, PF, PP, and PS, supporting H1.

Discussion

Key findings

Overall, the data analysis results show that all the hypotheses in this study are valid. The results provide the following key findings:

First, older people's health risk perception for COVID-19 is a second-order construct composed of four first-order (i.e., lower-order) constructs, including perceived probability, perceived severity, perceived controllability, and perceived familiarity. These four first-order constructs can well represent the impact of health risk perception on health information search behavior and affective response.

Second, during the early phase of COVID-19 pandemic, the health risk perception of older people not only directly affected their health information search behavior, but also influenced their health information search behavior indirectly by affecting their affective response and information sufficiency. The higher the individual's health risk perception level, the stronger the affective response, the lower the individual's grasp of their own

health information, and the more health information needed (the higher sufficiency threshold); and thus, the more active the health information search behavior.

Third, affective response plays an intermediary role in health risk perception and information sufficiency, and information sufficiency plays an intermediary role in affective response and health information search behavior.

Specifically, we found that health risk perception had significant positive effects on health information search behavior. The high infectivity and mortality rates of COVID-19, as well as the rapid spread of epidemic information through social networks, greatly affect the risk perception of COVID-19 among older people. The older people, who perceive themselves to be at higher risk of infection and severe consequences, which is coupled with their lack of confidence in epidemiological control and knowledge of COVID-19 information, are more motivated to seek health information.

We also found that affective response and information sufficiency have a mediating effect. The older people have declining physiological functions, low immunity, and many underlying diseases, which makes them more likely to be infected with infectious diseases and makes the consequences of infection more serious. During the COVID-19 outbreak, the new coronavirus pneumonia was a new infectious disease with a high infection rate and high mortality rate, and older people had insufficient awareness. The increase in reported cases of infection and the spread of unproven health information have placed older adults in an information disadvantage, making them more difficult to recognize health risks. Older people often show a more sensitive affective response to public health emergencies. They are more likely to experience negative emotions such as anxiety, fear, and future worry, which are manifested by a lower understanding of health information, stronger demand for health information, and higher information sufficiency threshold. Therefore, when the sufficiency threshold is higher than the health information the older person feels he or she currently has, more active health information search behaviors will be motivated. In addition, due to the influence of the Chinese governments' home isolation measures, traditional access to health information (such as newspapers) was interrupted, but older people had more free time and could rely more on social networks to obtain information on the novel coronavirus, a state that was more likely to trigger their social network health information search behavior.

Implications

COVID-19 is a new, intense, highly contagious, and high mortality infectious disease (80). In this study, we established a research framework for the correlation between health risk perception and health information search behavior in the context of COVID-19, which aims to provide a reference for future research on the correlation between public health risk perception and health information search behavior in the case of major infectious diseases. There are two main contributions: theoretical and practical.

The theoretical contributions of this study have three aspects. First, considering the characteristics of the early outbreak period of COVID-19 and the characteristics of older people's perception of public health emergencies, we set the health risk perception variable as a second-order construct, including four first-order constructs: perceived risk probability, perceived risk severity, perceived risk controllability, and perceived risk familiarity; We formed measurement items with reasonable reliability and validity. This measurement method of health risk perception improves on the measurement methods of health risk in previous studies on chronic diseases, bad living habits, conventional infectious diseases, etc. (31–33), and provides an effective reference for the development of public risk perception measurement tools in public health emergencies.

Second, we introduced health risk perception into the study of health information search behavior, replaced the perceived hazard characteristics in the RISP model with health risk perception, and focused on the internal correlation between older people's individual health risk perception and health information search behavior during the early phase of COVID-19 pandemic. Our results show that although older people are a vulnerable group in the information age (81), they will have active online health information search behaviors in the face of health risks, and their health risk perception not only directly affects their health information search behavior, but also indirectly affects their health information search behavior through affective response and information sufficiency. This meaningful discovery is not only a verification of the adaptability of the RISP model, but also a modification about the specific contextual application of the RISP model in the context of the global pandemic. More importantly, it provides a reference research framework for interactive research on older people's social network health risk perception and health information search behavior in specific epidemic situations from the three levels of cognition, emotion, and behavior, and expands the depth of RISP model research.

Finally, we found the mediating role of affective response and information sufficiency. During the COVID-19 outbreak, older people who are vulnerable to health risks were more likely to experience anxiety, fear, worry, etc.; lower understanding of health information; and greater demand for health information (higher thresholds of information sufficiency). In addition, home quarantine measures during the epidemic further limited the access of older people to information. When the information adequacy threshold is higher than the health information currently possessed by older people, they will be more motivated to search for health information. This mediation path fully reflects the uniqueness of older people's health information

search behavior on social networks during the epidemic. The results are helpful for us to further understand the psychological and informational behavior characteristics of older people in sudden public health events.

In addition to the theoretical significance, this study also has practical significance, as detailed below.

First of all, our research helps older people take the initiative in public health emergencies. Older people can obtain scientific health information on social networks to protect their own health and respond to an outbreak. Older people should be encouraged to improve their ability to search online and screen health information.

Second, health information providers can provide personalized and accurate health information services for older people based on health risk perception. For example, for low-risk awareness users, providers can push information on health risk hazards, epidemic conditions, and other related information to raise users' awareness; for high-risk awareness users, providers can provide relevant health information or facts about effective treatment to relieve users' tension. In addition, information sufficiency has a significant effect on health information search behavior, which suggests that information service providers should focus on improving this information sufficiency and attach importance to the health information needs of older people, as well as realizing the great potential. For example, governments and service providers should build a "suitable for older people" health information network platform. The platform should be designed to reduce the complexity of searching, with features such as enlarged font, automatic voice broadcasting, short video explanations, and voice commands for entering searches.

In addition, it is very important for public health departments to control the quality of the mass of information provided by social media. During public health emergencies, massive amounts of information are spread on social media (9), but the quality of the information is worrisome (82). In particular, older people whose health information recognition and processing ability is weak need more information assistance from the government. For example, authorities could detect false epidemic information and flag it as problematic, conduct quality certifications of health websites, improve the reporting channels of health information on the Internet, and disclose accurate epidemic information while exposing false health information. In addition, the government could encourage authoritative health websites and popular science platforms to create separate sections or versions for older people.

Limitations and further studies

In this study, which was affected by the early phase of the COVID-19 pandemic, an online network questionnaire was used instead of a traditional experimental study of search behavior; and the search behavior described, using a self-rating scale, was not as accurate, objective and sufficient as traditional experimental data would have been. In addition, the Chinese government implemented a strict home quarantine policy from January to April 2020 (42), and an offline survey was not possible in this quarantine period. Therefore, non-random sampling was used in this study, and the survey subjects were limited to older people who used smartphones and had no reading or writing impairments. The study ignored older adults who were less educated, did not use smartphones or were in poor health. Moreover, the effective sample size was only 646 cases; such a small sample size is not conducive to the development of the study results. Therefore, future research will expand the scope of the questionnaire and improve the sample representation.

There may be questionnaire comprehension bias in the elderly group due to their decline in physiological function, weakened comprehension and education level limitations. In future research, experimental research will be considered to determine the characteristics of the health information search behavior of older people. Further research can also explore whether the health risk cognition of older people changes before and after the search, and the influencing factors of the change.

Furthermore, the study did not take into account the influence of different social media platforms (including instant messaging software, dating software, short video platforms, and so on) on older people's information searching behavior, which can be further analyzed and discussed in subsequent studies. In addition, from January to March 2020, the cumulative confirmed cases and cumulative deaths of COVID-19 varied greatly in different regions of China. The Hubei province had the highest number of confirmed cases and cumulative deaths, followed by Zhejiang, Guangdong, Henan, and Hunan (83). However, this study did not fully consider the influence of regional infection rates on the information search behavior of older people. This is also a point that further research should focus on.

In addition, this study lacked a comparative study and analysis between older people and young people and did not consider the effects of aging characteristics on health risk perception and health information search behavior. In future research, we can conduct a differential study on the impact of health risk perception on online health information search behavior among different age groups, and add research variables of aging characteristics into the study, such as vision, hearing, thinking ability, and chronic diseases.

Finally, our study focused on the association between health risk perception and health information search behavior in older adults during the COVID-19 outbreak. Although COVID-19 is a global public health emergency, its specificity limits the results of our study. Due to the diversity of public health emergencies, the impact of a pandemic may be different from the impact of other emergencies. We cannot also compare COVID-19 with another pandemic. In future studies, we can look for more data to study the association between health risk perception and

health information search behavior of older people in a variety of public health emergencies. This will make a huge contribution to the health of all people.

Conclusion

Considering the vulnerability of older people to public health emergencies, especially in the context of COVID-19, we proposed a research framework for health risk perception and health information search behavior based on the RISP model. Using a questionnaire and verifying model, we found that the health risk perception of older people during the COVID-19 outbreak not only directly affected their health information search behavior, but also had an indirect impact on their health information search behavior by affecting affective response and information sufficiency: the stronger the affective response, the lower the grasp of health information and the more health information needed (the higher sufficiency threshold), and thus the more active the health information search behavior. This study also redefined the variable of health risk perception and provided a tool for the measuring health risk perception during the epidemic. It provides valuable advice to older people, government public health departments, and health information service providers—advice that can improve the active role of online social networks during sudden public health events.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Research Ethics Committee of Wenzhou Medical University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

CZ, WL, and YM contributed to conception and design of the study. CZ and WL organized the database and wrote the first draft of the manuscript. WL performed the statistical analysis. YM wrote sections of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Association between social capital and depression among older adults of different genders: Evidence from Hangzhou, China

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In China, it is critical to help older adults cope with depression due to the emerging impacts of factors such as increased life expectancy and the "one-child" family planning policy. Meanwhile, differences in retirement age have different effects on health in older adults of different gender. The relationship of gender differences in social capital and depression across the elderly population was unclear. Focusing on this demographic, this study conducted a telephone survey to explore the relationship between social capital and depression. Referring to electronic medical records, we randomly selected 1,042 elderly respondents (426 men, 616 women) from four areas in Hangzhou. We used social capital measurements and the Geriatric Depression Scale (GDS-15) to assess social capital and depression, respectively, then employed a multivariate logistic regression and structural equation modeling to examine the associations between factors, along with a consideration of gender. This study was discovered that differences in both income and morbidity contributed to differences in social capital and depression. In our sample of elderly respondents, we also found gender-based differences in cognitive and structural social capital. Compared to men, women were more likely to attain higher social capital and less likely to develop depression. At the same time, social networking and social engagement had negative impacts on depression in women, which was not the case for men. We found that lower reciprocity (men and women), social work (men), and trust (women) indicated higher risks of depression. Reciprocity and social networks were significantly and negatively correlated with depression among male respondents; in the male model, factors of trust, reciprocity, and social participation had positive effects on reducing the risk of depression, while social networks had a negative effect. For elderly persons, these findings suggest that mental health is affected by differences in social capital caused by policy differences and cultural differences caused by gender differences.

KEYWORDS

social capital, depression, older adults, gender, trust, reciprocity, social network, social participation

Introduction

The relatively affluent eastern part of China has an aging population. With the strict family planning policy (the one-child policy) and the advancement of urbanization, the proportion and number of older adults in China is set to increase rapidly, and this has resulted in tremendous changes in both health and social capital. Depression has become one of the most common disorders among older adults, and the phenomenon of social isolation has been recognized as a growing medical, social, and public health problem (1). Data from the 2013 survey of the China Health and Retirement Longitudinal Study (CHARLS) showed that 34% of community-dwelling older adults experienced depressive symptoms and the proportion of urban older adults with depressive tendencies was close to 25% (2). Depression is one of the most common health problems for older people worldwide, and depression in Chinese older adults appears to have some geographical variance and an era-defining characteristic. First introduced in 1980, China's "one-child" policy has since effectuated the "4-2-1" family composition (i.e., four grandparents, two parents, one child). By extension, an increasing number of Chinese older adults are living alone (3). This is a public health concern, as evidence shows that older persons with "empty-nests" are more likely to have depressive symptoms when compared to peers without this type of living arrangement (4). With socio-economic development and urbanization, the number of older adults that have moved from rural areas to cities has increased. Additionally, some studies have found that better economic status, more social support, and better health in China are the main reasons why the urban older people have a lower prevalence of depression than the rural older adults (5, 6). Apart from personal variables such as gender, age, occupation, marital status, and education level, factors such as behaviors, lifestyle, and self-care skills influence depression in the urban older people (7–9). Meanwhile, differences in retirement age have different effects on health in older adults of different gender. For example, women tend to have better health status than men as post-retirement age increases (10). The 5-year gap in retirement age is also an influential factor in the cumulative incidence of chronic disease, leading to higher health risks for older adults who retire at more advanced ages (11). In terms of social capital, different retirement ages are further associated with different changes in the social network between genders, though individuals who retire earlier are more likely to perceive community identities (12). By contrast, cognitive decline after retirement directly weakens social capital for elderly persons (13).

In recent years, the social capital of older people has become a global public health priority. Social capital means that "the efficiency of society can be improved by activating collaborative activities, such as trust, norms, and networks (14)." It has become clear that the weakening of social capital leads to an increased risk of depression in the older adults (15, 16). In China, scholars have recently begun to focus on gender differences in social capital and depression across the elderly population. Some important findings have been made in this direction. For example, one study found that retired female elderly persons in China increased their social capital by actively integrating into social organizations (17). In similar regard, both the neighborhood environment and cognitive social capital are particularly significant factors among the female elderly, but community social capital appears weaker in the urban male elderly when compared to female counterparts (18). Moreover, variations in social capital due to gender differences in the elderly are reflected in family relationships. Here, women are more likely to gain social capital from family members and relatives, while men are more likely to obtain social capital from friendships established in professional organizations (19). Given these factors, gender differences in depression are increasingly prominent among elderly persons in China. One study found that women who participated in social activities (especially religious activities) were more willing to reduce their risk of depression through social organizations (20). Due to changes in both the family structure and social capital, depression has also risen among elderly persons who desire more companionship from children, wherein female elderly persons who do not have the opportunity to engage in child care are at a higher risk of depression (21). In males, cognitive decline is a major cause of reduced social capital, and also contributes to an increased risk of depression (22).

Structural and cognitive social capitals are positively correlated with depression among the older adults in China (23). Past research indicates that cognitive social capital, which includes trust and reciprocity, is a major factor of depression (24). The social network hierarchy included in structural social capital was significantly associated with depression, whereas social participation was not associated with depression (25). A study based on the classification regression tree model found that social capital and depression had a combined relationship and implied that different dimensions of social capital would have combined effects on depression in older adults (26–28). Similarly, different environmental factors (e.g., upbringing or work culture) can affect social capital and increase symptoms of depression and anxiety (29). With such negative consequences, it is critical to address the impacts of social capital on mental health in the urban elderly. This is especially the case for the government, which should adopt policies that expand social capital for all elderly persons, as such provisions are known to both improve overall mental health and reduce the prevalence of mental health disorders (30). Evidence shows that mental health factors partially mediate the relationship between social capital and depression, and can also affect self-perception in the elderly (31). In areas with severe aging, suicide rates have been found to increase as a direct result of depression caused by insufficient social capital (32). Given these concerns, many countries and regions with large aging populations implement

health intervention policies that aim to reduce mental illness. At the same time, social capital generates health differences under the influence of various factors. For the elderly, enhanced social capital promotes change in the external social environment and improves internal mental health, thereby enhancing social status, addressing gender differences, and targeting other factors that lead to variations in health status (33). Social capital can also be subdivided into the individual and community types; men tend to have advantages in both, which creates differences in self-rated health (34). It is also important to monitor the health impacts of online social capital in elderly populations, as the Internet has become a primary communication medium. While this form of capital improves health for some elderly persons, it may exacerbate existing inequities for those who do not interact online (35). In other words, social capital imposes additional health effects due to the introduction of new factors in the information age.

The literature discusses many socioeconomic and social capital-related factors that affect depression in older adults, including explanations of the various interrelationships between those factors. A range of such influences pertain to gender. For example, gender-based social inequities in traditional society have enabled men to gain more social capital than women (36). However, elderly women are more willing to participate in community activities after retirement, which leads to better mental health vs. their male counterparts (37). The income gap between men and women also narrows after retirement; in China, women are most often the primary family financial managers at this time, and are also more willing to perform this duty, which further leads to differences in mental health between genders (38). Still, there is no gender-based explanation for the influence of social capital on depression, nor is there a suitable analysis of the logical relationship between these factors. Focusing on China, the 5-year gap in retirement age between men and women has created large differences in social capital during post-aging, especially when compared to the conditions in other countries. Based on this, we hypothesized that both cognitive social capital and structural social capital have different effects on depressive status in older adults depending on their sex. Figure 1 illustrates our hypothetical model.

Methods

Procedure and participants

A cross-sectional survey was conducted among older adults (Male aged ≥60 years, Female aged ≥55 years) in Hangzhou, Zhejiang Province, People's Republic of China. According to the 2015 Hangzhou Population Yearbook, 493,000 and 561,000 male and female retired elderly persons reside in Hangzhou, respectively. To achieve a confidence level of 99.5% margin of error and 50% response distribution, our survey required minimum sample sizes of 383 males and 383 females. Based on research experience, telephone surveys may incur 50% rates of loss to follow-up. In this study, we required at least 1,020 respondents, as we aimed for average sample sizes in four regions, including 300 in each region for a total of 1,200 respondents. Based on the male-to-female ratio across the elderly population in Hangzhou, we recruited 552 males and 648 females.

All surveys were conducted by family doctors and recorded by volunteer college students. Telephone survey training was conducted prior to survey initiation. The survey inclusion criteria were: (1) sign a contract with their family doctor; (2) men must be retired and over 60 years of age, while women must be retired and over 55 years of age; (3) can answer questions clearly. The survey exclusion criteria were: (1) refused to participate in the telephone survey; (2) unable to answer questions accurately. With the cooperation of primary medical service institutions (Tianshuiwulin Health Center, Changqing Chaoming Health Center, Zhalongkou Health Center, Kaixuan Health Center), we disseminated the questionnaire information to respondents *via* telephone. Thus, we received 1,042 responses (recovery rate of 86.8%), including 284 from Tianshui Wulin Health Center, 271 from Changqing Chaoming Health Center, 252 from Zhanongkou Health Center, and 235 from Kaixuan Health Center. The survey period was from October to December 2016.

Demographic characteristics, health-related factors, and health status

Questions on gender, age, marital status, educational background, annual family income, illness, exercise regimens, smoking habits, drinking habits, family structure, and years of residence were included in the questionnaire (Table 1).

Measures

Measures of depression

The Geriatric Depression Evaluation Scale (GDS-15) (Chinese version) was used in this study. It is one of the most used scales for depression screening in China (39). The GDS-15 is a simple test consisting of 15 questions. The subject answers "yes" (1 point) or "no" (0 points) to a situation related to depression. A total depression score is calculated as the sum of all scores for each item answered with "yes." According to the GDS scoring standard, scores of 0–4 points indicate no depression, while scores of 5–9 points indicate mild depression, and scores of 10–15 points indicate severe depression.

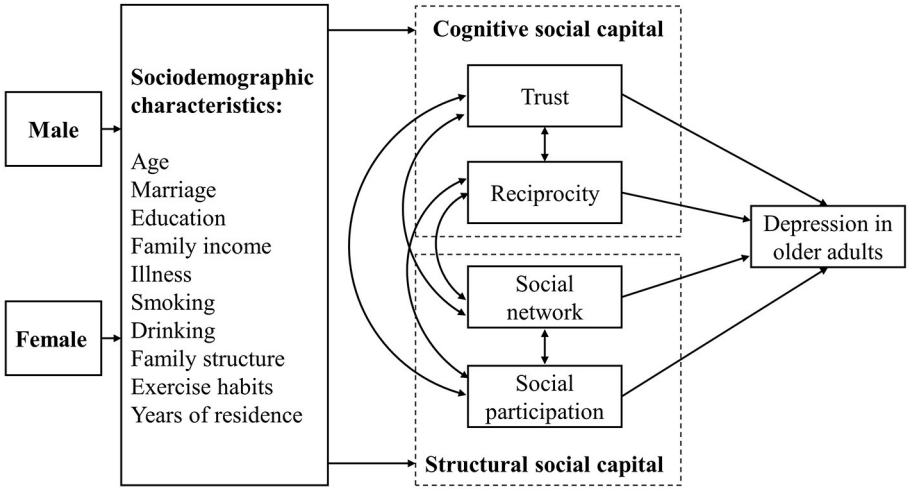

FIGURE 1
Hypothetical model.

Measures of social capital

Social capital was measured by simplifying a scale, which consisted of nine items of cognitive social capital and five items of structural social capital (Table 2) (40). Responses were provided on a five-point Likert scale, with "strongly agree," "agree," "neutral," "disagree," and "strongly disagree" corresponding to 5, 4, 3, 2, and 1 point respectively. Here, higher social capital scores indicate more social capital. This scale has been confirmed to be reliable and effective in surveys (Cronbach's α coefficient = 0.814) (41).

The social network adopted the "Access to Social Capital" method (42). This method indirectly obtained the total number of social networks by asking the professional status of family members, friends, and acquaintances of the respondents based on their occupations. In traditional Chinese culture, different levels of professional prestige exist within the social network. Individuals who work in government, education, and healthcare have higher social recognition and professional prestige than those who work in business, services, and agriculture. Older persons believe that friends with high levels of social approval will bring more social resources to help them cope with difficulties during retirement. As such, friends with high social recognition can obtain higher social network scores. The main indicators include network diversity (total number of network member occupations), network top (highest reputation among network members), and network differences (the highest reputation score of the network members minus the lowest reputation score). Supplementary Table 1 shows the professional status scores of occupations in this study. The Professional Status List of Chinese Occupations shows 20 types of occupation. Network diversity refers to the total number of occupations a respondent reported (ranging from 0 to 20); the top range of the network was 0–95 points, and the network difference was 0–94 points. Factor analysis of the three variables led to a social network, and the scores of the three variables were standardized and added together to calculate the social network score. The Social Network Score Calculation Formula is as follows:

$$= \sum_{i=n}^{i} \frac{(\alpha - \alpha_{\min})(\alpha_{\max} - \alpha_{\min})}{n} + \frac{(\beta - \beta_{\min})(\beta_{\max} - \beta_{\min})}{n} + \frac{(\gamma - \gamma_{\min})(\gamma_{\max} - \gamma_{\min})}{n}.$$

where α = network diversity, β = top range of the network, and γ = network difference.

The number of participants in social organizations and participation frequency were calculated for social participation. Social organizations included political groups and associations; industry groups; volunteer circles; civic movements/consumer movements; groups related to religions, hobby, and sports, senior citizens' clubs; and production/employment. Respondents answered "yes (=1)" or "no (=0)" to whether they participated in an organization. The number of participations in activities for the older adults in each year is taken as the frequency of participation. This method is widely used in Asian population studies (43).

Social capital scores were categorized by quartiles: low, slightly low, slightly high, and high (44). These quartile scores are helpful for analyzing overall social capital levels and clarifying any differences in levels between genders (45, 46). The trust was divided into low (0–18 points, 28.6 per cent), slightly low (19–21 points, 25.1 per cent), slightly high (22–24 points, 31.9 per cent), and high (25 points, 14.4 per cent).

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TABLE 1 Demographic characteristics of participants.

	Category	Male (*n*)	%	Female (*n*)	%
Age	Under 75	332	31.9	460	44.1
	75 or older	94	9.1	156	14.9
Marriage	Unmarried	4	0.4	6	0.6
	Married	370	35.5	504	48.4
	Divorced / widowed	52	4.9	106	10.2
Education	Primary school	108	10.4	218	20.9
	Middle school	218	20.9	332	31.9
	University	100	9.6	66	6.3
Family income	< 90,000 yuan	112	10.7	206	19.8
	More than 90,000 yuan	314	30.1	410	39.3
Illness	With illness	138	13.2	162	15.5
	Without illness	288	27.6	454	43.6
Smoking	Smoking	136	13.1	34	3.3
	Not smoking	214	20.5	572	54.9
	Quit smoking	76	7.3	10	0.9
Drinking	Drinking	165	15.8	100	9.6
	Not drinking	175	16.8	454	43.6
	Quit drinking	86	8.3	62	5.9
Family structure	Have cohabitants	398	38.2	570	54.7
	live alone	28	2.7	46	4.4
Exercise regimen	Have	376	36.1	540	51.8
	Have not	50	4.8	76	7.3
Years of residence	< 10 years	82	7.9	115	11.0
	10–30 years	256	24.6	382	36.7
	More than 30 years	88	8.4	119	11.4

1. Family income: Based on the average annual family income in Hangzhou (88,421 yuan in 2016), the options were trimmed to "below 90,000 yuan" and "above 90,000 yuan." 2. Illness: For persistent diseases, multiple answers were selected for hypertension, hyperlipidemia, diabetes, cancer, joint pain/backache/nerve pain, kidney disease, liver disease, obesity, gastrointestinal disease, eye disease, and other diseases under treatment. If participants were using any treatment they fell into the "with illness" category, and if not, they were in the "without illness" category.

Reciprocity was divided into low (0–12 points, 27.1 per cent), slightly low (13–16 points, 34.1 per cent), slightly high (17–19 points, 15.2 per cent), and high (20 points, 23.8 per cent). Social networks data were subjected to the normalization test (Shapiro-Wilk), and divided into low (0–0.31 points, 33 per cent), slightly low (0.32–0.64 points, 22.9 per cent), slightly high (0.65–0.93 points, 20.8 per cent), and high (0.94–3 points, 23.4 per cent). Social participation was divided into low (0–1 points, 33.2 per cent), slightly low (2–3 point, 48.6 per cent), slightly high (4–5 points, 15.2 per cent), and high (above 5 points, 5 per cent).

Statistical analysis

We used *t*-tests and the one-way analysis of variance (ANOVA) to differentiate social capital scores for different social characteristics. We used the χ^2 test to investigate associations between groups in terms of age, marital status, education, illness, smoking, drinking, family structure, exercise regimen, and years of residence. Moreover, we analyzed factors that influenced the impact of social capital on depression using the ordinary least squares (OLS) regression as a robustness analysis. Multivariate logistic regression models calculating odds ratios (ORs) and corresponding confidence intervals (CIs) were applied. Model 1 was not adjusted, while Model 2 was adjusted for age and educational background, and Model 3 included age, educational background, family annual income, exercise regimens, and years of residence. We tested for multicollinearity using the stepwise regression. After completing the collinearity diagnosis, the eigenvalue of the Model 1 regression model was 0.32, with a condition index of 2.29; the eigenvalue of the Model 2 regression model was 0.40, with a condition index of 2.53; the eigenvalue of the Model 3 regression model was 0.52, with a condition index of 3.87. We found no multicollinearity between variables. Finally, we performed structural equation modeling to analyze the effect of social capital on depression and distinguish differences in the path

TABLE 2 Social capital scale.

	Elements	Concept	Content
Cognitive social capital	Trust	Strangers trust	Most people can be trusted
		Social atmosphere trust	The fallen item returns to its original owner
		Public staff trust	Public organization staff can be trusted
		Family doctor trust	Family doctors are reliable
		Neighbor trust	Neighbors can be trusted
	Reciprocity	Cared by neighbors	Neighbors are worried about others in addition to caring for themselves
		Mutual help atmosphere	Most residents help each other
		Caring about neighbors	Help him/her if the neighbor is in trouble
		Support for public welfare	You support what is beneficial to others
Structural social capital	Social network	Network diversity	Total number of network
		Network top	member occupations Highest reputation
		Network differences	among network members The highest reputation score of the network members minus the lowest reputation score
	Social participation	Number of organizations	The number of participants in social organizations
		Frequency of participation	Frequency of participation in events per year

coefficients of social capital and depression between genders. IBM SPSS Statistics 20.0 and Amos 20.0 (IBM) were used as the analysis software.

Results

Descriptive results

The average GDS score for the older adults was 2.65 ± 3.79 points. Based on the GDS scoring criteria, 0–4 was "without depressive symptoms," 5–9 was "with depressive symptoms," and 10–15 was "depression." "With depressive symptoms" and "depression" were included in a depressive tendency group. The rate of depressive tendency was 20.7 per cent (Figure 2). Based on this GDS score, "without depressive symptoms" and "depressive tendency" were analyzed separately (47).

The "depressive tendency" group consisted of 37.4 per cent men and 62.6 per cent women. Based on the results of the χ^2 test, a statistically significant association was found between the groups in terms of education, annual family income, illness, and years of residence. Compared to the "without depressive symptoms" group, those in the "depressive tendency" group had a relatively high proportion of participants who attended middle school and a relatively high proportion of family members with an annual income of < 90,000 yuan, a relatively high incidence of illness, and who had lived locally for more than 10 years (Table 3).

Social capital scores were affected by individual socioeconomic status, with differences in age, marital status, family income, and disease status (Table 4). The average score was 20.53 ± 3.63. The trust scores of people under the age of 75 were higher than those older than 75 years, the scores of married people were considerably higher than those of unmarried people, and the scores of those who were divorced or widowed were higher than those of unmarried people. The chronic illness scores of those with illness were lower than those without illness, and those participating in exercise regimens scored higher than those who did not. Reciprocity scores for people under 75 were lower than those of people aged 75 or older; scores for elementary school graduates were lower than those for university graduates or above; and people with an annual family income of <90,000 yuan scored lower than people receiving over 90,000 yuan.

Social network scores for people under the age of 75 were lower than those for people aged 75 or over, and those for people not participating in exercise regimens were lower than for those who participated in exercise regimens. Regarding the subjective economic situation, older adults who could afford living expense scored higher than those who could not. The average social participation score was 1.09 ± 1.15, and 137 people did not participate in regional organizations. The social participation scores of highly educated people were higher than those of

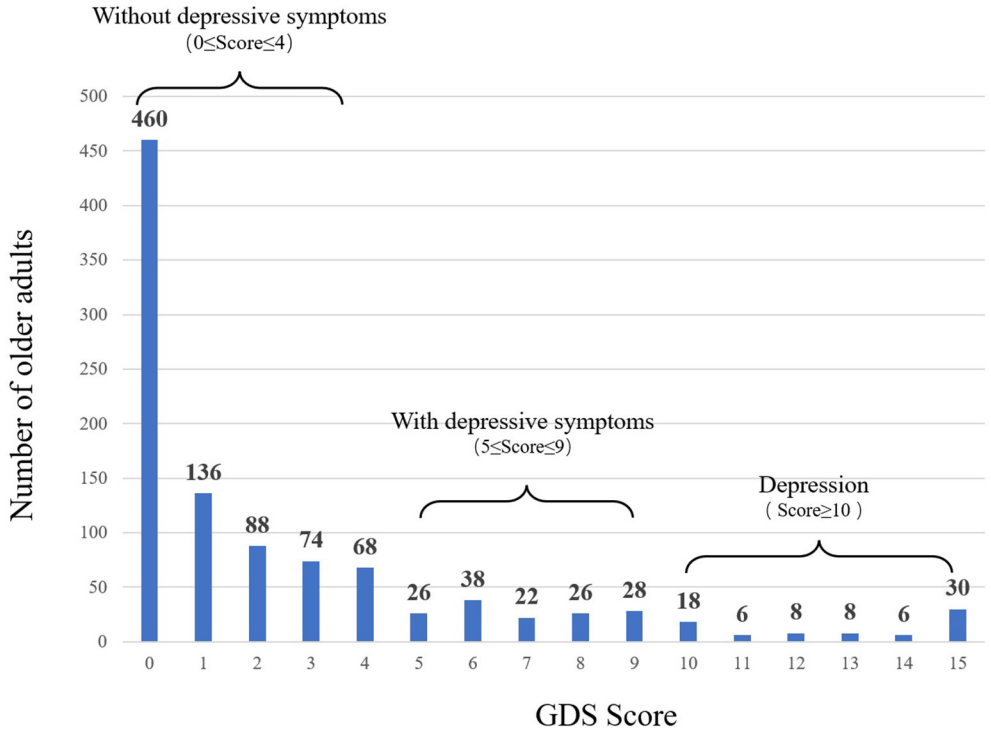

FIGURE 2
Depressive situation of older adults.

the less educated. People not participating in exercise regimens scored lower than those who participated.

The associations between socioeconomic factors, social capital, and depression for different gender groups

To further explore the impact of social capital on depression, we analyzed the impact by gender (Table 5). In China, there is a 5-year gap in retirement age between men and women (i.e., 60 for men and 55 for women). In the rural context, this gender-based difference leads to different changes in social capital for elderly persons, which then leads to changes in mental health (48). Model 1 was unadjusted; Model 2 controlled for age and educational background; and Model 3 controlled for age, educational background, family annual income, illness, family composition, exercise habits, and years of residence.

Model 1 shows that reciprocity and social networks were negatively correlated with depression in the male group. Compared with the high reciprocity and social network groups, low reciprocity and social network groups were associated with high levels of depression. Trust, reciprocity, and social participation were negatively correlated with depression in females. Compared with the high trust and social participation groups, the low trust and social participation groups were associated with high levels of depression.

Model 2 shows that reciprocity and social network remained significantly negatively correlated with depression, but the correlation degree was reduced in the male group. Trust, reciprocity, and social participation were significantly negatively correlated with depression, and the degree of correlation increased in the female group.

Model 3 shows that reciprocity and social network were significantly negatively correlated with depression in the male group. Trust, reciprocity, social network, and social participation were significantly negatively correlated with depression, and the degree of correlation increased in the female group.

The relationships between social capital (i.e., trust, reciprocity, social network and social participation) and depression for different gender groups

For the male model (Figure 3), the goodness-of-fit indices indicated a good fit in the analysis of the path model. The χ^2/df value (322.643/83 = 3.88) was close to 3 and satisfied

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TABLE 3 Comparison of depressive situations.

	Category	Without depressive symptoms *n* (%)	Depressive tendency *n* (%)	χ^2	*p*
Gender	Male	334 (32.1)	92 (8.8)	0.33	0.566
	Female	492 (47.2)	124 (11.9)		
Age	Under 75	626 (60.1)	166 (15.9)	0.11	0.744
	75 or older	200 (19.2)	50 (4.8)		
Marriage	Unmarried	6 (0.6)	4 (0.4)	2.39	0.303
	Married	696 (66.8)	178 (17.1)		
	Divorced / widowed	124 (11.9)	34 (3.3)		
Education	Primary school	276 (26.5)	50 (4.8)	12.60	0.002
	Middle school	488 (46.8)	156 (15.0)		
	University	62 (6.1)	10 (0.9)		
Family income	< 90,000 yuan	192(18.2)	126(12.1)	99.3	<0.001
	More than 90,000 yuan	634 (60.8)	90 (8.6)		
Illness	With illness	556 (53.3)	176 (16.9)	14.75	<0.001
	Without illness	260 (24.9)	40 (3.8)		
Smoking	Smoking	128 (12.3)	42 (4.0)	2.061	0.357
	Not smoking	628 (60.3)	158 (15.2)		
	Quit smoking	70 (6.7)	16 (1.5)		
Drinking	Drinking	224 (21.5)	42 (4.0)	5.376	0.068
	Not drinking	486 (46.6)	142 (13.6)		
	Quit drinking	116 (11.1)	32 (3.1)		
Family structure	Have cohabitants	770 (73.9)	198 (19.0)	0.626	0.429
	live alone	56 (5.4)	18 (1.7)		
Exercise regimen	Have	724 (69.5)	192 (18.4)	0.274	0.619
	Have not	102 (9.8)	24 (2.3)		
Years of residence	< 10 years	171 (16.4)	26 (2.5)	8.638	0.013
	10–30 years	492 (47.2)	146 (14.0)		
	More than 30 years	163 (15.6)	44 (4.2)		

the model fit. The GFI (0.92) and CFI (0.91) values for the model were higher than 0.90, and the RMSEA value (0.073) was lower than 0.08. Trust, reciprocity, and social participation had a positive effect on reducing depression risk, but social networks seem to have a negative effect on depression. The effect of trust on depression was 0.89; the direct influence of reciprocity on depression was 0.91; the impact of social network on depression was −0.02, and the effect of social participation on depression was 0.24.

For the female model (Figure 4), the goodness-of-fit indices indicated a good fit in the analysis of the path model. The χ^2/df value (394.380/81 = 4.87) ranged from 3 to 5, which satisfied the model fit, The GFI (0.89) and CFI (0.88) values for the model were higher than 0.85, and the RMSEA value (0.087) was close to 0.08. Trust and reciprocity had a positive effect on reducing depression risk. However, unlike those for males, social network and social participation had a negative effect on depression. The effect of trust on depression was 0.28; the effect of reciprocity on depression was 0.67; the effect of social network on depression was −0.09; and the effect of social participation on depression was −0.6.

Discussion

The highlight of this study was the discovery that differences in both income and morbidity contributed to differences in social capital and depression. In our sample of elderly respondents, we also found gender-based differences in cognitive and structural social capital. Compared to men, women were more likely to attain higher social capital and less likely to develop depression. At the same time, social networking and social engagement had negative impacts on depression in women, which was not the case for men.

TABLE 4 Relationship between basic attributes and social capital.

Category		Trust			Reciprocity			Social network			Social participation		
		Score	t	*p*	Score	t	*p*	Score	t	*p*	Score	t	*p*
Gender	Male	20.89 ± 3.51	1.87	0.062	15.50 ± 3.61	−0.01	0.990	0.75 ± 0.59	−1.12	0.262	1.12 ± 0.99	0.64	0.522
	Female	20.28 ± 3.71			15.51 ± 3.50			0.81 ± 0.62			1.06 ± 1.09		
Age	Under 75	20.84 ± 3.54	3.51	<0.01	15.28 ± 3.58	−2.64	<0.01	0.95 ± 0.71	3.56	<0.01	1.13 ± 1.04	1.53	0.126
	75 or older	19.54 ± 3.77			16.23 ± 3.31			0.73 ± 0.57			0.96 ± 1.08		
Family income	Less than / 90,000	20.13 ± 3.66	−1.68	0.093	14.87 ± 3.53	−2.71	<0.01	0.86 ± 0.61	1.89	0.059	1.15 ± 1.06	0.92	0.356
	More than / 90,000	20.71 ± 3.61			15.78 ± 3.51			0.75 ± 0.61			1.06 ± 1.05		
Illness	With illness	19.85 ± 3.66	−7.02	<0.01	15.49 ± 3.51	−0.17	0.864	0.81 ± 0.67	1.26	0.206	1.09 ± 1.03	0.08	0.93
	Without illness	22.21 ± 2.96			15.55 ± 3.63			0.73 ± 0.42			1.08 ± 1.12		
Family structure	Have cohabitants	20.57 ± 3.66	0.87	0.384	14.45 ± 3.54	−1.31	0.189	0.78 ± 0.61	−0.83	0.407	1.11 ± 1.07	1.81	0.071
	Live alone	20.03 ± 3.25			16.24 ± 3.49			0.86 ± 0.59			0.78 ± 0.75		
Exercise regimen	Have	20.71 ± 3.63	3.06	<0.01	15.55 ± 3.50	0.71	0.476	1.01 ± 0.80	3.14	<0.01	1.16 ± 1.07	4.32	<0.01
	Have not	19.22 ± 3.42			15.21 ± 3.81			0.75 ± 0.57			0.56 ± 0.75		

Category		Trust				Reciprocity				Social network				Social participation			
		Score	SS	MS	F	Score	SS	MS	F	Score	SS	MS	F	Score	SS	MS	F
Married			148.5	74.2	5.72 **		28.94	14.47	1.15 ns		0.01	0.01	0.02 ns		1.08	0.54	0.48 ns
	Unmarried	15.60 ± 2.30				13.60 ± 2.88				0.83 ± 0.47				1.20 ± 0.44			
	Married	20.67 ± 3.62				15.46 ± 3.55				0.78 ± 0.63				1.07 ± 1.05			
	Divorced / widowed	20.05 ± 3.57				15.86 ± 3.52				0.77 ± 0.54				1.19 ± 1.12			
Education			22.3	11.1	0.84 ns		100.47	50.23	4.05 *		0.13	0.06	0.17 ns		26.02	13.01	12.15**
	Primary school	20.68 ± 3.56				15.01 ± 3.54				0.79 ± 0.60				0.78 ± 0.84			
	Middle school	20.39 ± 3.66				15.62 ± 3.51				0.78 ± 0.62				1.19 ± 1.09			
	University	21.11 ± 3.71				16.75 ± 3.57				0.73 ± 0.59				1.53 ± 1.23			

*p < 0.05, **p < 0.01, /, Currency RMB yuan; ns, no significance; SS, Sum of squared deviations; MS, Mean square.

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TABLE 5 Impact of social capital on depression.

		Depression					
		Male			Female		
		Model 1 OR (95%CI)	Model 2 OR(95%CI)	Model 3 OR(95%CI)	Model 1 OR(95%CI)	Model 2 OR(95%CI)	Model 3 OR(95%CI)
Trust	High	1.00	1.00	1.00	1.00	1.00	1.00
	Relatively high	1.35 (0.57–3.17)	1.38 (0.57–3.30)	1.02 (0.40–2.60)	1.53 (0.60–3.94)	1.69 (0.64–4.44)	1.26 (0.44–3.59)
	Relatively low	1.25 (0.54–2.90)	1.37 (0.58–3.22)	0.96 (0.38–2.43)	1.21 (0.45–3.25)	1.23 (0.45–3.37)	1.05 (0.37–2.98)
	Low	0.86 (0.38–1.92)	0.88 (0.38–2.01)	0.70 (0.29–1.67)	2.83 (1.13–7.07)*	3.07 (1.19–7.87)*	3.08 (1.14–8.29)*
Reciprocity	High	1.00	1.00	1.00	1.00	1.00	1.00
	Relatively high	1.35 (0.52–3.50)	1.35 (0.52–3.52)	1.29 (0.47–3.50)	3.37 (1.46–7.78)*	3.66 (1.55–8.61)*	3.70 (1.54–8.88)*
	Relatively low	1.78 (0.79–4.00)	1.83 (0.79–4.23)	2.58 (1.03–6.44)*	4.81 (2.16–10.67)*	5.06 (2.25–11.38)*	4.93 (2.15–11.29)*
	Low	2.71(1.25–5.87)*	2.57(1.16–5.70)*	2.97(1.30–6.81)*	2.26 (0.85–6.00)	2.75 (1.02–7.49)*	2.90 (1.03–8.12)*
Social network	High	1.00	1.00	1.00	1.00	1.00	1.00
	Relatively high	2.15 (0.82–5.62)	2.04 (0.76–5.44)	1.65 (0.59–4.59)	1.85 (0.93–3.69)	1.54 (0.76–3.14)	1.98 (0.92–4.21)
	Relatively low	2.31 (0.97–5.52)	2.06 (0.83–5.10)	1.61 (0.62–4.19)	2.18 (1.01–4.74)*	1.99 (0.90–4.41)	2.78 (1.18–6.56)*
	Low	2.85 (1.21–6.68)*	2.51 (1.05–6.09)*	2.84 (1.12–7.18)*	1.80 (0.85–3.80)	1.58 (0.73–3.41)	2.17 (0.94–4.99)
Social participation	High	1.00	1.00	1.00	1.00	1.00	1.00
	Relatively high	1.26 (0.45–3.53)	1.18 (0.40–3.50)	0.89 (0.27–2.92)	1.91 (0.85–4.30)	2.49 (1.05–5.89)*	3.24 (1.29–8.13)*
	Relatively low	1.26 (0.43–3.66)	1.15 (0.40–3.35)	0.74 (0.22–2.45)	1.94 (0.87–4.31)	2.68 (1.14–6.30)*	3.60 (1.43–9.04)*
	Low	1.80 (0.65–4.95)	1.82 (0.68–5.11)	1.31 (0.42–4.10)	1.73 (0.68–4.41)	1.91 (0.73–5.02)	2.28 (0.84–6.19)

OR, odds ratio; 95% CI, 95% confidence interval; *$p < 0.05$. Model 1: no adjustment; Model 2: age, educational background; Model 3: age, educational background, annual family income, illness, family structure, exercise habits, years of residence.

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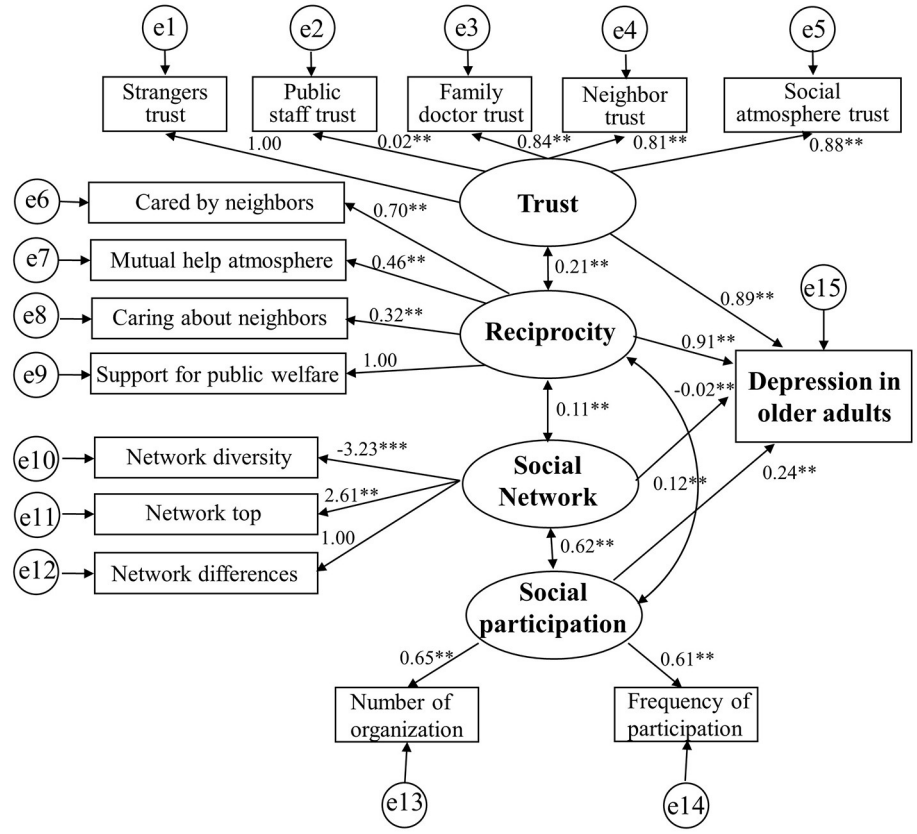

FIGURE 3
The relationship between social capital and depression in male model.

Previous studies have shown that social capital is closely related to health and well-being (49–51). In this context, older adults with lower social capital appear more likely to develop depression (52). With the rapid aging of the Chinese population, it is important to explore the risks of these types of illness, which are more likely to affect older adults. In this study, the sample produced a depression score of 6.24 ± 1.73, with 66.6% of respondents showing some form of depression based on GDS scores of 5 or higher. While urban populations are generally at a higher risk of depression, research has shown that younger high-income groups are at a lower risk than older high- and low-income groups (53). In this study, respondents with annual family incomes ≥ 90,000 yuan had a lower risk of depression than those with incomes < 90,000 yuan. Given the increased Gini coefficient for income among elderly persons in China, there are also differences in their depression levels (54). Compared with income differences, social capital still appears to have greater impacts on depression in this demographic (55). Moreover, elderly persons in China are directly at a higher risk of depression due to the one-child policy, phenomenon of empty nesters, and weakening social network (56, 57). Although the elderly population in Hangzhou shows relatively high income levels, their risk of depression is still increasing due to rising prices and diminished income after retirement (58).

After adjusting our model for relevant variables, we found that social capital had different effects on depression between genders. This may be because social capital and depression are influenced by policies that pertain to gender. For example, men and women have different retirement ages, and thus enter the community at different times; therefore, the social network weakens more for men, which increases their risk of depression (59). On the other hand, elderly female empty-nesters significantly outnumber their male counterparts, and elderly women generally have lower incomes than elderly men, both of which decrease social participation and increase the risk of depression for women (60).

We also found significant differences in "trust" depending on age, marital status, chronic conditions, and exercise habits. This supports previous research showing that both "increased age" and the "prevalence of chronic diseases" are associated with decreased trust in older adults (61). In this context, sick elderly persons often prefer to stay at home in favor of going out for activities, as is particularly common in traditional Chinese culture (62). Research has also shown that married older adults

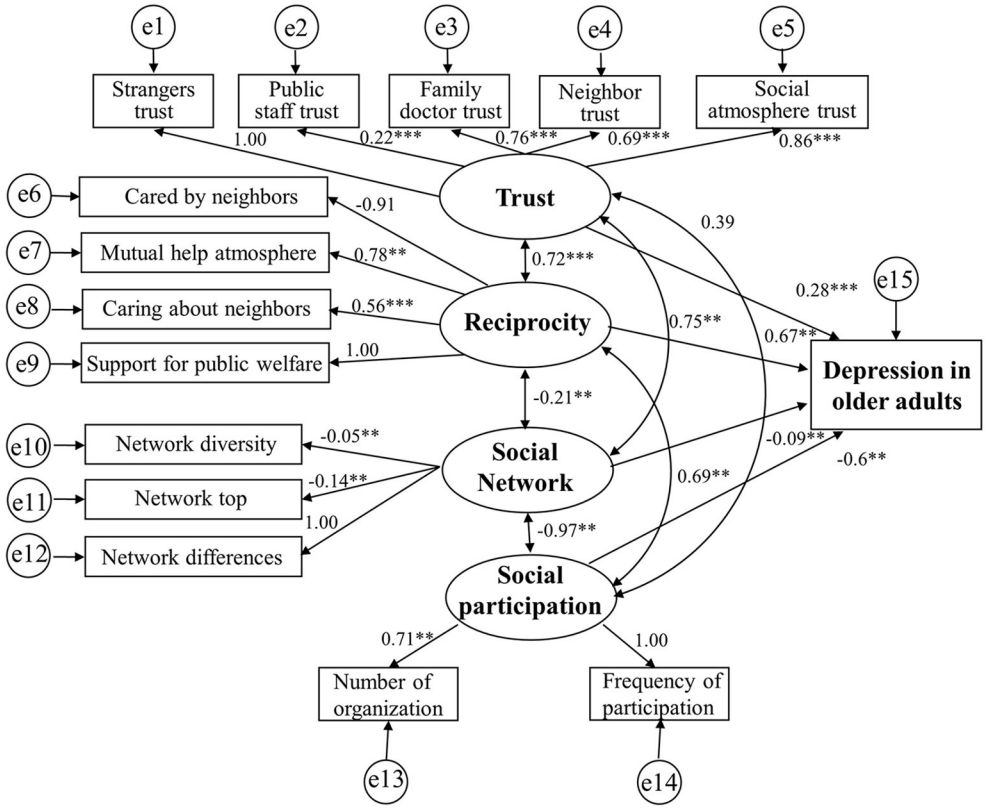

FIGURE 4
The relationship between social capital and depression in female model.

generate higher "trust" indexes than single persons; in turn, older adults are more likely to engage in athletic activities when they have higher "trust" in public regional organizations (63). It is important to encourage this willingness, as elderly persons now have a greater range of choices due to both the increasing number of social organizations that provide relevant services and greater potential for interactions within various community organizations, all of which facilitate the attainment of higher social capital (64). We also found that women with low "trust" had a higher risk of depression in all adjusted models, which suggests that decreased "trust" is a risk factor for depression.

Next, we found a significant difference in "reciprocity" depending on age and annual family income. In relation to depression, our results showed that the risk increased in males as "reciprocity" decreased. In addition, the risk of depression in females was significantly lower only in the group with high "reciprocity" (adjusted Models 2 and 3). Given these findings, it is necessary to separately consider that the low "reciprocity" female group has a lower risk of depression than the slightly higher "reciprocity" male group. While increased social activity has expanded social networks for women, a recent rise in fraud has led to declined trust and reciprocity. In this regard, the main reason for declined structural social capital is the frequent occurrence of malignant social events (65). A survey on depression among older adults in rural China found that a stronger economy was associated with higher reciprocity (66). In urban areas, however, reciprocity has been influenced due to the fact that increasingly cold neighborhood relationships have replaced economic relationships (67). One researcher reported that "people with higher education build relationships through reciprocity," and thus suggested that regional educational institutions should work to improve education levels in their respective areas (68). With the regular development of health education activities for the elderly in urban communities, mutual remuneration has gradually increased.

In addition, we found differences in the "social network" depending on age and exercise regimens. There was a significantly higher risk of depression for males in the low "social network" group, which suggests that a decrease in the social network is a risk factor for depression. This may be addressed through engagement in certain activities. For example, a previous study found that participation in walking clubs was an important social networking factor for older adults in Hong Kong (69). In similar findings, the diversification of

sports clubs appears to broaden the social network for men more so than for women, wherein older men are more willing to make new friends through sports activities (70).

Further, we found a significant difference in "social participation" depending on the education background and presence/absence of exercise regimens. However, the only significant association was that the group with a slightly lower risk of depression had more females than the group with a slightly higher risk of depression (adjusted Models 2 and 3 with reference to "social participation"). This may be less associated with depression than "trust," "reciprocity," and "social networks." "Social participation" refers to cases in which older adults participate in local community activities and organizations; it is closely related to social capital, and influenced by education background and family support (71). Since social organizations in traditional Chinese communities are primarily managed by government agencies, many elderly persons are reluctant to participate due to the lack of innovative activities (72). This limits the role of depression risk reduction through increased social participation. A previous study found that older persons who expanded their social networks also increased their frequency of organizational participation, and that social participation in older age was associated with community involvement from middle age (73). Likewise, more elderly persons are engaging in social participation as companies begin to offer diverse social activities in traditional communities (74).

As a new contribution to the literature, this study found evidence of a gender-based influence in the relationship between depression and social capital. Here, "trust and reciprocity" had a strong impact among elderly female respondents, which is not in accordance with international research. Multiple studies have reported that females are at a higher risk of depression than males (75, 76). As "trust" and "reciprocity" are strongly related to depression, it is thought that close relationships are significant factors for females. In the Chinese context, it is common for females to have weak friendships after retirement. In southern China, retired female elderly persons also play stronger family roles than their male counterparts, thus increasing their sense of family trust and willingness to participate in social activities (77). As for specific activities, one study reported that traditional Chinese square dancing was suitable for the female elderly, and could help reduce their risk of depression (78).

According to our structural equation model, the investigated social capital variables directly affected depression and influenced each other. There were also clear differences in the path coefficients between males and females. Due to gender-based differences in retirement policies and social security, men and women hold different community status, which creates variations in their social capital. Moreover, we found an association between "trust" and "reciprocity" in males with persistent critical illness (79). Males also had a greater overall risk of depression due to decreased "trust" and "reciprocity," likely because Chinese males work longer than Chinese females and feel more uncomfortable upon retirement, which makes it difficult to quickly integrate into the community environment (80). By contrast, females adjust better to community life because they are more attuned to their families and retire earlier (81). It should also be mentioned that an increase in the social network did not reduce the risk of depression in the current study, as this finding directly contradicts existing reports (82, 83). This is likely because the social networks of Chinese retired older adults differ from those found in the workplace. Since older adults must therefore rebuild their community networks after retiring, efforts to increase one's social network in the employment context does not reduce the risk of depression.

In sum, our findings show that social capital has different impacts on depression in older adults depending on their gender. For elderly populations in China, the risk of depression will continue to rise due to both the increasing aging population and impact of delayed retirement policies. In fact, there is evidence that differences in retirement age will always lead to differences in social capital among older adults (84). The can be addressed through the Chinese government by gradually optimizing the structure of the labor force through delayed retirement policies and adjusting the influence of gender differences, both of which should help maintain health in the elderly (85).

This study also had limitations. First, all participants were 60 years of age or over and lived in Hangzhou, China, which limits generalizability. Although we found that social participation negatively impacted mental health in women, the specific elements of social participation require continued investigation. As such, future studies should both increase the number of participants and expand the scope of the survey area. Second, the activity ability of participants could not be measured by analyzing the relationship between their depressive situation and social capital. In future research, we plan to differentiate the effects of social capital on depression according to gender across the whole population. At the same time, we will consider how China's delayed retirement policy has impacted social capital and depression among the retired elderly.

Conclusion

In this study, we investigated the relationship between depression and social capital among older adults in Hangzhou, China. Among the social capital indicators, "social network" was found to be significantly associated with depression in males, while "trust" and "reciprocity" were found to be significantly associated with depression in females. In addition, the results of this study suggest that relationships with familiar people, such as family members, neighbors, and local organizations, are particularly important for older adult women. To prevent depression in older adults in the community, it is necessary to improve their social capital through a social system that

encourages social participation and efforts that focus on reciprocity. In terms of measures to enhance social capital, structural social capital (social network and social participation) is used as the main method, combined with the improvement of trust between neighbors, which ultimately reduces the risk of depression.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

This study was approved by the Waseda University Ethics Committee (ID: 2018-278).

Author contributions

XW contributed to the conception of the study. AO contributed significantly to analysis and manuscript preparation. SZ performed the data analyses and wrote the manuscript. KL helped perform the analysis with constructive discussions. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.863574/full#supplementary-material

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Influence of perceived importance of the internet on life satisfaction and health of the older people: An analysis based on intermediary and moderating effects

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With the global growth of the aging population, healthy aging and active aging has become an important goal for the future social development of all countries. The purpose of this study is to explore the potential relationships between the older people's perceived importance of the Internet, family atmosphere, behavioral independence, life satisfaction, and health. The data come from the China Family Panel Studies' fourth wave (2015–2016) and fifth wave (2017–2018) investigations. According to an analysis of data of 5,948 people over 60 years old performed using LISREL 8.8 software, the selected cases answered the same questions about the perceived importance of the Internet, life satisfaction, and health status in two waves of surveys. The results show that life satisfaction and self-rated health have cross influences, while at the same time both are persistent in the time baseline, and family atmosphere and behavioral independence play an important intermediary role. Therefore, strengthening parent–child interaction, promoting parent–child relationships, and improving behavioral independence can effectively improve the life satisfaction and health status of the older people.

KEYWORDS

family atmosphere, health status, structural equation model, perceived importance of the internet, life satisfaction

Introduction

The number and proportion of older people aged 60 and above are increasing worldwide. According to public data from the World Health Organization, the global population aged 60 and above was one billion in 2019 but is predicted to increase to 1.4 billion in 2030 and 2.1 billion in 2050 (1). Against the background of global aging, caring for older people is an indispensable and urgent social governance goal of all countries worldwide (2). According to data released by the National Bureau of Statistics of China in

2020, the number of older people aged 60 and above in China reached 264 million, accounting for 18.70% of the total population, of which 161 million were aged 65 and above, accounting for 13.50% of the total population (3). Some experts predict that the number of people aged 65 and above may rise to 330 million by 2050, accounting for about a quarter of the total population (4). China is rapidly becoming an aging society. Due to the large number of older people, the Chinese government attaches great importance to their health problems, and vigorously advocates the strategy of healthy and active aging, aiming to create a favorable social environment for the upcoming severe situation of an aging population in China.

Internet information is disseminated all over the world, and China accounts for a significant amount of global Internet use (5, 55). In terms of use of the Internet, the older people represent a vulnerable group. With the development of society, paperless offices, digital banking, travel health codes, and so on all require use of network devices (6); therefore, exploring perceptions of the Internet among the older people is particularly important for enhancing the life satisfaction of this group (7). Studies have found that the higher the frequency of Internet use, the higher the individual's life satisfaction (8, 9). Some studies have also pointed out that moderate Internet use can help people temporarily overcome negative emotions, so that their negative emotions can be transferred or even reduced, thus achieving the effect of relieving anxiety and depression and promoting physical and mental health. Online communication with friends, relatives, and even strangers through the Internet is helpful to vent personal feelings, greatly dispel negative emotions, and has a lasting effect (10). A study pointed out that the Internet can provide users with rich and colorful instant information, and its impact on people's health is becoming increasingly important (11). For example, the health knowledge at a person's fingertips on the Internet can provide answers to immediate health needs for different groups of people, greatly improve an individual's health literacy (12), and positively influence their health-care service needs (13), thus promoting individual health management (14). Therefore, it is worth exploring whether perceived importance of the Internet impacts the life satisfaction and health of the older population.

Family atmosphere refers to the environment created by the behavior or language used among family members (54), such as *via* communication and interpersonal relationships (15). Communication and dialogue between parents and children can significantly enhance the emotional depth between them and create a positive, warm atmosphere in the home. Through successful interactions, misunderstanding and dissatisfaction will be minimized and harmonious coexistence between parents and children will be promoted, thereby improving the happiness of family members (16). Some studies have pointed out that the more times a person communicates with their parents and the more family activities are undertaken, the more harmonious the parent–child relationship will become. Hence, the parent–child relationship is positively related to the life satisfaction of family members. A good relationship helps to improve family members' life satisfaction (17). Some scholars have also pointed out that the intergenerational interaction between parents and children has a positive correlation with their satisfaction with the parent–child relationship, and this will positively affect their satisfaction with family life (18). The dialogue and communication between parents and children, and humanitarian care among families can not only promote the establishment of a harmonious parent–child relationship for the older people, but also help them to have a healthy physical and mental state and reduce the risk of depression (19) and chronic diseases (20). At the same time, mutual health care among family members also helps to promote the physical activity of the older people and makes them more willing to go out to participate in healthy activities in the process of communication with family members, so as to maintain a healthy physical condition (21) and reduce the risk of chronic diseases (22). For example, the "filial piety culture" strongly advocated in China aims to build a harmonious and positive family atmosphere, encouraging family members to help each other and strengthening communication and exchange. This can not only improve the family atmosphere, but also enhance the happiness and physical and mental health of family members (23). However, there is a need to further examine whether family atmosphere influences the relationship between perceived importance of the Internet and life satisfaction and health of older people through a mediating effect.

Behavioral independence is a basic strength of individuals with respect to the quality of their daily life. It refers to not being attached or subordinated to a relationship, and relying on one's own strength to complete tasks. In terms of ideology, it refers to having independent thoughts, an independent personality, and the ability to live alone (52). The older people become older, their ability to act independently also declines. In rehabilitation medicine, behavioral independence is the most basic ability of people at home and in the community. If it is damaged or reduced, this will directly limit self-caring ability and affect connection with others and society (24). Therefore, in the opinion of most experts and scholars, behavioral independence is very important for the older people, and it is one of the important indicators reflecting their quality of life (25). The existing research shows that older people with good behavioral independence are usually willing to take an active part in community activities and housework. Their mental state will be improved accordingly due to their physical activity. Their depression will be obviously lower, the threshold of dysthymia will be relatively high (26), and they can have higher subjective

Abbreviations: PII, perceived importance of the Internet; FA, family atmosphere; IDB, independent behavior; LF16, sense of safety in 2015–2016; SH16, self-rated health in 2015–2016; LF18, sense of safety in 2017–2018; SH18, self-rated health in 2017–2018; SD, standard deviation; SEM, structural equation modeling.

well-being (27). Moreover, older people with better independent behavioral ability generally have better nutrient absorption capability and are more willing to actively participate in physical or intellectual work, which will greatly reduce their risk of Alzheimer's disease (28). Overall, older people's perceptions of the importance of the Internet can promote their life satisfaction and self-rated health independently and through family atmosphere and behavior—the latter of which needs to be further verified with reference to national survey data.

What is the relationship between the perceived importance of the Internet, life satisfaction, and self-rated health of older people? Are family atmosphere and behavioral independence mediating factors between perceived importance of the Internet and life satisfaction/self-rated health? Did life satisfaction and self-rated health in 2016 affect life satisfaction and self-rated health in 2018? There has been little research on the impact path between perceived importance of the Internet and the life satisfaction and health of the older people. Therefore, based on existing theories and literature, several research hypotheses are shown (see Figure 1). These are as follows: H1-1) The importance of the Internet as perceived by the older people will have a positive impact on life satisfaction in 2016; H1-2) The importance of the Internet as perceived by the older people will have a positive impact on self-rated health in 2016; H2, H3) Family atmosphere and behavioral independence play a potential mediating role in the relationship between perceived importance of the Internet and life satisfaction and self-rated health; H4) There will have a persistent cross effect between life satisfaction and self-rated health.

Materials and methods

Participants

The data was obtained from the fourth wave (2016) and fifth wave (2018) surveys of the China Family Panel Studies (CFPS), which is a nationally representative, biennial longitudinal survey of Chinese communities, families, and individuals launched in 2010 by the Institute of Social Science Survey of Peking University, China. The CFPS is designed to collect individual-, family-, and community-level longitudinal data in contemporary China. The research performed a baseline survey in 25 provinces, municipalities, and autonomous regions in China, and finally completed interviews with 14,960 households and 42,590 individuals, which were conducted every 2 years. A total of 36,892 people were surveyed in the fourth wave (2016) and 37,354 in the fifth wave (2018). The selection process of the research samples is shown in Figure 1. A total of 36,892 people participated in the fourth wave of the survey. First, 8,149 individuals that did not participate in the fifth wave of surveys were excluded. Second, 21,482 people younger than 60 years old were excluded. Finally, 1,313 individuals with a large number of blank questionnaires were excluded. Thus, the final sample comprised 5,948 people.

Measures

Perceived importance of the network

Perceived importance of the Internet was measured by two indicators, including "the importance of the Internet as an information channel" and "the importance of Mobile phone short message as an information channel." A 5-point Likert scale was used, ranging from 1 (very unimportant) to 5 (very important). The higher the total score, the more important the Internet was considered to be.

Life satisfaction

In the fourth and fifth waves, life satisfaction was measured by asking participants about their own life satisfaction, A 5-point Likert scale was used, ranging from 1 (very dissatisfied) to 5 (very satisfied). The higher the total score, the more satisfied the older people were with their lives.

Self-rated of health

Self-rated of health was measured by asking the participants, "What do you think of your health?" A 5-point Likert scale was used, ranging from 1 (unhealthy) to 5 (very healthy). The higher the total score, the healthier the individual considered themselves to be.

Family atmosphere

Family atmosphere included two aspects: parent–child relationship and parent–child interaction. The parent–child relationship was measured by asking the respondents, "How is the relationship with your children?" A 5-point Likert scale was used, ranging from 1 (not very close) to 5 (very close). Parent–child interaction was mainly defined by asking questions about contact frequency with children and meeting frequency with children. A 5-point Likert scale was used, ranging from 1 (never) to 5 (every day). The higher the total score, the higher the level of parent–child interaction.

Behavioral independence

This study used seven items to measure the behavioral independence of the older people, including whether they can use public transportation independently, whether they can perform independent kitchen activities, whether they can do outdoor activities independently, whether they can do laundry independently, whether they can do cleaning independently, whether they can shop independently, and whether they can eat independently. Participants described their situation according

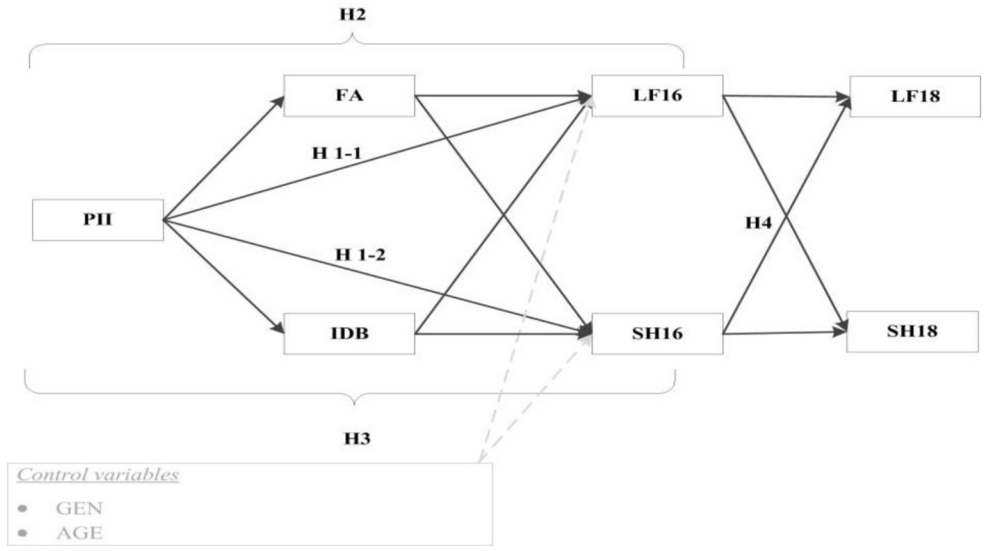

FIGURE 1
Hypothesized model of the research framework. PII, perceived importance of the Internet; FA, family atmosphere; IDB, independent behavior; LF16, life satisfaction in 2015–2016; SH16, self-rated health in 2015–2016; LF18, life satisfaction in 2017–2018; SH18, self-rated health in 2017–2018.

to the questions (0 = no, 1 = yes). The Cronbach's alpha value for independent behavior in the present study is 0.87.

Data analysis

The distributions of background characteristics and independent, mediating, and dependent variables were expressed in terms of the frequency distribution, mean, maximum, and minimum. Structural equation modeling was used to test the mediation effect. The mediating variables were family atmosphere and behavioral independence. The independent variable was the perceived the importance of the Internet and the dependent variable was sense of safety and self-rated health (Figure 2). The incremental fit index (IFI), comparative fit index (CFI), non-normed fit index (NNFI), adjusted goodness-of-fit index (AGFI), and normal fit index (NFI) indicate a good fit to the data when values exceed 0.90 (29, 30). The root mean squared error of approximation (RMSEA) value of <0.05 indicated a "close fit" (31, 32). Additionally, Bollen's relative fit index (RFI) measures the discrepancy between the model evaluated and the baseline model, indicating good model–data fit for values close to 1 (33). A Hoelter's Critical N (CN) of 200 or better indicated a satisfactory model–data fit (34). The effects specified were estimated by means of the maximum likelihood method to estimate the polyserial, polychoric, and product–moment correlations by programming in PRELIS2 (35). Statistical analyses were conducted using SPSS 22 and LISREL 8.8 statistical software.

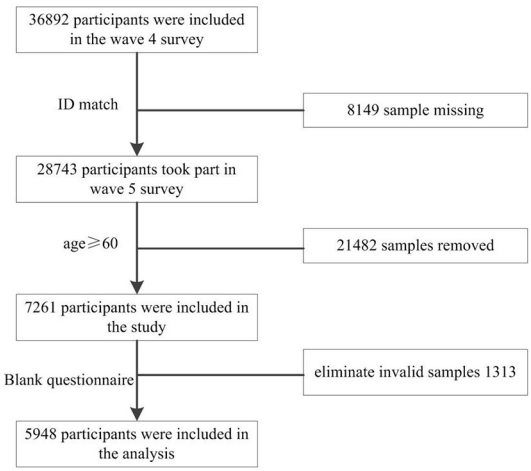

FIGURE 2
Flow chart depicting participant inclusion and exclusion.

Results

Descriptive data

Table 1 shows the main demographic characteristics and descriptive statistics of the respondent variables. Among the

5,948 participants, 3,033 were male and 2,915 female, and their ages were mainly between 60 and 69 years old. The average score of perceived importance of the Internet was 1.42 (SD = 0.82). Among the variables of family atmosphere, the average score of parent–child interaction was 3.26 (SD = 1.51). In response to questions about the parent–child relationship, 39.00% of respondents said close and 43.56% very close. The average score of life satisfaction in 2016 was 3.87 (SD = 1.05), and the score of life satisfaction in 2018 was 4.25 (SD = 0.92). In 2016, 26.78% rated their health as being unhealthy, 23.69% as average, 32.09% as relatively healthy, 10.57% as healthy, and 6.86% as very healthy. In 2018, 29.86% rated their health as being unhealthy, 16.96% as average, 36.45% as relatively healthy, 8.98% as healthy, and 7.75% as very healthy.

TABLE 1 Descriptive statistics variables of the sample (n = 5,948).

Variable	$n^{\#}$	%	Mean	SD
Control variable				
Sex				
Male	3,033	50.99		
Female	2,915	49.01		
Age				
60–69	4,174	70.17		
70–79	1,537	25.84		
≥80	237	3.98		
Independent variable				
Perceived importance of the Internet [1–5]			1.42	0.82
Mediating variable				
Family atmosphere				
Parent–child interaction [1–5]			3.26	1.51
Parent–child relationship				
Very bad	27	0.49		
Bad	55	0.99		
Common	882	15.96		
Better	2,156	39.00		
Very good	2,408	43.56		
Independent behavior [0–1]			0.94	0.16
Dependent variable				
Life satisfaction in 2016 [1–5]			3.87	1.05
Self-rated health in 2016				
Unhealthy	1,593	26.78		
average	1,409	23.69		
relatively healthy	1,909	32.09		
healthy	629	10.57		
Very healthy	408	6.86		
Life satisfaction in 2018 [1–5]			4.25	0.92
Self-rated health in 2018				
Unhealthy	1,776	29.86		
average	1,009	16.96		
relatively healthy	2,168	36.45		
healthy	534	8.98		
Very healthy	461	7.75		

Total number < n = 5,948 due to missing.
[1–5], [1–0]: The range of a single item.

Mediation analyses

Using structural equation modeling (SEM), we determined the p-value ($p > 0.05$). Based on these, the insignificant path was removed from the model, and the final model was obtained. Compared with the original model, the final model's degree of fit improved to some extent, with RMSEA = 0.037, NNFI = 0.95, CFI = 0.96, IFI = 0.96, AGFI = 0.99, and CN = 857.20 (Table 2). The final model is shown in Figure 3. Findings show that older people's perception of the importance of the Internet has a significant positive impact on family atmosphere and behavioral independence ($p < 0.05$). It had a significant negative impact on life satisfaction in 2016 ($p < 0.05$), but had no significant correlation with self-rated health in 2016. Family atmosphere and behavioral independence were significantly positively correlated with life satisfaction and self-rated health in 2016 ($p < 0.05$). At the same time, life satisfaction and self-rated health in 2016 were both positively significantly related to life satisfaction and self-rated health in 2018 ($p < 0.05$).

First, Table 3 lists the paths from the older people's perception of the importance of the Internet to their life satisfaction and self-rated health. We found that the perceived importance of the Internet has a direct positive effect on family atmosphere ($\beta = 0.21$, $p < 0.001$), and a significant positive effect on behavioral independence ($\beta = 0.08$, $p < 0.05$) (Figure 3). We did not find that it has a direct impact on the self-rated health of the older people. At the same time, we found that the total effect of the perceived importance of the Internet and life satisfaction was 0.08 ($p < 0.001$), and the direct effect was negative ($\beta = -0.10$, $p < 0.001$), indicating that the perceived importance of the Internet can positively affect life satisfaction through intermediary variables. Therefore, H1 is partially supported.

Second, the model shows that family atmosphere has a direct impact on life satisfaction and self-rated health, among which family atmosphere positively affects life satisfaction ($\beta = 0.76$, $p < 0.001$), and the direct impact on self-rated health is 0.46 ($p < 0.001$). Behavioral independence also has a direct impact on life satisfaction and self-rated health: the higher the behavioral independence of the older people, the better their life satisfaction and health. Therefore, H2 and H3 are supported to some extent.

Finally, the study found that the older people's life satisfaction and self-rated health have a continuous cross effect, specifically, the life satisfaction of the older people in 2016 has a significant positive impact on their life satisfaction and self-rated health in 2018. The higher the life satisfaction of the older

TABLE 2 Measures of goodness-of-fit for perceived the importance of the Internet, life satisfaction, and self-rated health model of the older people.

Model	RMSEA	NNFI	CFI	IFI	AGFI	CN
Initial model	0.037	0.95	0.96	0.96	0.99	847.23
Delete PII→ SH	0.037	0.95	0.96	0.96	0.99	853.02
Delete GEN→ LF16 #	0.037	0.95	0.96	0.96	0.99	857.20

PII, perceived importance of the Internet; SH16, self-rated health of the older people in 2016; GEN, gender; LF16, life satisfaction of the older people in 2016.
Goodness-of-fit of the final model.

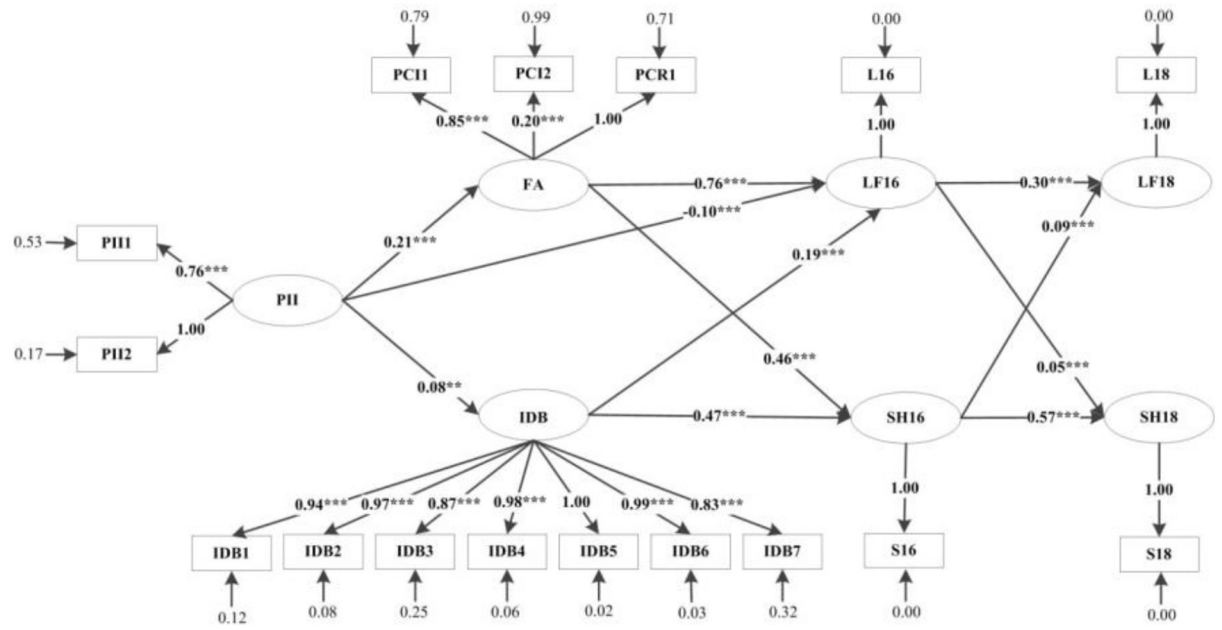

FIGURE 3
Structural equation modeling results. PII, perceived importance of the Internet; FA, family atmosphere; IDB, independent behavior; LF16, life satisfaction in 2015–2016; SH16, self-rated health in 2015–2016; LF18, life satisfaction in 2017–2018; SH18, self-rated health in 2017–2018; $^{**}p < 0.01$, $^{***}p < 0.001$.

people in 2016, the higher it is in 2018 ($\beta = 0.30$, $p < 0.001$), and the healthier the older people in 2018 ($\beta = 0.05$, $p < 0.001$). In addition, the healthier the older people in 2016, the higher their life satisfaction ($\beta = 0.09$, $p < 0.001$) scores and self-rated health ($\beta = 0.57$, $p < 0.001$) scores in 2018. Therefore, H4 is supported.

Discussion

This study uses an intermediary model to test the influence of the perceived importance of the Internet on the life satisfaction and self-rated health of the older people. The results show that the perceived importance of the Internet can positively affect the life satisfaction and self-rated health of the older people through family atmosphere and behavioral independence. At the same time, this study also found that there is a persistent cross effect between life satisfaction and self-rated health of the older people.

With the development of communication technology, human society has entered the digital era (36, 37). For the older people, the higher their perception of the importance of the Internet, the more they will use network devices. Communication equipment is a tool and means of digital communication (38). The older people can talk with their children by using mobile phones or PCs. Studies have shown that effective communication can promote family harmony (39), while a good family atmosphere can promote personal physical and mental health (40). Family atmosphere plays an important role in the life of the older people. Harmonious family relationships and full family interaction can optimize the health management services of the older people, reduce their depression and the risk of illness and also help to improve their life satisfaction (41–43). Therefore, in order to improve the health status of the older people and enhance their life satisfaction, it is necessary to create a good family atmosphere, attach importance to family care, give the older

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TABLE 3 Direct and indirect effects of the older people's perceived importance of the Internet on life satisfaction and self-rated of health.

Variables	Life satisfaction in 2016			Self-rated health in 2016			Life satisfaction in 2018			Self-rated health in 2018		
	Direct effect	Indirect effect	Total effect	Direct effect	Indirect effect	Total effect	Direct effect	Indirect effect	Total effect	Direct effect	Indirect effect	Total effect
Perceived importance of the Internet	−0.10***	0.18***	0.08***	—	0.14***	0.14***	—	0.04***	0.04***	—	0.08***	0.08***
Family atmosphere	0.76***	—	0.76***	0.46***	—	0.46***	—	0.27***	0.27***	—	0.30***	0.30***
Independent behavior	0.19***	—	0.19***	0.47***	—	0.47***	—	0.10***	0.10***	—	0.28***	0.28***

**$p < 0.01$, ***$p < 0.001$.

people material and economic support, and conduct regular online and offline communication activities with them, giving full play to Internet technology, so as to encourage them to establish a positive psychological state and maintain their physical and mental health.

Behavioral independence plays an important intermediary role in the relationship between the perceived importance of the Internet and the older people's life satisfaction/self-rated health. With the increase of age, an individual's function gradually declines, which may be accompanied by obstacles that greatly affect their life satisfaction and health status (44, 45). At present, with the development of science and technology, the traditional lifestyle has changed, and IC cards, intelligent washing machines, and integrated kitchen and bathroom facilities have all provided enhancement to daily life (46, 47). However, older people often lack the ability to deal with new things, and the question of how to improve their behavioral independence has become an important issue (48). Studies have increasingly shown that learning the requisite skills to use smart devices, engage in outdoor activities, and use the Internet can improve older people's behavioral independence. For example, the use of smart wheelchairs and smart glasses can enhance older people's mobility and reading ability, and greatly improve their independence. At the same time, use of the Internet can improve the cognition level of older people with respect to new things; this can improve their independence and change their lifestyle, which plays an important role in improving their life satisfaction and health (49). In order to effectively resolve the "digital divide" experienced by the older people, the speed of development of aging-friendly construction can be improved by setting up special actions for Internet applications that are aging-friendly and barrier-free. The older people can also be prompted to adapt to the intelligence era through peer education and other methods, so as to enhance their ability to act independently, and thus improve their quality of life and health.

The study found that the life satisfaction and self-rated health status of the older people in China in 2018 were higher than in 2016. One of the reasons may be that since 2016 China has formulated the "Healthy China 2030" plan, and actively carried out educational activities for the older people covering fitness, health-care, prevention and treatment of diseases, and rehabilitation. It has also optimized the living arrangements, transportation, medical care, and nursing environment for the older people. Creating a safe, convenient, comfortable, and barrier-free livable environment for the older people has greatly improved their expected healthy life and happiness (50). In addition, research shows that the life satisfaction of the older people and their self-rated health have a continuous cross effect. Previous studies have found that life satisfaction is related to health status, but the causal relationship is not clear. The results of this study show that life satisfaction and self-rated health are cross influenced and have a certain persistence. That is, front-end self-rated health (2015–2016) has a higher impact

on back-end life satisfaction (2017–2018) than front-end life satisfaction (2015–2016). The standardized coefficients are 0.09 and 0.05, respectively. At the same time, the influence of life satisfaction and self-rated health is persistent, which is consistent with previous research results (51, 53). This may be because the higher the individual's life satisfaction in the previous year, the better their material living standard, which improves future physical and mental health to a certain extent. Therefore, from the perspective of prevention, preventing diseases should be given priority in order to improve the physical and mental health of the older people, thus effectively maintaining their life satisfaction.

To sum up, the perceived importance of the Internet has an important impact on the life satisfaction and health of the older people. Moreover, family atmosphere and behavioral independence play an important mediating role in perceived importance of the Internet and life satisfaction and health of the older people. Therefore, there is a need to increase the frequency of Internet use by the older people and reduce the digital divide. In addition, in order to create a harmonious family atmosphere, children should be encouraged to guide the older people on how to use Internet devices, and help strengthen the independence of the older people, especially in terms of thought, personality, and life. Finally, life satisfaction and self-rated health of the older people have a continuous cross effect, and initiatives should start from the prevention side to improve the life satisfaction and health of the older people.

Limitations

Some limitations to this study warrant consideration. First, the associations among perceived importance of the Internet, family atmosphere, behavioral independence, life satisfaction, and self-rated health are cross-sectional in the study and can be further validated using longitudinal data in the future. Second, since the information was gathered from the participants in the study, self-report/recall bias may have existed. However, it is not easy to achieve continued participation among cohorts of older people in a cohort study, and the sample size should not be ignored. As a result, our findings with acceptable goodness-of-fit indices deserve greater attention. Finally, our study used a Chinese family tracking survey. In the future, the CFPS data could be combined with the China Healthy Pension Tracking Survey, and qualitative case analysis of the older people's Internet use, health status, and life satisfaction could be conducted.

Conclusions

The life satisfaction and health status of the older people should be matters of continuous concern. Life satisfaction and self-rated health have cross influences, and they are persistent on the time baseline. Family atmosphere and behavioral independence each play an important intermediary role in the older people's perception of the importance of the Internet and their life satisfaction/self-rated health. Therefore, strengthening parent–child interaction, promoting parent–child relationships, and promoting behavioral independence can effectively improve the life satisfaction and health status of the older people.

Data availability statement

The original contributions presented in the study are included in the article/supplementary materials, further inquiries can be directed to the corresponding author/s.

Ethics statement

This study was approved by the Ethical Review Committee of Peking University Biomedical (IRB00001052-14010), and all participants signed informed consent. The patients/participants provided their written informed consent to participate in this study.

Author contributions

M-mJ and KG designed the study, analyzed results, drafted, revised the manuscript, and acquisition of funding. M-mJ and Z-yW drafted and revised the manuscript. KG and P-pG analyzed results and revised the manuscript. All authors read and approved the final article.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Association between social capital and self-rated health among community-dwelling older adults

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Background: It is less known about whether the association of social capital with self-rated health (SRH) varies by the presence of health conditions and how social capital, together with other variables, is linked to self-rated health in later life.

Objectives: This article aimed to explore the association of social capital with self-rated health and to examine whether the association varies among older people with and without health conditions, with a special focus on how social capital and relevant factors have an effect on self-rated health among community-dwelling older adults.

Methods: Cross-sectional data were obtained from a survey that commenced from July to September 2017 in Anhui Province. Data on socio-demographic information, social capital (six dimensions), and self-rated health were analyzed. Binary logistic regression and classification and regression tree (CART) models were used to estimate the association.

Results: Based on the findings, we found that social capital regarding less social support (adjusted odds ratio (*AOR*) = 1.57, 95% *CI*: 1.21–2.04), and less reciprocity (*AOR* = 1.73, 95% *CI*: 1.29–2.31) were associated with self-rated health among general older adults. Social capital as measured by less social participation (*AOR* = 1.55, 95% *CI*: 1.06–2.27), less cohesion (*AOR* = 0.63, 95% *CI*: 0.42–0.94), and less reciprocity (*AOR* =1.77, 95% *CI*: 1.17–2.68) were linked to self-rated health among older people with health conditions. While social capital regarding less social support (*AOR* = 2.15, 95% *CI*: 1.39–3.33) was related to self-rated health among older people without health conditions. We observed the interacting effect of social capital in the CART model, an implication that much focus should be geared toward vulnerable subgroups, especially depressed and lonely older people, as they have low reciprocity and little cohesion.

Conclusion: This work demonstrates that social capital may be relevant in devising programs and measures to improve self-rated health among community-dwelling older adults with comorbidity.

KEYWORDS

social capital, self-rated health, older people, health aging, China

Introduction

The increasing aging population across the globe has compelled many nations to pay more attention to the health and well-being of older people (1). Empirical studies have concluded that self-rated health (hereafter referred to as SRH), a comprehensive concept and one of the subjective indicators of health (2, 3), is relevant in documenting the current status of health and forecasting health-related events likely to occur among older adults (4). Furthermore, previous investigations found that poor SRH is an important predictor of developing disability, morbidity, and mortality among older people (5, 6). Meanwhile, SRH is not only helpful in designing and implementing community health promotion and disease prevention programs but also in providing evidence on adult care (7).

Social capital is commonly referred to as public resources accessible and available to individuals through social relations and community engagement (8). In practice, several dimensions, such as social support, social connection, trust, cohesion, reciprocity, and social participation, were used to measure social capital (2, 9, 10). Previous studies have documented that social capital may be particularly beneficial for older people due to their degeneration in health and the increasing need for care and support in later life (1, 2). In recent decades, studies have explored the relationship between social capital and various health outcomes of older people (11–13), especially for SRH (14–17). Notably, such studies implicated social capital as a modifiable social resource that can be used in promoting SRH among older people in their later life (18–20). For instance, positive impacts of social capital (i.e., trust, civic participation and reciprocity, social support, and reciprocity) on SRH were observed among older people (9, 10, 21–23). In addition, the association between social capital and successful aging through the evaluation of subjective health and well-being has been documented (13, 24).

Although much research has confirmed the association of social capital with SRH among common older populations (2, 15, 25, 26). However, less is known about whether the association varies among older people with and without health conditions. Prior studies have proved that older individuals with comorbidities are vulnerable groups who have different perceptions of health which might impact their SRH (27, 28). Therefore, when designing programs or activities from the perspective of social capital to promote SRH among older people, it is necessary to examine such an association.

Furthermore, current studies exploring factors (such as, demographic, socio-economic, and social capital) individually associated with SRH are useful. Yet, how these factors together are associated with SRH is unclear. More comprehensive and sophisticated approaches are warranted to examine how these factors co-exist or interact with SRH (8, 17). Knowledge about these interactions will reveal potential mechanisms by which social capital is linked to SRH and guide more targeted and precise prevention programs in public health policy and clinical care practice. Given this, we employed a classification and regression tree (CART) model, which is a novel and sophisticated nonparametric approach and can be used to explore complex combinations or interactions among variables (29, 30).

To close these research gaps, we here aimed to achieve two main objectives. First, we aimed to examine the relationship between social capital and SRH and whether the association varies among older people with and without health conditions. Then, we explored the potential interactive effects of social capital and relevant factors on SRH among community-dwelling older adults.

Materials and methods

Study design and data collection

To obtain a representative sample, a multi-stage stratified cluster random sampling method was applied to recruit study participants. Following the local household registration system, individuals aged ≥60 years were ascertained. With the help and coordination of local community workers, each subject was personally visited at their home and engaged in a face-to-face interview by skilled and trained graduate students from the Anhui Medical University through a structured and interviewer-administered questionnaire. Before commencing the interviews, a verbal understanding of the purposes and procedures of the study and written informed consent were obtained. Initially, a total of 1,935 participants were interviewed, of whom 1,810 questionnaires were valid with a response rate of 93.5%. Details about our study design and sampling can also be found elsewhere (31–33).

Measures

Self-rated health

Here, we considered SRH as the dependent variable, which was assessed with one general question. Typically, SRH, as a subjective indicator of health, was measured with a single item, which was reliable and valid based on findings from previous studies (1, 2, 34). In this study, participants were asked, "How do you rate your general health?" with responses ranging from very poor, poor, fair, good, and very good. For data analysis, we dichotomized the original responses into a binary variable: good health (0 = good, or very good) and poor health (1 = very poor, poor, or fair), which was similar to prior studies that investigated the relationship between social capital and SRH (3, 19, 35).

Social capital

Social capital, the main independent variable, was measured by a questionnaire containing six dimensions (social participation, social support, social connection, trust, cohesion, and reciprocity) and 22 items. For each domain of social capital, responses to the items were summed to generate an overall score. Notably, a higher score indicated a better social capital status. For data analysis, we dichotomized the scores of each dimension of social capital into two categories by taking the median value as the cut-off (36), such as social participation: high (≥6) and low (<6), social support: high (≥13) and low (<13), social connection: high (≥12) and low (<12), trust: high (≥13) and low (<13), cohesion: high (≥20) and low (<20), and reciprocity: high (≥11) and low (<11). Cronbach's α of the social capital questionnaire was 0.919. The details of the measurement have been previously published (31–33).

Other variables

Data on other variables, such as age (years), gender (male and female), body mass index (BMI; kg/m^2), living status (not living alone and living alone), residence (urban and rural), marital status (married/cohabited and single), education (primary school and below, junior school, and high school and above), smoking status (non-smoking, former smoking, and smoking), drinking status (non-drinking, former drinking, and drinking) were collected. In addition, health-related variables, such as functional ability, depression, and loneliness were measured. In this study, a composite Activities of Daily Living (ADL)/Instrumental Activities of Daily Living (IADL) scale containing of 14 items was utilized to assess functional ability, the 16-item Zung Self-Rating Depression Scale (SDS) was employed to measure the depressive symptoms, and a single item to measure how the participants feel about the sense of loneliness. A more description of our measurement tools has been published elsewhere (31–33).

To identify respondents with health conditions, each participant was asked to provide answers to whether they had a clinical diagnosis of the following conditions or impairments: high blood pressure, diabetes, heart disease (coronary or valve disease), hyperlipidemia, angina, chronic bronchitis (chronic obstructive pulmonary disease [COPD]/emphysema), cerebral infarction (stroke), coronary heart disease (CHD), cataract, arthritis, cancer, and liver or kidney-related diseases. Eventually, 1,280 participants classified the group with health conditions if they reported at least one kind of the above-mentioned conditions (27). Accordingly, 530 participants were grouped as having no health conditions.

Statistical analysis

Initially, the differences between good and poor SRH were evaluated by the chi-square test.

Second, to express our results, three binary logistic regression models with the odds ratio (*OR*) and adjusted odds ratio (*AOR*) and associated 95% confidence intervals (95% *CI*), namely, model 1, model 2, and model 3, were fitted separately. Based on previous studies (1, 37–39), we took some variables, such as age, gender, BMI, residence, living status, marital status, education, smoking status, and drinking status as potential covariates.

After this, we fitted a classification and regression tree (CART) model, with statistically significant variables in the unadjusted logistic regression model included, to examine the combined effect of social capital on SRH. In this model, SRH was categorized into subgroups by the most explanatory independent variables. Any possible interaction and combination with all social capital dimensions and other variables could generate these subgroups in the node. More detailed information about the CART model has been described in detail in our previous articles (31–33).

All statistical analyses were conducted using the Statistical Package for the Social Sciences, version 23.0 (SPSS Inc., Chicago, IL, USA). A two-sided level of 0.05 was considered significant.

Results

Results of descriptive analysis

Table 1 shows that over half of the sample was over 70 years old. As seen, about 72.3% (1,308/1,810) of the subjects reported poor SRH. Among them, 24.4% of the participants were aged between 65 and 69 years, and 58.8% of the respondents were female older adults. About 85.8% of the respondents were not living alone, 56.1% of them were residing in rural areas, 76.8% of them were married or cohabited, and 75.2% of the participants attended up to primary school. Notably, 78.4 and 83.6% of the subjects were non-smoking and non-drinking, respectively. More than half of the participants reported having a robust functional ability, and not being lonely while being depressed. Most of the participants with poor SRH reported a higher level of social capital concerning social participation, social connection, trust, and cohesion, but a lower level of social capital concerning social support and reciprocity.

Among respondents who reported good and poor SRH, there were differences regarding age, body mass index, living status, residence, education, drinking status, number of diseases, functional ability, depression status, loneliness, and social capital dimensions.

Results of logistic regression models

We fitted three logistic regression models (Table 2). In model 1 (the total subjects), two social capital dimensions were observed statistically associated with SRH, suggesting

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TABLE 1 Characteristics of participants stratified by self-rated health (SRH) status ($N = 1,810$).

Variables	Total ($N = 1,810$)	Phi and Cramer's V	Self-rated health		χ^2	p-value
			Poor ($N = 1,308$)	Good ($N = 502$)		
Age (years)		0.124			27.905	<0.001
60–64	399 (22.0)		251 (19.2)	148 (29.5)		
65–69	424 (23.4)		319 (24.4)	105 (20.9)		
70–74	421 (23.3)		302 (23.1)	119 (23.7)		
75–79	282 (15.6)		225 (17.2)	57 (11.4)		
≥ 80	284 (15.7)		211 (16.1)	73 (14.5)		
Sex		0.044			3.431	0.064
Male	770 (42.5)		539 (41.2)	231 (46.0)		
Female	1,040 (57.5)		769 (58.8)	271 (54.0)		
BMI (kg/m^2)		0.075			10.233	0.017
<18.5	189 (10.4)		148 (11.3)	41 (8.2)		
18.5–22.9	825 (45.6)		581 (44.4)	244 (48.6)		
23.0–27.4	644 (35.6)		457 (34.9)	187 (37.3)		
≥27.5	152 (8.4)		122 (9.3)	30 (6.0)		
Living status		0.052				
Not living alone	1,567 (86.6)		1,118 (85.5)	449 (89.4)	4.915	0.027
Living alone	243 (13.4)		190 (14.5)	53 (10.6)		
Residence		0.116			24.52	<0.001
Urban	801 (44.3)		532 (40.7)	269 (53.6)		
Rural	1,009 (55.7)		776 (59.3)	233 (46.4)		
Marital status		0.024			1.051	0.305
Married/cohabited	1,402 (77.5)		1,005 (76.8)	397 (79.1)		
Single	408 (22.5)		303 (23.2)	105 (20.9)		
Education		0.151			41.177	<0.001
Primary school and below	1,291 (71.3)		983 (75.2)	308 (61.4)		
Junior school	291 (16.1)		196 (15.0)	95 (18.9)		
High school and above	228 (12.6)		129 (9.9)	99 (19.7)		
Smoking status		0.014			0.367	0.832
Non-smoking	1,412 (78.0)		1,025 (78.4)	387 (77.1)		
Former smoking	99 (5.5)		71 (5.4)	28 (5.6)		
Smoking	299 (16.5)		212 (16.2)	87 (17.3)		
Drinking status		0.081			12.018	0.002
Non-drinking	1,484 (82.0)		1,094 (83.6)	390 (77.7)		
Former drinking	70 (3.9)		52 (4.0)	18 (3.6)		
Drinking	256 (14.1)		162 (12.4)	94 (18.7)		
Number of disease		0.421			321.185	<0.001
0	530 (29.3)		236 (18.0)	294 (58.6)		
1	714 (39.4)		556 (42.5)	158 (31.5)		
2	347 (19.2)		304 (23.2)	43 (8.6)		
>2	219 (12.1)		212 (16.2)	7 (1.4)		
Functional ability		0.189			64.586	<0.001
Robust	1,032 (57.0)		670 (51.2)	362 (72.1)		
Limited	778 (43.0)		638 (48.8)	140 (27.9)		

(Continued)

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TABLE 1 (Continued)

Variables	Total ($N = 1,810$)	Phi and Cramer's V	Self-rated health		χ^2	p-value
			Poor ($N = 1,308$)	Good ($N = 502$)		
Depression		0.361			235.616	<0.001
Normal	890 (49.2)		497 (38.0)	393 (78.3)		
Depressed	920 (50.8)		811 (62.0)	109 (21.7)		
Loneliness		0.193			67.386	<0.001
No	1,110 (61.3)		726 (55.5)	384 (76.5)		
Yes	700 (38.7)		582 (44.5)	118 (23.5)		
Social participation		0.144			37.617	<0.001
High	1,043 (57.6)		696 (53.2)	347 (69.1)		
Low	767 (42.4)		612 (46.8)	155 (30.9)		
Social support		0.212			81.025	<0.001
High	906 (50.1)		569 (43.5)	337 (67.1)		
Low	904 (49.9)		739 (56.5)	165 (32.9)		
Social connection		0.142			36.332	<0.001
High	1,279 (70.7)		872 (66.7)	407 (81.1)		
Low	531 (29.3)		436 (33.3)	95 (18.9)		
Trust		0.200			72.279	<0.001
High	1,023 (56.5)		659 (50.4)	364 (72.5)		
Low	787 (43.5)		649 (49.6)	138 (27.5)		
Cohesion		0.169			51.403	<0.001
High	1,078 (59.6)		712 (54.4)	366 (72.9)		
Low	732 (40.4)		596 (45.6)	136 (27.1)		
Reciprocity		0.245			108.235	<0.001
High	978 (54.0)		608 (46.5)	370 (73.7)		
Low	832 (46.0)		700 (53.5)	132 (26.3)		

the adjusted odds ratio (*AOR*) of having poor SRH was shown to be 1.57 times (95% *CI*: 1.21–2.04) and 1.73 times (95% *CI*: 1.29–2.31) more likely for people with a lower social capital concerning social support and reciprocity, respectively.

In model 2 (subjects with health conditions), three capital dimensions were observed to be statistically associated with SRH, indicating that the *AOR* of experiencing poor SRH was shown to be 1.55 times (95% *CI*: 1.06–2.27), 0.63 times (95% *CI*: 0.42–0.94), and 1.77 times (95% *CI*: 1.17–2.68) more likely for people with a lower social capital as to social participation, cohesion, and reciprocity, respectively.

In model 3 (subjects without health conditions), statistical significance remained was only found for one social capital dimension, showing the AOR of experiencing poor SRH was shown to be 2.15 times (95% *CI*: 1.39–3.33) more likely for people with a lower social capital regarding social support.

Results of the CART model

As shown in Figure 1 (the total subjects), depression, loneliness, social support, reciprocity, cohesion, functional ability, and trust were found to be linked to SRH, suggesting the interaction relationships between social capital and other variables were observed.

In particular, subjects who were depressed (Node 1) and lonely (Node 4), also reported a lower level of cohesion and were at the largest risk of experiencing poor SRH (Node 10). Meanwhile, those without depressive symptoms (Node 2), a high level of social support (Node 5) and a robust functional ability (Node 11) were least likely to experience poor SRH (Node 11). In addition, those who have less social support (Node 6) and less trust (Node 14) were inclined to suffer poor SRH when compared with those with a higher level of trust (Node 13). Similarly, those depressed respondents (Node 1) but not lonely (Node 3), who reported a lower level of reciprocity (Node 8)

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TABLE 2 Results of the odds ratio (*OR*) for developing poor self-rated health.

	Model 1		Model 2		Model 3	
	OR (95% CI)	AOR (95% CI)	OR (95% CI)	AOR (95% CI)	OR (95% CI)	AOR (95% CI)
Age (years)						
60–64	REF.	REF.	REF.	REF.	REF.	REF.
65–69	1.79 (1.33–2.42)***	1.93 (1.37–2.72)***	1.92 (1.23–2.99)**	2.23 (1.35–3.68)**	1.07 (0.64–1.78)	1.12 (0.63–2.00)
70–74	1.50 (1.12–2.01)**	1.60 (1.14–2.24)**	1.41 (0.92–2.15)	1.66 (1.02–2.69)*	1.28 (0.79–2.07)	1.19 (0.67–2.10)
75–79	2.33 (1.63–3.32)***	2.31 (1.54–3.48)***	1.95 (1.19–3.21)**	2.25 (1.28–3.97)**	1.80 (0.99–3.28)	1.55 (0.77–3.14)
≥80	1.70 (1.22–2.38)**	1.38 (0.92–2.09)	1.33 (0.83–2.15)	1.27 (0.71–2.26)	2.13 (1.25–3.63)**	1.51 (0.75–3.04)
Sex						
Male	REF.	REF.	REF.	REF.	REF.	REF.
Female	1.22 (0.99–1.50)	1.10 (0.81–1.49)	1.30 (0.96–1.75)	1.27 (0.84–1.94)	0.99 (0.70–1.40)	0.92 (0.55–1.56)
BMI (kg/m^2)						
18.5–22.9	REF.	REF.	REF.	REF.	REF.	REF.
<18.5	1.52 (1.04–2.21)*	1.33 (0.87–2.02)	1.89 (0.98–3.65)	1.67 (0.83–3.40)	1.94 (1.14–3.30)*	1.59 (0.85–2.97)
23.0–27.4	1.03 (0.82–1.29)	1.14 (0.88–1.48)	0.83 (0.60–1.14)	0.87 (0.61–1.24)	1.05 (0.71–1.56)	1.35 (0.86–2.11)
≥ 27.5	1.71 (1.11–2.62)*	1.78 (1.10–2.87)*	1.37 (0.76–2.46)	1.33 (0.69–2.54)	1.52 (0.72–3.20)	1.95 (0.83–4.54)
Living status						
Not living alone	REF.	REF.	REF.	REF.	REF.	REF.
Living alone	1.44 (1.04–1.99)*	1.29 (0.83–1.99)	1.67 (1.02–2.73)*	1.89 (1.01–3.54)*	1.06 (0.62–1.82)	0.76 (0.36–1.59)
Residence						
Urban	REF.	REF.	REF.	REF.	REF.	REF.
Rural	1.68 (1.37–2.07)***	1.19 (0.92–1.54)	1.65 (1.22–2.22)**	1.11 (0.78–1.59)	2.08 (1.47–2.96)***	1.51 (0.96–2.39)
Marital status						
Married/cohabited	REF.	REF.	REF.	REF.	REF.	REF.
Single	1.14 (0.89–1.46)	0.70 (0.49–1.00)*	0.99 (0.70–1.40)	0.52 (0.32–0.84)**	1.23 (0.81–1.88)	1.10 (0.61–2.01)
Education						
High school and above	REF.	REF.	REF.	REF.	REF.	REF.
Primary school and below	2.45 (1.83–3.28)***	1.21 (0.84–1.75)	2.54 (1.70–3.81)***	1.20 (0.74–1.97)	2.31 (1.37–3.88)**	1.29 (0.67–2.47)
Junior school	1.58 (1.11–2.27)*	1.29 (0.86–1.93)	1.64 (0.99–2.71)	1.36 (0.78–2.36)	1.53 (0.81–2.88)	1.24 (0.60–2.54)
Smoking status						
Non–smoking	REF.	REF.	REF.	REF.	REF.	REF.
Former smoking	0.96 (0.61–1.51)	1.35 (0.76–2.39)	0.71 (0.40–1.23)	1.19 (0.59–2.42)	0.50 (0.16–1.63)	0.49 (0.12–1.96)
Smoking	0.92 (0.70–1.21)	1.21 (0.83–1.77)	1.09 (0.70–1.68)	1.43 (0.82–2.51)	1.13 (0.74–1.72)	1.25 (0.69–2.27)
Drinking status						
Non-drinking	REF.	REF.	REF.	REF.	REF.	REF.
Former drinking	1.03 (0.60–1.78)	0.97 (0.50–1.89)	0.82 (0.42–1.61)	0.83 (0.36–1.89)	0.49 (0.12–1.91)	0.57 (0.12–2.65)
Drinking	0.61 (0.46–0.81)***	0.62 (0.43–0.88)**	0.73 (0.48–1.11)	0.74 (0.44–1.24)	0.64 (0.41–1.01)	0.53 (0.30–0.94)*
Functional ability						
Robust	REF.	REF.	REF.	REF.	REF.	REF.
Limited	2.46 (1.97–3.08)***	1.71 (1.29–2.27)***	2.27 (1.65–3.11)***	1.58 (1.07–2.34)*	1.93 (1.34–2.80)***	1.35 (0.82–2.22)

(Continued)

TABLE 2 (Continued)

	Model 1		Model 2		Model 3	
	OR (95% CI)	AOR (95% CI)	OR (95% CI)	AOR (95% CI)	OR (95% CI)	AOR (95% CI)
Depression						
Normal	REF.	REF.	REF.	REF.	REF.	REF.
Depressed	5.88 (4.63–7.48)***	3.75 (2.84–4.94)***	5.88 (4.16–8.30)***	3.78 (2.55–5.62)***	4.45 (3.04–6.51)***	2.93 (1.84–4.66)***
Loneliness						
No	REF.	REF.	REF.	REF.	REF.	REF.
Yes	2.61 (2.07–3.29)***	1.59 (1.21–2.09)**	2.51 (1.80–3.50)***	1.58 (1.07–2.32)*	2.06 (1.40–3.01)***	1.40 (0.88–2.22)
Social participation						
High	REF.	REF.	REF.	REF.	REF.	REF.
Low	1.97 (1.58–2.45)***	1.13 (0.87–1.47)	2.40 (1.73–3.33)***	1.55 (1.06–2.27)*	1.69 (1.19–2.40)**	0.87 (0.56–1.35)
Social support						
High	REF.	REF.	REF.	REF.	REF.	REF.
Low	2.65 (2.14–3.29)***	1.57 (1.21–2.04)**	2.32 (1.71–3.17)***	1.39 (0.96–2.02)	3.32 (2.32–4.75)***	2.15 (1.39–3.33)**
Social connection						
High	REF.	REF.	REF.	REF.	REF.	REF.
Low	2.14 (1.67–2.75)***	0.92 (0.68–1.24)	2.15 (1.49–3.10)***	0.99 (0.64–1.53)	1.95 (1.30–2.91)**	0.81 (0.49–1.34)
Trust						
High	REF.	REF.	REF.	REF.	REF.	REF.
Low	2.60 (2.08–3.25)***	1.23 (0.91–1.65)	2.45 (1.77–3.37)***	1.29 (0.85–1.95)	2.42 (1.68–3.48)***	1.05 (0.64–1.75)
Cohesion						
High	REF.	REF.	REF.	REF.	REF.	REF.
Low	2.25 (1.80–2.82)***	0.85 (0.63–1.14)	1.74 (1.27–2.38)**	0.63 (0.42–0.94)*	2.66 (1.83–3.87)***	1.13 (0.68–1.89)
Reciprocity						
High	REF.	REF.	REF.	REF.	REF.	REF.
Low	3.23 (2.57–4.05)***	1.73 (1.29–2.31)***	3.08 (2.23–4.27)***	1.77 (1.17–2.68)**	2.92 (2.03–4.22)***	1.59 (0.98–2.57)

Model 1, Model 2, and Model 3 included 1,810, 1,280, and 530 participants, respectively.
OR, odds ratio; AOR, adjusted odds ratio; 95% CI, 95% confidence intervals.
*$p < 0.05$; **$p < 0.01$; and ***$p < 0.001$.

were more likely to suffer the poor SRH in comparison with those who reported a higher level of reciprocity (Node 7).

Discussion

This study explored the relationship between social capital and SRH, with a focus on exploring whether the association varies with the presence of health conditions and how social capital, together with other variables, is linked to SRH among community-dwelling older adults in the Anhui province of China. We found that a few dimensions of social capital were associated with SRH and such associations varied by the presence of health conditions. Furthermore, potential mechanisms for how social capital is linked to SRH were reported. Specifically, older people with depression, loneliness, and functional ability limited, while reporting less social capital concerning social support, trust, cohesion, and reciprocity were prone to have poor SRH.

Our analyses indicated that, among the total participants, social capital in terms of social support and reciprocity, were positively associated with SRH, suggesting that older people who have more social support (such as, mental support and material support) and reciprocity (reciprocal willingness with their relatives, friends/neighbors, and strangers) are more likely to have better SRH, which is consistent with prior studies (10, 23). Similarly, such an association was also observed among older people without health conditions, which also suggested that high-level social support was a protective factor against poor SRH. While this association altered among older people with health conditions. In other words, social capital regarding social participation and reciprocity was positively connected with SRH, indicating the protective role of social participation

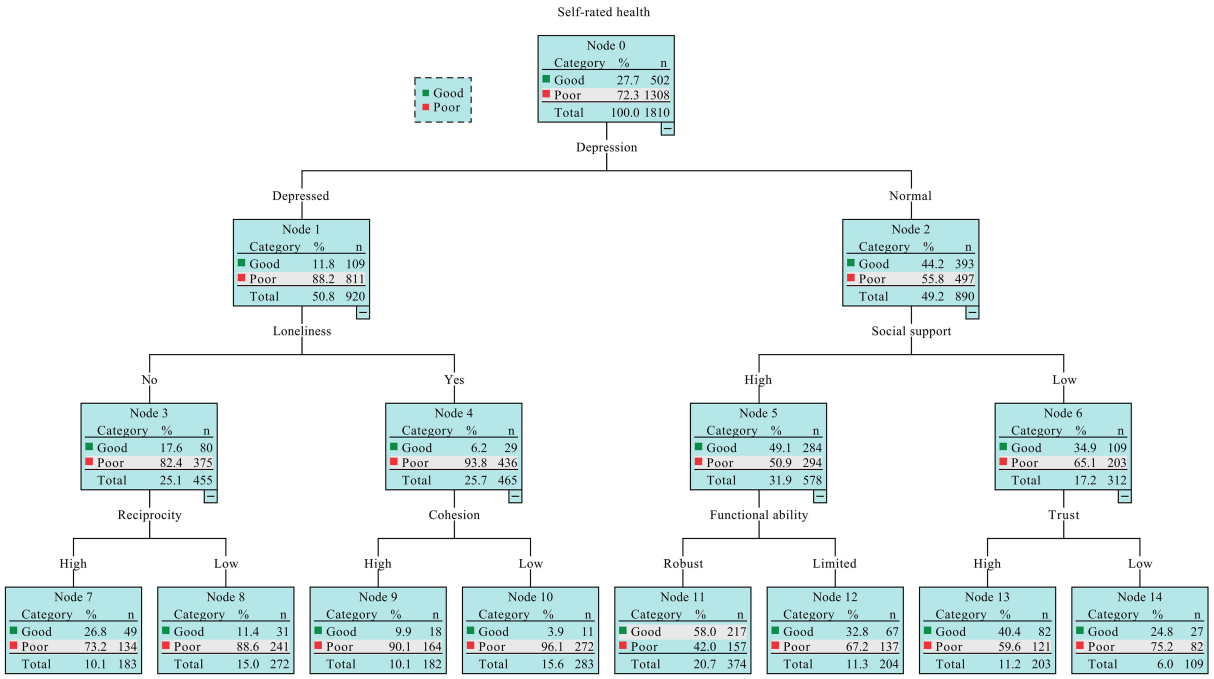

FIGURE 1
The classification and regression tree (CART) model output of the combinations of social capital factors and variables.

and reciprocity for these communities. Though such protective roles were also documented in other studies (17, 40, 41), unlike these studies, our study paid special attention to these vulnerable groups, which validated the association of social capital with SRH is moderated by the presence of health conditions. In contrast to prior findings, which found the benefit of cohesion to SRH (42), our results reported that cohesion was negatively connected with SRH. A possible reason may be that older people with health problems are less willing to communicate or interact with others, thereby leading to less attachment to the surrounding community (43), which also emphasizes that more research is needed in the future. More importantly, the variations also emphasize that different measures concerning social capital to decrease the development of poor SRH should be well designed.

Nevertheless, based on our analyses, social connection, one of the six social capital indicators, was found to have no association with SRH, which was different from a prior study that reported an existing association of age peers with better SRH (44). This may be explained by the different items used to evaluate the social connection in the two studies. For example, in our study, 3 items (denoting the frequency of the older people getting in touch with their children, relatives, friends, or neighbors) were used to assess social connection, whereas that study used one item (indicating their agreement with the question about how they feel connected to their peers) to assess the association. This difference may imply that connection with peer groups is more crucial than connection with other individuals among older people. Of note, most of the previous research evaluated social capital using different indicators or dimensions. Therefore, findings on the role of social capital on SRH among older people are inconclusive, partly due to a lack of widely accepted definition and measurement of social capital (1).

In this work, we found a joint effect of social capital on SRH using a CART model. Other than the aforementioned social capital dimensions, such as social participation and trust (17, 40, 41, 45), social support (10), cohesion (42), and reciprocity (23), were found to be associated with SRH. Elsewhere, a study revealed that depression (46), loneliness (47), and functional ability (48), were associated with SRH among older adults. However, based on the current knowledge, few studies have explored how the interaction between these variables impacts SRH among older people. In the present study, depression was revealed to be the most important factor linked to SRH. Low levels of social capital, such as cohesion and depression with loneliness denoted the highest rate of developing poor SRH. Similarly, the combination of a low level of social capital (social support, reciprocity, and trust), loneliness, and limited functional ability suggests a greater possibility of the occurrence of poor SRH.

Our findings on the joint effects of social capital and other factors on SRH, not only, can be utilized to identify which

subsets of elders are most liable to exhibit SRH. However, elucidating the potential mechanisms by which social capital is linked to SRH contributes to developing tailored and accurate measures to improve SRH among community-dwelling older adults. Specifically, special attention should be paid to those older people with health problems who are depressed and have functional ability limitations, also had a lower social capital, such as reciprocity. In addition, older adults without health conditions are encouraged to maintain good mental health, robust functional ability, and powerful social support from their children, relatives, friends, or community members to maximize the chance of having good SRH. More importantly, for general advanced age communities, to have good SRH, multiple programs or initiatives containing how to prevent depressive symptoms, loneliness, and functional limitation and cultivate the shape of social support, reciprocal, and trusting relationship with others, and cohesion in the community should be well designed in daily life. However, in addition to the above-mentioned significance and importance of the CART model results, some cautions should be made, as we described, this model is nonparametric, it is best to refer to the explanation together with another regression model when interpreting the result.

The present study has some major strengths. First, we utilized a valid and reliable scale, including six items to determine individual social capital in China. Hence, our work may promote the development of social capital in health research. Second, methodologically, we employed a sophisticated and comprehensive nonparametric CART model, which, together with results obtained by the logistic regression model, allowed us to explore the interplay of multiple variables and better explore the relationship between social capital and SRH. More importantly, we explored the interactive association between social capital and SRH, which further throws light on depicting potential mechanisms behind this association.

However, a few limitations should be acknowledged in our study. First, this was a cross-sectional study, making it hard to determine the causal association between social capital and SRH. Second, the data analyzed were collected by self-report, which could be associated with a risk of recall bias due to false or inaccurate responses from the participants. Furthermore, the social capital data analyzed in this study were only measured at an individual level, we did not include community-level social capital, and hence a study that incorporates community-level social capital may better appreciate the role of social capital theory in the future.

Conclusions

This study provides evidence on the association between social capital and SRH, which shows that the relationship between social capital and SRH varies by the presence of health conditions among community-dwelling older people. Additionally, to better maintain SRH, much focus should be devoted to older people with health conditions and less reciprocity and social participation.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Biomedical Ethics Committee, Anhui Medical University (No. 20150297). The patients/participants provided their written informed consent to participate in this study.

Author contributions

ZB and JY participated in the survey, the data analysis, and writing of the article. ZW, WC, and CC contributed to the data collection. ZH and RC participated in the design of the study, contributed to quality control and data processing, and revised the manuscript. All authors have read and approved the final version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The micro-macro interplay of economic factors in late-life loneliness: Evidence from Europe and China

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Individual socioeconomic status has a significant impact on whether older adults can initiate and maintain social relationships and participate in society, hence it affects loneliness. At the macro level, income inequality is expected to increase the risk of loneliness by eroding social cohesion and trust, while welfare generosity might protect people from loneliness. The aim of the study is to explore whether income inequality and welfare generosity at the country level moderate the effect of socioeconomic status at the individual level on late-life loneliness. Data were obtained from the HRS family of surveys – the Survey of Health, Aging and Retirement in Europe (SHARE) (wave 5, 2011/12) and China Health and Retirement Longitudinal Study (CHARLS) (wave 2, 2012/13). Respondents aged 50 years and older from twelve European countries and China were included in the study. Logistic country fixed effect models were used in the analysis. The findings show a stronger effect of individual socioeconomic status on late-life loneliness in more income-unequal societies and a weaker effect in more welfare-generous societies. There is a need to consider the impact of income distribution and welfare spending on the risk of loneliness among those older adults with low socioeconomic status when tailoring preventive programs and interventions to reduce loneliness among this vulnerable group.

KEYWORDS

income inequality, welfare generosity, loneliness, older people, Europe, China, socioeconomic status

Introduction

Loneliness has been defined as the subjective feeling of a mismatch between desired and actual number of meaningful social contacts (1). As people age, their level of loneliness increases (2) because considerable changes in life circumstances, including bereavement and health decline, accompany old age (3–5). The prevalence of loneliness in old age varies geographically. In the European setting, cross-country comparative studies show that the prevalence of loneliness among older adults aged 60 and older generally is lowest in Northern European countries, followed by Southern European

countries, and highest in Central and Eastern European countries (6, 7). Literature on China reports prevalence rates of loneliness similar to their peers in Central and Eastern Europe (8–11).

A large body of literature shows that individual-level characteristics such as age, gender, health, marital status, socioeconomic status, social participation, social support, and social networks are associated with older adults' loneliness (12–17). To explain these cross-country differences in late-life loneliness, many studies focus on differences in population composition between countries (6, 7, 18, 19). However, these studies invariably show that country variation in loneliness partially remains after controlling for compositional differences. This has led to an increasing awareness that loneliness is not an exclusively individual phenomenon, but is embedded in social, cultural, and material contexts (20, 21). In recent years, several researchers have taken up the gauntlet by investigating whether country-level characteristics [macro-level factors, such as societal individualism (22, 23), level of trust (24), and type of welfare regime (25)] and interactions between individual characteristics and country (micro-macro interplay) help to explain cross-country differences in late-life loneliness. Lykes and Kemmelmeier (22), for instance, examined whether the experience of older adults' loneliness is culturally related. They ranked European countries on Hofstede's index of collectivism-individualism (26), where being part of traditional kinship networks is more normative in collectivistic societies and personal choice in forming social relationships is more valued in individualistic societies. Besides higher levels of loneliness among older adults in collectivistic societies, findings show that less frequent family contact is more closely linked to loneliness in collectivistic societies, while less frequent contact with friends weighs more in individualistic societies. Zoutewelle-Terovan and Liefbroer (23), looking at the effect of non-normative life transitions (i.e., never and off-time occurrence of partnership and parenthood) on late-life loneliness in twelve European countries, examined whether cross-country variation in the size of the effects could be explained by country differences in familialism values and opinions on economic insecurity. Results show that only the effect of childlessness (compared to those who experienced having a child "on time") was larger in countries where individuals felt more strongly attached to traditional, familialism values. Rapoliene and Aartsen (24) were interested in whether the higher prevalence of late-life loneliness in Eastern European post-totalitarian countries, compared to other European countries and Israel, can be ascribed to lower levels of trust in people (generalized trust) and in the system: although lower levels of both types of trust were observed, generalized trust and trust in the system did not appear to directly affect loneliness. Instead, a low level of generalized trust was found to lead to social disengagement, in turn increasing the likelihood of feeling lonely. A final example is the study of Nyqvist et al. (25), who explored the impact of state involvement in social welfare on late-life loneliness, directly and indirectly through individual resources (like living conditions and level of social integration). They divided 20 European countries into five welfare regimes: Nordic, Continental, Anglo-Saxon, Southern, and Eastern. The Nordic regime, known for its high extent of state involvement in social welfare, had the lowest proportion of older adults feeling lonely (some of the time, most of the time, almost all of the time), followed by the Continental and Anglo-Saxon regimes. Older adults living in the Nordic regime were less dependent on their own social resources for loneliness compared to regimes where loneliness was to a greater extent conditioned by family and other social ties. It remains unclear, however, whether these findings are actually linked to differences in level of state welfare provision, as dummies for type of regime instead of specific country-level factors (such as social welfare spending and benefit receipt) were included.

To the best of our knowledge, no research has yet been conducted on the extent to which country-level economic factors influence the effect of individual-level socioeconomic status on older adults' loneliness. This study aims to investigate this micro-macro interplay of economic factors. Specifically, we will examine the moderating effects of countries' income inequality and welfare generosity on the association between individual-level household income and loneliness in later life.

Theoretical framework

Individual-level socioeconomic status and loneliness

Empirical studies have repeatedly shown that older adults with lower socioeconomic statuses (captured by factors like low educational level, low income, residential dissatisfaction, and living in deprived neighborhoods) are more likely to be lonely (14, 20, 27–29). While there is virtually no literature directly linking socioeconomic status to the experience of loneliness, several theoretical pathways have been proposed through which low socioeconomic status increases the risk of loneliness. Nearly all pathways consider socioeconomic status as a distal factor affecting the more proximate conditions for people's ability to optimize and diversify social contacts, and in turn loneliness (6, 18, 20, 30). The most-often cited pathway is that individuals of low socioeconomic status have fewer financial resources for initiating and maintaining social relationships (18, 31): for example, sufficient income is needed to invite people into one's home for a drink or dinner, or to go on an outing together. Financial resources also allow people to fully participate in society by being able to afford memberships in clubs and organizations, transport costs, and leisure activities. Another explanation is that lower socioeconomic groups generally have poorer social skills and lower self-esteem, which makes them less confident and uninhibited in social interactions and hence less

attractive to others (6, 32). One pathway suggests the enhanced risk of poor physical and/or mental health status or reduced functioning, which can lead to fewer social interactions and lower participation in the wider society, including employment, volunteering, and leisure and other social activities (6, 33–35). Last, there is the greater likelihood of living in a deprived neighborhood, where there is often an accumulation of physical and socioeconomic problems (unsafe public spaces, lack of social cohesion, low participation levels, high proportion of low-income households) resulting in restricted social interactions (36–39). In an English representative survey, Victor and Pikhartova (40) pointed out that older people living in the most deprived areas were more likely to experience loneliness than their counterparts living in the least deprived areas.

Income inequality, welfare generosity and loneliness

Income inequality at the country level may increase the risk of loneliness by eroding social cohesion and trust (24, 41). In egalitarian societies where differences in social status, power, and wealth are less prominent, people are more likely to be cooperative and have harmonious social relationships with others, generating mutual trust; in less egalitarian societies, people are less caring of others and more likely to compete with each other and distrust others (42–44). The social distance between people is greater in less egalitarian societies and individuals' social connections with the outside world are looser, increasing the risk of loneliness (43, 45, 46).

A high level of state involvement in welfare provisions may protect individuals from loneliness (25). By making social services and benefits available to individuals, people in generous welfare states are less dependent on personal and social resources to establish relationships with others, which increases people's ability to be socially integrated (25, 47, 48). Such generous welfare support can help individuals obtain their desired social capital, social networks, and trust (48, 49), lowering the likelihood of loneliness.

Impact of individual-level socioeconomic status on loneliness in the context of income inequality and welfare generosity

Income differences are not only about comparison of income itself, but more about differences in quality of life and the perception of its social fairness (44, 50, 51). In societies with high income inequality, people with low socioeconomic status are aware that the good and rich social life enjoyed by their counterparts from the upper classes is never within their means. Studies show that relative deprivation, a sense of having less than one feels entitled to, causes stress as well as feelings of exclusion and being less valued (20, 27, 52). This implies that, at the individual level, low socioeconomic status has a stronger effect on loneliness in a more income-unequal society. We hypothesize that older adults with a lower socioeconomic status in countries with less egalitarian income distribution are more likely to be lonely than their counterparts in countries with more egalitarian income distribution (Hypothesis 1).

A high level of state involvement in welfare provisions may particularly protect socioeconomically disadvantaged people from loneliness. It decreases the risk of living in poverty, hence increasing the ability to be socially engaged (36, 47). People with access to social services and benefits as a backup have better chances of establishing and maintaining a social network without being excessively hampered by basic livelihood concerns, such as food, housing, and medical care (20, 53), and of being socially integrated. Nyqvist et al. (25) exemplified this latter point by showing that older adults living in the Nordic regime, characterized by a high extent of state involvement in social welfare, were less dependent on their own social resources for loneliness compared to those living in regimes with a lower level of state involvement. The state may fund services that allow people to interact socially and participate in social activities. The above implies that, at the individual level, low socioeconomic status has a weaker effect on loneliness in a more generous welfare society. We therefore hypothesize that older adults with a lower socioeconomic status in countries with more generous welfare provisions are less likely to be lonely than their counterparts in countries with less generous welfare provisions (Hypothesis 2).

Materials and methods

Data sources

Data of the dependent variable and all individual-level predictors were obtained from the HRS family of surveys—the Survey of Health, Ageing and Retirement in Europe (SHARE) (wave 5, 2011/12) and China Health and Retirement Longitudinal Study (CHARLS) (wave 2, 2012/13). Both are representative panel surveys of the non-institutionalized older population (54), providing a unique opportunity to probe late-life loneliness in the countries studied. Harmonized datasets developed by the Gateway to Global Aging Data were also used where the comparable variables were provided (for more information, refer to www.g2aging.org). Two country-level predictors were selected based on World Development Indicators (World Bank estimate), Eurostat, and the China National Bureau of Statistics. In the study, respondents aged 50 years and older from twelve European countries (Austria,

Belgium, Czech Republic, Denmark, Estonia, France, Germany, Italy, the Netherlands, Slovenia, Spain, Sweden)[1] and China were included in the analyses. After removing individuals with missing values on any of our variables of interest ($N = 10{,}879$ (14.91%)), the final sample comprised 62,084 respondents. Excluded respondents were slightly older, less educated, in poorer health, and living in households with lower income.

Dependent variable

The dependent variable of loneliness was generated based on respondents' report to the question "How often do you feel lonely?." In the harmonized CHARLS, the question has four answer options: "rarely," "some or a little of the time," "occasionally or a moderate amount of time," and "most or all of the time." SHARE wave 5 uses a three-category response scale: "hardly ever or never," "sometimes," and "often." By recoding "rarely/some or a little of the time" in CHARLS and "hardly ever or never" in SHARE to 0 and other categories to 1, a binary variable was created, contrasting older adults with loneliness and the counterparts without loneliness.

Independent variables

Individual-level socioeconomic status

Respondents' household income and the individual-level socioeconomic status variable were obtained from harmonized datasets. Income measures in the Harmonized CHARLS are expressed in Chinese yuan, income measures in the SHARE in nominal euros from wave 2 (56, 57). To make this comparable across the countries studied, we generated a categorical variable (4 groups) with the highest quartile (richest group) as reference group, indicating the respondent's household income per capita position measured in quartiles estimated separately for each country.

Country-level income inequality and welfare generosity

The two country-level independent variables are the Gini index to measure income inequality and social expenditure as percentage of GDP to measure welfare generosity. Gini index is used as a sophisticated measurement to assess inequality across the entire society (45). It measures the extent to which the distribution of income among individuals or households within an economy deviates from a perfectly equalitarian distribution. Data used in this study are based on primary household survey data obtained from government statistics agencies and World Bank country departments. For more information and methodology, see PovcalNet (iresearch.worldbank.org/PovcalNet/index.htm). A Gini index of 0 represents perfect equality, an index of 100 implies absolute inequality – so the lower its value, the more egalitarian the distribution of income in a country.

Welfare generosity is one of the common quantitative indicators of welfare state effort and, as in this study, is mostly measured by social expenditure as percentage of GDP (49). For European countries, data of social expenditures were collected by Eurostat, comprising social benefits that consist of transfers, in cash or in kind, to households and individuals to relieve them of the burden of a defined set of risks or needs; administration costs representing the costs charged to the scheme for its management and administration; and other miscellaneous expenditures of social protection schemes (payment of property income and other)[2]. For China, the social expenditure scale based on the National Bureau of Statistics[3] (2017) consists of government expenditures, in cash or in kind, in six domains: health, pension and elderly services, welfare for the disabled, employment protection, housing security, and other social services. Data from 2012 were used for all studied countries. Figure 1 shows income inequality and welfare generosity for these countries.

Gini index and social expenditure as percentage of GDP are correlated ($r = -0.64$, $N = 13$). With some exceptions, there is a European north-west/south-east divide with higher income inequality and less generous welfare resources in the Southern and Eastern countries. China has the highest income inequality and the lowest level of welfare generosity. Due to the considerable correlation, we examined these two country-level predictors and their interaction with individual-level income status separately.

Covariates

We included several covariates in the analysis that are well-known predictors of loneliness: age, gender (0 = male, 1 = female), marital status, household size, educational level, work status, health status, and child living proximity (12, 15, 58). The variable age (in years) was centered at its country sample mean. Marital status was a nominal variable with four categories: married or partnered (reference group), separated or divorced, widowed, never married. Household size was measured as the total number of persons currently residing in the household:

1 Because Israel and Switzerland are not EU countries, and Luxembourg is an extremely small and wealthy country with only 62.9% respondents with citizenship status (55), we dropped these country samples.

2 Source: Eurostat, Expenditure on social protection, https://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=tps00098.

3 Source: National Bureau of Statistics, Comparative Analysis of Social Security Expenditure between China and EU (in Chinese), http://www.stats.gov.cn/tjzs/tjsj/tjcb/dysj/201709/t20170929_1539209.html.

TABLE 1 Characteristics of the study population.

	Austria	Belgium	China	Czech Rep.	Denmark	Estonia	France	Germany	Italy	Netherlands	Slovenia	Spain	Sweden	Overall
Age (mean)	66.85	65.45	61.99	66.55	64.88	67.94	67.14	64.46	66.38	65.68	66.51	67.70	67.99	65.84
Female (%)	57.80	54.74	49.91	58.62	53.43	61.23	57.04	52.37	54.45	54.75	56.86	53.77	53.30	57.80
Marital status (%)														
Married/partnered	65.71	71.80	87.19	70.05	78.05	67.16	68.54	79.94	79.46	79.64	74.35	80.01	77.69	76.17
Divorced/separated	11.78	10.65	1.22	10.69	7.95	9.15	8.88	6.91	2.88	6.86	4.26	2.90	8.55	6.78
Widowed	15.68	12.57	10.80	17.47	10.00	18.69	16.63	9.07	11.89	10.08	16.73	12.02	8.72	12.93
Never married	6.83	4.98	0.79	1.79	3.99	4.99	5.96	4.08	5.77	3.43	4.66	5.07	5.04	4.12
Education (%)														
High	26.16	33.79	1.30	13.05	42.45	21.60	21.46	29.61	8.28	27.81	17.38	10.56	30.82	20.21
Medium	61.68	48.69	10.03	74.39	47.44	72.95	43.89	68.68	44.91	61.58	72.73	31.39	47.61	49.66
Low	12.16	17.52	88.67	12.56	10.11	5.45	34.65	1.71	46.81	10.62	9.89	58.05	21.57	30.13
Working (%)	26.70	33.57	66.72	32.30	48.52	37.62	30.87	43.50	25.45	37.74	18.97	26.67	43.65	38.77
Subjective health (%)														
Very good	33.07	28.66	9.86	16.88	54.69	5.14	20.60	20.52	21.25	28.04	17.84	19.17	43.84	22.81
Good	35.52	44.17	14.02	38.49	23.34	23.13	42.47	39.42	36.10	43.49	44.68	39.27	32.39	33.55
Fair	24.71	21.77	53.90	30.57	16.91	50.31	26.07	30.35	30.28	23.89	25.62	28.43	18.49	31.61
Poor	6.71	5.40	22.22	14.06	5.07	21.41	10.86	9.72	12.37	4.58	11.86	13.13	5.28	12.03
IADLs (mean)	0.03	0.04	0.09	0.03	0.03	0.05	0.04	0.03	0.04	0.02	0.03	0.05	0.02	0.04
Household size (%)														
1	30.42	24.17	4.94	24.32	21.79	26.37	27.83	17.93	15.36	20.67	18.49	13.51	22.93	19.51
2	53.26	55.56	35.38	56.96	65.08	56.88	56.99	63.56	46.49	64.95	50.73	52.85	69.47	54.61
3+	16.32	20.26	59.68	18.72	13.13	16.76	15.18	18.52	38.16	14.38	30.78	33.63	7.60	25.88
Children (%)														
Childless	12.39	12.19	1.88	4.32	8.22	8.89	10.45	11.81	12.46	10.57	6.77	10.56	7.19	8.63
Lives with at least one child	15.12	17.92	45.10	16.78	11.37	15.45	11.11	18.30	30.65	13.07	29.60	28.07	8.84	21.84
At least one child lives nearby	52.86	51.65	41.76	60.48	45.42	46.79	40.46	47.41	38.61	51.78	55.11	45.87	52.22	47.97
All children live far	19.63	18.24	11.26	18.42	35.00	28.86	37.98	22.48	18.28	24.58	8.53	15.50	31.75	21.57
N	*3,922*	*5,241*	*8,785*	*5,256*	*3,809*	*5,287*	*4,078*	*5,444*	*4,382*	*3,909*	*2,791*	*5,483*	*4,186*	*62,573*

The italic values indicate the number of observations.

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1 (reference group), 2, 3 or more. Educational level was recorded using the International Standard Classification of Education (59) and divided into three categories: low (less than lower secondary education), medium (upper secondary or vocational training), and high (tertiary education, reference group). Work status was generated from the response to whether (= 1) or not (= 0) working for pay last year (CHARLS), and since the last interview or in the last four weeks (SHARE). Subjective health was assessed by asking respondents to report their health status, with response options from 1 "excellent" to 5 "poor." Due to a low proportion of respondents answering "excellent," we combined "excellent" with "very good." Limitations in instrumental activities of daily living (IADLs) were assessed by asking respondents whether they experience any difficulty performing six tasks: managing money, taking medications, shopping for groceries, preparing a meal, cleaning the house, making phone calls. An IADLs summary score adjusted by the number of IADL questions with missing values was used in the analyses. Child living proximity variable was categorized into "no child" (reference group), "live with at least one child," "at least one child lives nearby," or "all children live far." Table 1 shows the characteristics of the study population.

Analytical approach

We first descriptively explored the association between an individual's loneliness and household income on a micro level per country (Table 2) and the correlations between country-level factors and prevalence of loneliness (Figure 1). Next, logistic country fixed effect models were built to examine the risk of feeling lonely by the individual's household income status, and how the potential influence of individual-level income varied in two macro contexts measured as Gini index and social expenditure (Table 3). In the fixed effect models the data from different countries were pooled, and the model specification included distinct country intercepts estimated as the coefficients on country dummies (Denmark is the reference group). The country dummies are controls and do not reflect a test of the research hypotheses. As we expected income inequality and welfare generosity to be a trigger and a buffer against the risk of loneliness among socioeconomically disadvantaged older adults, the cross-level interaction of the individual-level and the country-level variables were included to operationalize the moderating effect of macro contexts on the association between individual socioeconomic status and late-life loneliness. In doing so, the individual effects of economic status are allowed to differ between countries (60).

Compared with the multilevel approach, which is a more straightforward strategy to examine multilevel hypotheses (61), the FE method can be applied with small samples at a higher level, avoiding the omitted variable bias (58), such as influence of cultural norms on loneliness. One limitation of FE models is that estimates of the fixed parameters may be imprecise, particularly if associated with country-level factors, but they are generally unbiased (62–64).

TABLE 2 Descriptive statistics for the sample of older adults (50+) by country.

	N	Feel lonely (%)	Household income per capita		*p*[a]
			Mean	SD	
Austria	*3,877*	17.28	17,306	11,128	
Belgium	*5,150*	24.72	26,012	30,120	***
China[b]	*8,785*	22.21	9,766	24,240	***
Czech Republic	*5,177*	28.88	5,330	3,393	+
Denmark	*3,774*	9.78	24,976	13,789	***
Estonia	*5,266*	26.41	5,603	5,191	***
France	*4,049*	30.23	23,527	116,363	**
Germany	*5,386*	17.16	18,930	13,303	***
Italy	*4,361*	33.16	11,241	22,174	*
Netherlands	*3,858*	22.47	22,372	21,904	**
Slovenia	*2,788*	18.33	7,465	7,988	**
Spain	*5,455*	22.40	9,711	8,724	*
Sweden	*4,158*	22.17	28,800	15,899	***

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
[a]Pearson Chi-square test is used to determine whether there is a statistically significant difference in the likelihood of feeling lonely by quartile of household income per capita groups.
[b]Income measures for the 12 European countries are expressed in euros, for China in yuan. The average yuan-to-euro exchange rate was 0.1233 at the time of the survey.
[c]The italic values indicate the number of observations.

Results

The descriptive statistics by country in Table 2 show that the highest prevalence of loneliness among older adults was in Italy, France, the Czech Republic, and Estonia (26–33%). Denmark had the lowest proportion of lonely older adults (10%), followed by Austria and Germany (17%). In the remaining countries, including China, the prevalence of loneliness ranged between 22 and 25%. Sweden, Belgium, Denmark, France, and the Netherlands had the highest household income per capita (above 20,000 euros), the Czech Republic, Estonia, Slovenia, Spain, and China the lowest (below 10,000 euros and 9,766 Chinese yuan). Bivariate analysis showed a significant negative association between individuals' household income and loneliness in each country, except for Austria. Correlations between prevalence of loneliness and the two country-level economic factors (Gini index and social expenditure) were low and not statistically significant (see Pearson correlation coefficient *r* and *p*-value in Figure 1).

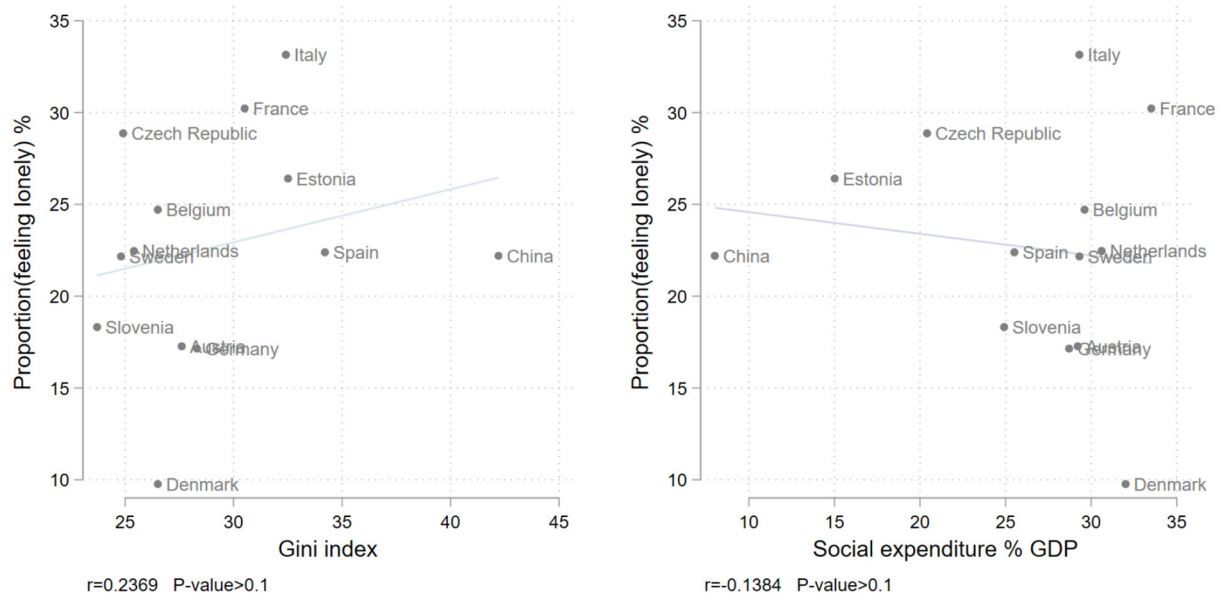

FIGURE 1
Gini index, social expenditure as percentage of GDP, and prevalence of loneliness by country.

Table 3 shows the estimated coefficients from logistic country fixed effect (FE) models for the impact of individual-level household income and its interaction effect with country-level Gini index and social expenditure on loneliness. Model 1 included the estimates of individual-level household income. The lower the household income, the greater the likelihood of feeling lonely. Compared to those in the highest quartile of income, the odds ratio for older adults in the lowest quartile was 1.16 (95% CI: 1.09–1.23). The contextual moderating effects at the macro level were estimated in models 2–3. In both macro contexts—income inequality measured as Gini index and welfare generosity measured as social expenditure as percentage of GDP—we found a significant interaction effect with the individuals' household income in the expected direction, supporting our two hypotheses: older adults with lower socioeconomic status in less income-equal societies are more likely to be lonely than their counterparts in more income-equal societies (Hypothesis 1), and older adults with lower socioeconomic status in societies with more generous welfare expenditures are less likely to be lonely than their counterparts in less generous societies (Hypothesis 2).

Figure 2 visualizes these associations by showing the average marginal effects of individual-level household income status on loneliness in various income-unequal conditions and levels of welfare generosity. The left graph in Figure 2 shows that in the most inequitable context, the likelihood of loneliness was most pronounced among older adults who were in the lowest income quartile compared to their age peers in the higher income quartiles, whereas in a more income-equal society the effect of individual-level household income had less impact on likelihood of loneliness. For the interaction effect of social expenditure and household income on loneliness, the right graph in Figure 2 shows that for older adults living in a country with less generous

TABLE 3 Fixed effect models: main effect and interaction effects on the occurrence of feeling lonely for older adults ($N = 62{,}084$).

	Model 1	Model 2	Model 3
Household income status (ref.: highest 25%)			
Upper 25%	0.060*	−0.321	0.232*
Lower 25%	0.124***	−0.439**	0.461***
Lowest 25%	0.146***	−0.372*	0.353***
Household income & Income inequality			
Upper 25% × Gini		0.013*	
Lower 25% × Gini		0.018***	
Lowest 25% × Gini		0.017**	
Household income &Welfare generosity			
Upper 25% × social expenditure			−0.007
Lower 25% × social expenditure			−0.014***
Lowest 25% × social expenditure			−0.009*
Pseudo R-squared	0.129	0.130	0.130
AIC	58326.2	58317.8	58317.1
BIC	58624.4	58643.1	58642.4

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
Coefficients omitted for control variables: age, gender, marital status, education, employment, self-rated health, functional limitations, household size, child and living arrangement, and country.

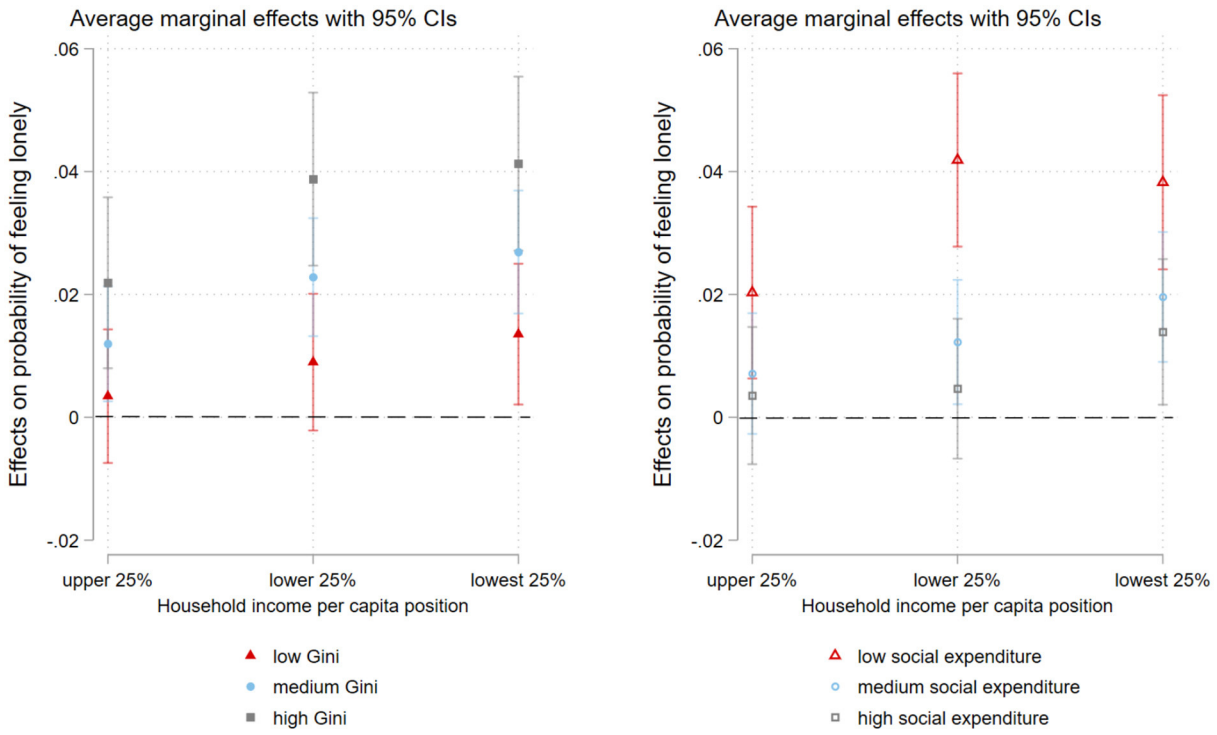

FIGURE 2
Average marginal effects of individual-level household income status (compared to the highest 25%) on probability of feeling lonely in different macro contexts.

welfare resources, household income was closely associated with risk of loneliness. However, for the lowest income group in societies with lower social expenditures, the risk of loneliness was not as high as for the low-income group.

Discussion

The aim of our study was to examine whether country-level income inequality and welfare generosity moderate the effect of individual-level socioeconomic status on late-life loneliness. Our results showed a significant interaction effect between Gini index of income inequality at the macro level and household income at the micro level on loneliness, which supports our first hypothesis. This finding is in line with Du, King and Chi (42), who found an interplay between countries' income inequality and individual income, and individuals' subjective wellbeing and psychological distress. Our results also show a significant interaction effect on loneliness between welfare states' social expenditures and individual household income, supporting our second hypothesis. This finding confirms previous research indicating that lower socioeconomic classes are more strongly affected by the level of state involvement in welfare provisions (43, 64, 65).

There is, however, a difference in the impact of income inequality and welfare states' social expenditures for the low and lowest socioeconomic classes. When there is more income inequality in a country, the higher likelihood of loneliness is nearly equal for the low and lowest socioeconomic classes, whereas with lower state social expenditures the likelihood of loneliness is significantly higher for the low socioeconomic class than for the lowest class. One possible explanation for the latter difference could be related to the selective means-tested or residual model, which has been criticized for trapping low-income people in relative poverty because in that welfare model their savings result in a loss of opportunities to receive welfare benefits from the government (66). In societies with the least generous welfare resources, the key focus lies on improving the living conditions of the poorest, enabling them to get access to food, sanitation, and housing (45, 53). For example, Estonia, which has a relatively low level of welfare generosity, applies the basic welfare model to prevent people from falling into extreme poverty (67). A similar situation exists in China, which has the least generous welfare system of all the countries studied (see Figure 1). Although China has significantly developed and reformed its social welfare and elder care, the government has continued to use the residual welfare model, which provides the poorest older adults in need with basic benefits for food, clothing, housing, medical treatment, and funeral services (68,

69). If the welfare system does not target the low socioeconomic group they do not receive welfare resources, their feelings of relative deprivation are likely to rise, and the risk of loneliness will increase.

Our study sheds light on the importance of more equalitarian income distribution and more generous welfare provision spending in preventing or reducing loneliness among older adults of low socioeconomic status. Individuals are embedded in larger material and societal contexts that shape the actual or perceived quality of living conditions and create opportunities for social integration (6, 20). There is a need not only to target individuals at risk, but also to identify contextual aspects of societies in terms of loneliness prevention and alleviation (70). In light of this study, anti-poverty measures, income maintenance programs, and comprehensive pension systems are highly recommended, as is ensuring equity and fairness in provision. National and local governments could also offer free or low-cost services to older adults of low socioeconomic status, allowing them to interact socially and participate in social activities.

Data availability statement

The Survey of Health, Ageing and Retirement in Europe (SHARE) is centrally coordinated at the Munich Centre for the Economics of Aging (MEA). The China Health and Retirement Longitudinal Study (CHARLS) is conducted and supported by Peking University, the National Natural Science Foundation of China, the Behavioural and Social Research Division of the National Institute on Aging and the World Bank. The harmonized datasets of both surveys were publicly released through the website of the Gateway to Global Aging Data (www.g2aging.org).

Ethics statement

Ethical review and approval and written informed consent for participation were not required for this study because this study is based solely on publicly available secondary data. It is in accordance with the national legislation and the institutional requirements.

Author contributions

The research idea and design were conceived by JW. Data collection and cleaning were performed by JZ and JW. Statistical analyses were conducted by JZ under the cooperation and discussion with JW and TF. JW took the lead in writing the manuscript. TF and JZ provided feedback and revised several versions of the manuscript. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The impact of adult children rural–urban migration on left-behind parents' health: Evidence from China

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Population aging and rural–urban migration have posed challenges to the elderly support system in developing countries that lack social safety net and services. Given that there is no consistent conclusion in the literature on whether adult children's internal migration can improve or impair their left-behind parents' health, little is known about the effect mechanisms. This paper investigates the comprehensive impact of adult children's migration on the health of their parents in rural China by analyzing the income effect and time allocation effect. The empirical analysis uses the rural sample of the China Health and Retirement Longitudinal Study (CHARLS) in 2013, 2015, and 2018. We found that adult children migration can improve parents' physical health, mainly thanks to the income effect. The analysis of the mechanism found that although the income effect has a positive effect on parents' health, the time allocation effect has a negative effect on parents' health because of the lack of care and increased working hours of parents. Our findings suggest that providing social care services and enhancing intergenerational communication can be practical strategies to mitigate the negative effect of children's migration to rural left-behind elderly parents.

KEYWORDS

adult children migration, left-behind parents, physical health, mental health, remittances, rural China

Introduction

Population aging and rural–urban migration have posed potential challenges to the elderly support system in developing countries that lack institutional support. As the largest developing country in the world, China has been experiencing rapid population aging, which is more rapid in rural areas than that in urban areas (1, 2). In 2020, China's population of 60 years or older accounted for 18.70% of the total population, and this proportion in rural areas reached 23.81% (2), while elderly care in developing countries much relies on the family, particularly in Asia countries with filial piety culture (3–5), because of the absence of adequate social safety net and service. Along with the

aging population, China has also been experiencing rapid urbanization, and massive rural laborers have migrated to cities. In 2020, there were 285.6 million rural-to-urban migrants (6). Out of the total aging population, over 37% are left behind in the rural areas because of the massive migrant labor (7). There is a geographical distance between the migration of adult children and their parents, which makes it difficult for left-behind parents to obtain care and support from their children.

In China, internal migration for a better job is an important way to increase income for many rural households (8, 9). Rural–urban migration is often considered by young individuals as a substitute for acquiring further education (10, 11). There is an obvious trend to provide money rather than companionship and care in supporting the elderly. In rural China, it is often observed that the parents receive more remittances from their migrant children (12–14). Received remittances could improve their nutritional level and improve their health (3, 15). However, migration increased the distance between parents and children, thus making the children less likely to take care of their left-behind parents (16). Due to the absence of children in their life, parents not only need to spend more time on household chores and agriculture production but also increase their loneliness and psychic burden (17). Therefore, it is unclear the exact effect of adult children's migration on their parents' health.

Scholars have increasingly been interested in the influence of adult children's internal migration on their left-behind parents' health, but their conclusions are not consistent. Some literature found that adult children migration can improve the left-behind elderly parents' physical and mental health (18–20). Oppositely, some studies have proved that adult children's migration significantly impairs the health of their parents (3, 16, 21). Other literature has furtherly explored the mechanism by which adult children migration exerts health effects. Böhme et al. found that the transnational migration of adult children could improve their parents' health by significantly reducing agricultural working hours and increasing leisure time (22). Yi et al. found that migrants' remittances can compensate for the adverse health effects of adult children's migration on their parents (4). However, such work remains scarce. In particular, few studies systematically investigate the mechanism of the effect of adult children's migration on their parents' health.

This paper contributes to the literature by empirically demonstrating there are two mechanisms, the income effect and the time allocation effect, of adult children's migration on parents' health. Meanwhile, this paper explores the interaction impact of these two mechanisms on parental health. Although the interaction impact of the two mechanisms is of importance to understand exactly how adult children's migration affects parents' physical and mental health, many existing studies have ignored it. This paper intends to fill the gap. In this study, we investigate the comprehensive impact of adult children migration on the health of their elderly parents in rural China by analyzing the income effect and the time allocation effect, and their interaction.

Theoretical framework

The aged social security system of rural China has not yet been perfected (7, 19). Rural elderly care relies a lot on adult children (4). Adult children's financial support and care are two essential factors for parents' health (23–25). However, as the distance between migrant children and their left-behind parents increased, the support behaviors of migrant children, which affect the health of their parents, were adjusted accordingly (3).

Adult children's migration may affect their parents' health in two ways. The first way is parents may adjust their time arrangements for agricultural production and domestic labor after the children's migration, which is referred to as the "time allocation effect" (22). As an important labor force in the family, adult children's migration will increase the parents' time required for agricultural production (26). As an important provider of parental support, adult children's migration not only decreases parental care support but also increases the time that parents spend on domestic labor (7, 27). Especially, the Chinese left-behind parents often bear onerous tasks of caring for grandchildren (28–30). Heavy production and domestic labor may cause parents to become unable to take care of their own health and enjoy their leisure time, which has a negative impact on their physical and mental health (31–34). In addition, the lack of migrant children's care and spiritual support aggravates the parents' feelings of loneliness (15). Therefore, the "time allocation effect" produced by adult children's migration may have a negative impact on the left-behind parents' health.

The second way is that parents may receive more remittances from their migrant children, which could have a positive effect on their parents. This effect is referred to as the "income effect" (35). The migration of labor has led to an obvious trend of monetization in the supply of traditional family support. In general, in rural households with migrated labor, the parents could receive higher intergenerational remittances (12–14). As a compensatory family support resource, the remittance by migrant children is not only an important way to maintain the intergenerational relationship but also the most important source of parents' income. As a result, parents can afford to pay higher costs for improving their health, such as diet, leisure, or medical care (3, 15). According to the theory of health economics, more health inputs will improve health (36, 37).

These two ways can influence each other. On the one hand, migrant children's remittance can reduce the parents' labor supply time and, to a certain extent, alleviate the negative impact of "time allocation effect." The reason is that the employment income of the migrant children can replace or compensate for agricultural income and reduce their family's dependence on agricultural production. Families can reduce the agricultural

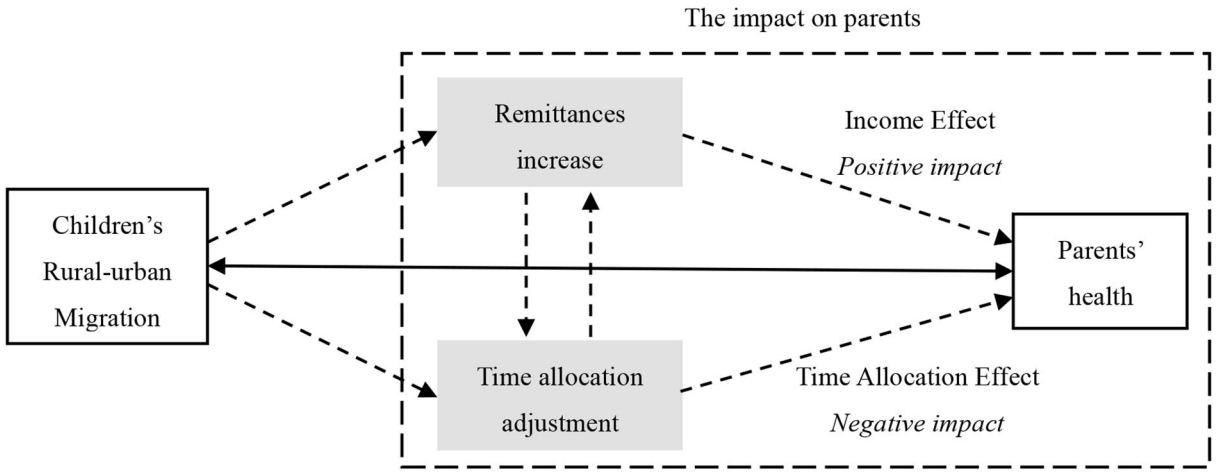

FIGURE 1
Theoretical mechanism of the impact of children's migration on their parents' health.

working time of the elderly parents through land transfer. On the other hand, parents who take care of their grandchildren not only need to input time and energy but also need to bear economic costs, which weakens the positive impact of the "income effect." Babysitting grandchildren is highly correlated with obtaining financial support from the offspring. Migrant children may increase their financial support to their parents because their parents help to take care of their children (38), and parents use the remittance to cover the daily expenses of caring for their grandchildren, which may weaken the positive impact of the "income effect" on the health.

Obviously, adult children's migration affects parents' health through two opposing mechanisms. The overall health effect of children's migration depends on the respective strengths of these two mechanisms. That is, if the positive impact of the "income effect" is greater than the negative impact of the "time allocation effect," children migration will improve the health of their parents. Conversely, adult children migration will worsen the health of their parents. Figure 1 shows the theoretical mechanism of the impact of children's migration on their parents' health. This paper used empirical analysis to evaluate the overall effect of children migration on parents' health and verify the effects of these two mechanisms on parents' health.

Methods

Data

The data in this paper are from the China Health and Retirement Longitudinal Study (CHARLS) organized by Peking University. The CHARLS is a nationwide social panel survey project that is specifically aimed at aging individuals in the Chinese population. The survey subjects are middle-aged and elderly people who are 45 years old and older. The project collects data at three levels: the individual, family, and community (village) levels. The CHARLS gathers data on personal health status, medical care, work and retirement, family income, population information, and intergenerational support for children, as well as the community (village) economy and population information. The sample covers 28 provinces in China. Since the 2011 national baseline survey, the CHARLS has been collecting data every 2 or 3 years. This article mainly used the mixed cross-sectional data from the 2013, 2015, and 2018 CHARLS. The response samples in the 2013, 2015, and 2018 CHARLS are 18,264, 20,284, and 19,816, respectively.

People who live in rural areas and have at least one adult child who is 45 years old and older were selected as the research sample. The CHARLS defines the urban and rural samples according to the urban–rural division code of the National Bureau of Statistics. After excluding the urban sample and childless sample, the sample size was 33,460. To obtain village-level information to control the influence of village-level economic and social factors, participants in the sample described above were matched with the data at the community (village) level from the 2011 CHARLS. After matching, there were a total of 30,261 participants.

Model specification

To evaluate the total effect of adult children migration behavior on their parents' physical and mental health, this paper used the following constructed econometric model:

$$H_i = \beta M_i + \theta Z_i + \varepsilon_i \quad (1)$$

where H_i is parent i's health level; M_i is an indicator of children's migration situation of parent i; Z_i indicates control variables, specifically including the variables of parental characteristics, children and family characteristics, and village-level characteristics, as well as year dummy variables and province dummy variables; and ε_i is an error term.

The model may have the problem of endogeneity because of the reverse causation between children's migration and the health of their parents. For instance, the poorer health of the parents is, the less likely the children are to work outside the home because they need to stay with their parents to provide care and support. Alternatively, parents with poor health may have a low economic income, which requires their children to migrate for work to earn income. This means that parents' health status affects their children's decision to migrate, which may lead to biased and inconsistent estimation results of the variables for children's migration. The abovementioned endogeneity problem has been fully discussed in existing studies and is usually dealt with by the instrumental variable method (21, 39). Drawing on existing studies, this paper selected the village-level rate of migration and the urban unemployment rate as the instrumental variables of children's migration and performed two-stage least squares estimation (2SLS) (22).

Theoretically, these two instrumental variables meet the conditions of correlation and exogenous. In terms of correlation, in a rural area, the migrant network in the village is an important source of information and social capital for farmers to seek jobs outside of the village. It can not only effectively reduce the cost of employment outside the village but also improve the probability of employment. Generally, the higher the rate of village-level migration is, the greater the possibility of their children's migrating for work. There are two possible effects of the urban unemployment rate on rural employment. The first is that the high unemployment rate in the local city promotes the transfer of rural labor workers to other cities to engage in non-agricultural work; the other is that the high urban unemployment rate causes the labor workers to stay in the countryside to engage in agricultural production. We do not discuss which of the two influences is dominant, but the above analysis shows that the urban unemployment rate is related to rural labor migration. In terms of exogeneity, village-level rate of migration and urban unemployment rate usually do not directly affect an individual's health. In fact, the village-level rate of migration and urban unemployment rate is related to the levels of economic and social development of a region, which may affect an individual's health. Therefore, we controlled for parental income, village-level characteristics, and province dummy variables in the econometric model, which could largely eliminate the endogeneity of instrumental variables.

To evaluate "time allocation effect" and "income effect," this paper used a multiple-step multiple mediator model. Hayes (2009) stated that when there are multiple mediation variables and the mediation variables interact with each other, a multiple-step multiple mediator model needs to be constructed to test for mediating effects (40). The following multiple-step, multiple mediator model was constructed:

$$C_i = a_1 M_i + \theta_1 Z_i + \varepsilon_{1i} \quad (2)$$

$$S_i = a_2 M_i + dC_i + \theta_2 Z_i + \varepsilon_{2i} \quad (3)$$

$$H_i = c' M_i + b_1 C_i + b_2 S_i + \theta_3 Z_i + \varepsilon_{3i} \quad (4)$$

where C_i is intergenerational care, S_i is children's financial support, and $\varepsilon_{1i}, \varepsilon_{2i}$, *and* ε_{3i} are random disturbance terms. It should be noted that the mediating effect of time allocation adjustments is analyzed in this paper using intergenerational care time as an example. The reasons are as follows: First, in terms of labor time allocation, intergenerational care time is more affected by children's migrating behaviors; second, grandparenting is also caused by the "incompleteness" of labor transfer, and in rural areas, intergenerational care is becoming increasingly common, so it is significant to study the impact of intergenerational care on parents' health (41). Third, when analyzing the mediating effect of labor time allocation, it is necessary to analyze the impact of labor time on health, but there may be an endogenous problem between labor time and health caused by reverse causation. Moreover, it is not beneficial at the technical level to find suitable instrumental variables to address the potential endogeneity, either by summing up the various types of labor time or by analyzing the impact of agricultural labor time on health separately.

Meanwhile, to overcome the potential endogeneity of children's migration behaviors in Equation (2), the same instrumental variables used above were selected, and Equation (2) was estimated using 2SLS. In Equation (3), migration and grandparenting time were also potentially endogenous variables, and the theoretical analysis partially suggested that the financial support provided by migrant children also influences parents' grandparenting behaviors. To this end, drawing on existing research, the number of grandchildren under 16 years of age and the average grandparenting time at the village level excluding the subject himself/herself were selected as the instrumental variables for grandparenting time (28, 29). Equation (3) was estimated using three-stage least squares (3SLS). Parental health status not only affects children's migration behaviors but may also affect children's financial support and parents' intergenerational care behaviors, so there are three potential endogenous variables (migration, children's financial support, and grandparenting time) in Equation (4). Based on the existing studies, the average of children's financial support at the village level excluding the subject himself/herself, and whether they are invited to participate in celebrations and ceremonies are the instrumental variables for children's financial support (16). Equation (4) was estimated using 3SLS.

Variable specification

Health measures

Since health is multidimensional (22), this paper selected multiple variables to measure the parents' physical and mental health. We measured physical health status in three ways: self-reported health (SRH), instrumental activities of daily living (IADL), and physical activity ability. SRH is a comprehensive evaluation indicator of physical health. It has a predictive effect on the individual's future morbidity and mortality (42, 43). However, as a subjective index, the main disadvantage of SRH is that it is easily affected by factors such as individual characteristics and social environments (44). Therefore, we also chose IADL and physical activity ability from an objective perspective to measure physical health. The above two variables were set in the form of the number of parents that could independently complete the activities. The larger the value, the better the health of the parents (19).

We chose the degree of depression and subjective well-being to measure the parents' mental health. The degree of depression was measured by the Depression Scale developed by the Center for Epidemiological Survey (CES-D) (45, 46). The CES-D score ranges from 10 to 40. The higher the score, the higher the degree of depression of the parents and the lower level of mental health. Subjective well-being (SWB) is also an index that has also been commonly used to measure mental health in related studies (16, 47, 48).

Migration measures

Migration was the key independent variable. Children's rural–urban migration is often expressed as long-distance geographical migration, that is, children's working and living places are transferred from rural areas to urban areas or to places that are far away from their hometowns. Migration is also manifested in the employment sector, that is, the transfer from the agricultural sector to the non-agricultural sector. Based on the existing literature, migration is defined as having non-agricultural employment with their habitual residence outside of the county where their parents habitually reside. The migration variable was set as a dummy variable (18, 25, 39).

Control variables

Considering that there are many factors that affect parents' health, we controlled for three types of independent variables: parental characteristics, children and family characteristics, and village-level characteristics (4, 19–22). Parental characteristics included seven variables: age, sex, years of education, whether spouses lived together, childhood health status, chronic diseases, and whether they had pension insurance. The two variables of childhood health and chronic diseases could reflect the initial health level of an individual and the genetic status of family health to a certain extent. The characteristics of children and family specifically included five variables: the number of children, the average age of the children, highest education level of the children, family income, and whether children were living together. The economic and social development levels of the village where their parents lived could also affect their health. In this paper, four variables were selected to measure village-level characteristics: the village's enterprise, activity facilities, elderly assistance organizations, and whether the residents of the village mainly used flushing toilets. To exclude the influence of the time effect and regional differences, the paper further controlled the year dummy variable and the province dummy variable.

In addition, this paper also examines the effects of the "income effect" and "time allocation effect" on parents' health. Two types of mediation variables were used in the article: One is the remittance provided by the children to their parents, and another is the grandparenting time variable from the perspective of labor supply Table 1 shows the definitions of all the variables.

Results

The effect of children's migration on parents' health

Table 2 shows the descriptive statistical results of the major variables. In general, the mean value of the parents' self-rated health was 2.74, which indicates that the self-rated health of middle-aged and elderly people in rural areas is between "bad" and "fair." The mean values of IADL and physical activity ability were 4.51 and 4.97, respectively, which indicated that the number of IADL and the physical activities that rural middle-aged and elderly individuals could independently complete was approximately 5. According to the definition of depression, a CES-D score $>$ 20 was considered to indicate depressive symptoms. The mean value of the parents' depression degree was 19.86. Based on calculation, approximately 38% of rural middle-aged and elderly people were suffering from mental depression. The mean value of the parents' life satisfaction was 3.23, which indicates that middle-aged and elderly people in rural areas were generally satisfied with their current life. The results of the group analysis show that there is no significant difference in physical and mental health between the parents with children at home and the parents with children away from home.

Table 3 shows the estimation results of the effect of adult children's migration on parents' physical and mental health using ordinary least squares (OLS) and 2SLS. The overidentification test showed that we could not reject the null hypothesis that "all instrumental variables were exogenous," indicating that the instrumental variables in each equation satisfied the exogeneity condition; the F-statistic values of the weak instrumental variable F-test for each equation were all $>$ 10, indicating that each instrumental variable passed the weak

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TABLE 1 Measurement of main variables.

Variables	Description	Form/Units
Health measures		
SRH	The interviewee's self-reported health	Very poor = 1, poor = 2, fair = 3, good = 4, excellent = 5
IADL	The number of interviewees who can independently complete 5 activities, including housework, cooking, shopping, making phone calls, and taking medicines	Number
Physical activity ability	The number of interviewees who can independently complete 5 activities, including jogging, walking, climbing stairs, bending the body, and lifting heavy objects	Number
CES-D	The CES-D score of the interviewee	Score
SWB	The subjective well-being of the interviewee	Not at all satisfied = 1, Not very satisfied = 2, Somewhat satisfied = 3, Very satisfied = 4, Completely satisfied = 5
Independent variables		
Migration	Whether the interviewee's children have migrated	No = 0, Yes = 1
Age	The age of the interviewee	Years
Sex	The sex of the interviewee	Female = 0, Male = 1
Education	The years of education of the interviewee	Years
Married	Whether the interviewee is married	No = 0, Yes = 1
Childhood health	Interviewee's health condition at 15 years old and younger	Very poor = 1, Poor = 2, Fair = 3, Good = = 4, Excellent = 5
Chronic diseases	The number of chronic diseases the interviewee has	↑
Pension	Whether the interviewee has participated in pension insurance	No = 0, Yes = 1
Social activities	In the past month, did the interviewee engage in the following social activities: socializing with friends, helping relatives and friends, surfing the internet	No = 0, Yes = 1
Number of children	The number of children of the interviewee	Number
Children's age	Average age of the children	Years
Children's education	The highest level of education of the interviewee's children.	Illiteracy = 1, Elementary school = 2, Middle school = 3, High school/Vocational school = 4, College = 5, Postgraduate = 6
Household income	Interviewee's family income in the past year, including agricultural production, non-agricultural production and operation, wages, and transferred income In addition, the logarithmic form of income	Yuan, logarithm
Residence	Whether the interviewee lives with one of their children	No = 0, Yes = 1
Enterprise	The number of enterprises in the residential village	Number
Activity venues	The number of sports, cultural and entertainment venues in the residential village.	Number
Elderly assistance organizations	Whether there are nursing homes, health care centers for elderly individuals, home-based elderly service stations, and other organizations that help the elderly population in the residential village	No = 0, Yes = 1
Toilet type	Whether the main type of toilet in the resident village is a flushing toilet	No = 0, Yes = 1
Intermediary variables		
Remittance	The number of financial support measures (including cash and in kind) that the interviewee received from all their children in the past year	Yuan
Grandparenting time	The amount of time interviewee spent caring for their grandchildren in the past year	Hours
Instrumental variables		
Village migration proportion	The ratio of the number of migrant people to the total population in the residential village	%
Urban unemployment rate	Urban unemployment rate in the residential city (data from the statistical yearbook of each city or a government work report)	%

TABLE 2 Descriptive statistical analysis of the main variables.

Variables	All samples			No migrant children		At least one migrant child		Difference
	Observation	Mean	S.D.	Mean	S.D.	Mean	S.D.	
Health measures								
SRH	29,454	2.74	1.05	2.68	1.05	2.78	1.04	−0.10***
IADL	30,254	4.51	1.06	4.51	1.06	4.51	1.06	0.00
Physical activity ability	30,240	4.97	1.87	5.03	1.85	4.92	1.89	0.10**
CES–D	30,236	19.86	8.33	19.14	6.98	20.45	9.25	−1.31***
SWB	30,230	3.23	0.80	3.22	0.79	3.23	0.80	−0.01**
Independent variables								
Migration	30,261	0.55	0.50					
Age	30,261	61.08	9.65	60.10	9.87	61.88	9.39	−1.78***
Sex	30,261	0.48	0.50	0.48	0.50	0.48	0.50	−0.01
Education level	30,261	4.57	3.98	4.57	3.94	4.58	4.01	−0.01
Married	30,261	0.87	0.33	0.87	0.34	0.88	0.33	−0.01***
Childhood health	29,889	6.99	61.00	5.42	46.26	8.27	70.68	−2.85***
Chronic disease	30,261	1.14	1.33	1.25	1.38	1.06	1.28	0.19***
Pension	30,261	0.83	0.37	0.80	0.40	0.86	0.35	−0.06***
Social activities	30,261	0.36	0.48	0.36	0.48	0.36	0.48	0.00
Number of children	30,261	3.07	1.69	2.75	1.45	3.33	1.83	−0.58***
Children's ages	30,206	33.85	9.61	32.67	10.48	34.80	8.72	−2.12***
Children's education levels	29,657	3.38	1.09	3.25	1.03	3.49	1.13	−0.24***
Household income	30,261	7.61	3.41	7.31	3.70	7.85	3.14	−0.54***
Residence	30,261	0.48	0.50	0.66	0.47	0.34	0.47	0.33***
Enterprises	29,912	2.91	8.27	3.53	9.47	2.40	7.10	
Activity venues	30,261	1.67	2.08	1.83	2.17	1.54	2.01	0.29***
Elderly assistance organizations	30,261	0.18	0.38	0.19	0.40	0.17	0.37	0.03***
Toilet type	30,261	0.24	0.42	0.25	0.43	0.22	0.42	0.02***
Intermediary variables								
Remittance	30,261	5244.94	15926.58	4027.93	11642.01	6237.04	18648.53	−2209.11***
Grandparenting time	30,261	1523.05	4864.82	1548.36	4895.43	1502.42	4839.77	45.94
Instrumental variables								
Village migration proportion	29,850	0.29	0.27	0.26	0.25	0.32	0.27	−0.06***
Urban unemployment rate	30,261	3.12	0.75	3.10	0.76	3.14	0.73	−0.03***

***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$. We severally adopted Mann–Whitney U–test, chi–square goodness–of–fit test, and two sample t–tests to test the difference for ordinal variables, nominal variables, and interval/ratio variables.

instrumental variable test and satisfied the correlation condition. As a result, the instrumental variables were valid.

The empirical results show, in terms of physical health, the estimated coefficient of migration variable was significantly positive in the SRH equation, IADL equation, and physical activity ability equation. The results show that parents' SRH, IADL, and physical activity ability were significantly increased when their children migrated for work. In terms of mental health, the migration variable's coefficient was negative in the CES-D equation and positive in SWB equation. The results show that parents' depression degree was decreased, and subjective well-being was improved when their children migrated for work, but these two coefficients were not statistically significant. This indicates that children's migration does not significantly improve the mental health of their parents.

The estimated results of other control variables were basically consistent with the theoretical and realistic expectations. As the parents grew older, their health gradually declined. There were obvious differences between fathers and mothers. Both the physical and mental health of fathers were significantly better than those of mothers. The higher the status level of childhood health was, the higher the level of physical health and mental health. Chronic diseases have a significant negative impact on parents' health. Income has

TABLE 3 Estimated results of the impact of migration on parents' health in rural families.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	SRH		IADL		Physical activity ability		CES–D		SWB	
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
Migration	0.008	0.472**	0.036***	0.645***	0.031	1.850***	0.052	0.424	0.011	−0.071
	(0.014)	(0.215)	(0.014)	(0.233)	(0.022)	(0.408)	(0.099)	(1.885)	(0.011)	(0.173)
Age	−0.005***	−0.004**	−0.022***	−0.022***	−0.045***	−0.044***	0.064***	0.063***	0.005***	0.005***
	(0.001)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)	(0.009)	(0.009)	(0.001)	(0.001)
Sex	0.150***	0.096***	0.169***	0.173***	0.718***	0.723***	−2.171***	−2.163***	0.060***	0.059***
	(0.013)	(0.017)	(0.013)	(0.014)	(0.022)	(0.024)	(0.102)	(0.103)	(0.010)	(0.010)
Education	0.002	0.010***	0.020***	0.020***	0.046***	0.045***	−0.169***	−0.173***	−0.006***	−0.006***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)	(0.014)	(0.014)	(0.001)	(0.001)
Married	−0.026	−0.000	0.032	0.019	0.102***	0.066*	−1.590***	−1.572***	0.101***	0.102***
	(0.019)	(0.025)	(0.022)	(0.023)	(0.034)	(0.038)	(0.174)	(0.178)	(0.016)	(0.017)
Childhood health status	0.000	0.066***	−0.000	0.000	−0.000	−0.000	0.002*	0.002*	−0.000	−0.000
	(0.000)	(0.007)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
Chronic diseases	−0.192***	−0.184***	−0.111***	−0.108***	−0.328***	−0.320***	0.816***	0.817***	−0.061***	−0.061***
	(0.005)	(0.005)	(0.005)	(0.006)	(0.008)	(0.009)	(0.035)	(0.036)	(0.004)	(0.004)
Pension	−0.016	−0.009	0.068***	0.054***	0.059**	0.015	−0.409***	−0.418***	0.034***	0.037***
	(0.016)	(0.021)	(0.016)	(0.018)	(0.027)	(0.032)	(0.122)	(0.134)	(0.013)	(0.014)
Social activities							−0.614***	−0.631***	0.045***	0.045***
							(0.093)	(0.093)	(0.010)	(0.010)
Number of children	−0.011***	−0.043***	−0.018***	−0.041***	−0.038***	−0.107***	0.232***	0.211***	0.007**	0.011
	(0.004)	(0.014)	(0.005)	(0.010)	(0.008)	(0.018)	(0.043)	(0.080)	(0.003)	(0.007)
Children's ages	−0.000	0.003**	0.002*	0.002	0.005***	0.005**	−0.021***	−0.021***	0.002*	0.001*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.008)	(0.008)	(0.001)	(0.001)
Children's education levels										
Elementary school	0.023	0.073	0.315***	0.234***	0.241**	0.013	0.408	0.403	−0.110**	−0.105*
	(0.054)	(0.083)	(0.083)	(0.088)	(0.103)	(0.122)	(0.616)	(0.660)	(0.051)	(0.055)
Middle school	0.046	0.078	0.379***	0.275***	0.402***	0.101	−0.226	−0.240	−0.087*	−0.079
	(0.054)	(0.088)	(0.082)	(0.091)	(0.103)	(0.129)	(0.613)	(0.687)	(0.051)	(0.057)
High school/vocational school	0.110**	0.129	0.408***	0.292***	0.541***	0.201	−0.655	−0.695	−0.057	−0.048
	(0.055)	(0.093)	(0.083)	(0.093)	(0.104)	(0.135)	(0.618)	(0.712)	(0.051)	(0.060)
College	0.147***	0.093	0.424***	0.245**	0.559***	0.035	−1.193*	−1.252	−0.031	−0.015
	(0.055)	(0.110)	(0.083)	(0.106)	(0.104)	(0.163)	(0.620)	(0.826)	(0.052)	(0.070)
Postgraduate	0.182**	0.050	0.500***	0.299**	0.682***	0.073	−0.542	−0.601	−0.000	0.016
	(0.077)	(0.138)	(0.089)	(0.118)	(0.132)	(0.197)	(0.761)	(0.949)	(0.066)	(0.086)
Household income	0.009***	0.008***	0.009***	0.007***	0.023***	0.019***	−0.100***	−0.100***	0.010***	0.010***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.004)	(0.013)	(0.014)	(0.001)	(0.002)
Residence	−0.010	0.095	−0.096***	0.072	−0.063***	0.437***	0.114	0.230	0.019*	−0.006
	(0.013)	(0.067)	(0.013)	(0.065)	(0.022)	(0.115)	(0.104)	(0.531)	(0.010)	(0.049)
Enterprises	0.002**	0.004***	0.001	0.002**	0.002	0.005***	−0.018**	−0.017**	0.002***	0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.007)	(0.008)	(0.001)	(0.001)
Activity venues	0.013***	0.016***	0.020***	0.022***	0.021***	0.027***	0.023	0.019	0.002	0.001
	(0.004)	(0.005)	(0.003)	(0.004)	(0.006)	(0.007)	(0.031)	(0.033)	(0.003)	(0.003)
Elderly assistance organizations	−0.027	−0.055**	0.008	0.020	0.027	0.057*	−0.242*	−0.247*	−0.008	−0.014

(Continued)

TABLE 3 (Continued)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	SRH		IADL		Physical activity ability		CES–D		SWB	
	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS
	(0.017)	(0.023)	(0.017)	(0.018)	(0.029)	(0.033)	(0.136)	(0.141)	(0.013)	(0.014)
Toilet type	−0.013	0.050*	0.076***	0.108***	0.198***	0.284***	−0.488***	−0.491***	0.001	0.009
	(0.019)	(0.028)	(0.019)	(0.022)	(0.032)	(0.039)	(0.155)	(0.171)	(0.015)	(0.017)
Year dummy										
2015	0.074***	0.074***	0.021	0.038**	0.080***	0.126***	−0.114	−0.114	0.318***	0.317***
	(0.015)	(0.016)	(0.015)	(0.016)	(0.024)	(0.029)	(0.087)	(0.098)	(0.011)	(0.012)
2018	0.265***		−0.130***	−0.316***	−0.323***	−0.889***	3.536***	3.431***	0.082***	0.105*
	(0.015)		(0.015)	(0.074)	(0.026)	(0.130)	(0.125)	(0.591)	(0.012)	(0.055)
Province dummy	Controlled									
Constant	2.733***	2.021***	5.290***	5.108***	6.829***	6.279***	19.639***	19.514***	2.496***	2.533***
	(0.082)	(0.149)	(0.104)	(0.130)	(0.146)	(0.203)	(0.791)	(0.996)	(0.072)	(0.091)
Observations	28,330	27,942	28,926	28,533	28,916	28,523	28,912	28,519	28,908	28,516
F value of endogenous test		25.765***		7.206***		24.454***		0.043		0.216
$\chi 2$ value of overidentification test		1.407		0.108		0.753		3.604*		0.856
F–value of weak instrumental variable test		52.103***		52.932***		53.118***		53.586***		53.531***

***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$. Robust standard errors are in parentheses; each model controlled for the dummy variables of 24 provinces; illiteracy was used as the reference group for children's education levels.

a significant positive effect on parental health. Furthermore, the more children the parents had, the worse their physical health level was, which indicates, to some extent, that increased child-rearing tasks are not good for parents' physical health. In contrast, with the aging of their children, the health level of parents increased correspondingly. A possible reason is that, after the children have grown, the care burden of parents is reduced on the one hand, and on the other hand, children can also help their parents by sharing labor. From the estimation results of the village-level characteristic variables, it can be seen that village economic and social development levels had a positive impact on the physical and mental health of middle-aged and elderly people.

Heterogeneous effects of adult children's migration on parents' health

The previous analysis found that children's migration was conducive to improving parents' health. Is there any difference in this effect for parents with different characteristics? Next, we look into the heterogeneous effects on several important dimensions: gender, number of children, and region. Table 4 reports the heterogeneity analysis results, and we focus on the estimates from 2SLS, and we use CHOW test to check the significant difference in the estimated coefficients in different groups.

Panel A shows results separately by male and female. The results based on separated samples show significant differences between father and mother. In the mother group, we can see that most of the absolute values of the estimated coefficients are smaller than those of the father group, and most of the estimated coefficients are insignificant. This indicates that child migration can improve fathers' health, but the improvement in maternal health is not significant. Panel B shows results separately by parents with one child and parents with more than one child. The results show that for parents with one child, children's migration did not have a positive impact on parents' health. But for parents with more than one child, children's migration had a significant positive impact on parents' physical health. Panel C shows results separately by region. According to the standard of the National Bureau of Statistics on the division of administrative regions, the samples are divided into three groups: east, middle, and west. The results of group regression showed that children's migration had a significant positive impact on the health of parents who are living in central rural

TABLE 4 Heterogeneity analysis results by 2SLS.

	(1) SRH	(2) IADL	(3) Physical activity ability	(4) CES–D	(5) SWB
Panel A: Gender					
Father	1.058***	0.241	1.257**	−3. 172**	0.296
Mother	0.469*	0.397	0.808	−0.473	−0.008
Chow test	23.49***	22.80***	16.80***	17.39***	2.78
Panel B: Number of children					
Only one child	−3.811	−1.899	−7.147	7.698	−1.848
More than one child	0.957***	0.553**	1.456***	0.820	−0.121
Chow test	10.06**	15.44***	9.56**	30.13***	11.66**
Panel D: Region					
East	0.068	−0.907	1.483	10.254	−0.960*
Middle	1.001***	0.969***	2.212***	−0.514	0.057
West	−3.586**	−0.794	−0.779	8.523	−3.391**
Chow test	47.13***	23.25***	18.33**	14.78**	19.92***

***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$. Robust standard errors are in parentheses. Control variables included the three types of variables mentioned above: parental characteristics, children and family characteristics, and village–level characteristics, as well as year dummy variables and province dummy variables.

China and little to no effect on the health of eastern parents. However, it has a significant negative impact on the self-rated health and life satisfaction of parents who are living in western rural China. Overall, our results suggest that children's migration has larger beneficial effects on parents who are male, have more than one child, and live in central rural China.

The mediation mechanism of adult children's migration on parents' health

Table 5 shows the estimated results of the mediation effect model with all variables normalized. All the instrumental variables used in each equation passed the overidentification test and the weak instrumental variable test, indicating that the instrumental variables were valid.

Columns (1) and (2) in Table 5 show the estimation results of Equations (2) and (3), respectively, that is, the effect of the children's migration on the intermediary variables. The results show that the time of parents' grandparenting time variable and the amount of remittance were significantly increased when their children migrated for work. Also, grandparenting time significantly increased the amount of remittance. The significance of the above variables indicates that intergenerational care and remittance were two effective mediation variables. Columns (3) to (7) in Table 4 are the estimation results of Equation (4), which is the effect of the mediation variable on the outcome variable, that is, parents' health. The results show that the coefficient of grandparenting time variable on CES-D was positive, the coefficients of the other four health measures were all negative, and all were significant at the statistical level of 1%, which indicates that the longer the intergenerational care time was, the higher the degree of depression the parents had, and the lower the SRH, IADL, physical activity ability, and SWB were. This implies that grandparenting time has a significant negative impact on parents' physical and mental health. The coefficient of remittance variable on CES-D was negative, and the estimated coefficients of the other four health indicators were all positive and statistically significant, which indicates that the more financial support children provided, the lower the degree of depression of the parents, and the higher the SRH, IADL, physical activity ability, and SWB were. This means that children's economic support had a significant positive impact on their parents' physical and mental health.

The mediation effects of grandparenting time and remittance were further calculated and compared. The mediation effect of the independent role of grandparenting time could be obtained by calculating the product of a_1 and b_1. Similarly, the mediation effect of the independent role of remittance could be obtained by calculating the product of a_2 and b_2. In addition, grandparenting time also plays a role in the chain-mediated effect by affecting adult children's economic support, which could be obtained by calculating the product of a_1, d, and b_2. The calculated results are shown in Table 6. The results show that the independent mediation effect of grandparenting time on SRH, IADL, physical activity ability, and SWB was negative, and the independent mediating effect on depression was positive. In contrast, the independent mediation effect of remittance on SRH, IADL, physical activity ability, and SWB was positive, the independent mediating effect on the degree of depression was negative, and the absolute

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TABLE 5 Estimated results of the multiple–step, multiple mediator model.

	(1) Grandparenting time	(2) Remittance	(3) SRH	(4) IADL	(5) Physical activity ability	(6) CES–D	(7) SWB
Migration	0.191*	0.202***	0.468***	0.476***	−0.001	0.674***	1.477***
	(0.099)	(0.037)	(0.022)	(0.065)	(0.733)	(0.075)	(0.100)
Grandparenting time		0.903***	−0.024**	−0.068*	−0.241***	0.205***	−0.371***
		(0.123)	(0.010)	(0.041)	(0.048)	(0.045)	(0. 066)
Remittance			0.039*	0.630***	0.813***	−0.883***	1.081***
			(0.022)	(0.079)	(0.098)	(0.089)	(0.142)
Independent variables				**Control**			
Observations	28,540	28,540	27,942	28,533	28,523	28,519	27,935
χ2 value of the overidentification test	0.162	6.924	46.490	10.557	32.672	32.710	157.258
P–value of the overidentification test	0.686	0.999	0.973	0.999	0.999	0.895	0.001

***p < 0.01, **p < 0.05, and *p < 0.1. Robust standard errors are in parentheses. Control variables included the three types of variables mentioned above: parental characteristics, children and family characteristics, and village–level characteristics, as well as year dummy variables and province dummy variables.

value of the independent mediation effect of grandparenting time was smaller than the independent mediation effect of remittance. In addition, grandparenting time also exerted a chain-mediated effect by affecting children's economic support, and the chain-mediated effect and independent mediation effect of grandparenting time were opposite.

Discussion

This study examined the question of how adult children's rural–urban migration influences left-behind parents' health using the rural sample of the China Health and Retirement Longitudinal Study (CHARLS) in 2013, 2015, and 2018. This study found that children's migration can improve left-behind parents' physical health, but has no significant impact on parents' mental health, while some previous studies also found adult children's outmigration has positive associations between children's migration and parents' physical health (18, 22), and no significant impact on parents' mental health (49, 50). A possible but not the only reason is that children migration has different effects on health through "income effect" and "time allocation effect." For the influence of children migration on physical health, the positive effect of children's financial support compensated for the negative effect of time allocation. But in terms of mental health, the positive effect of children's financial support on their parents' mental health cannot completely replace or compensate for the negative effect of the weakened care and mental support caused by the absence of the children on their parents' mental health.

The mediation impact mechanism of children's migration on parents' health is analyzed. The study demonstrated time allocation and children's financial support mediated the relationship between children migration and parents' physical and mental health in opposite directions. The empirical analysis showed that children rural–urban migration negatively affected parents' health by increasing the burden of intergenerational care but positively affected parents' health by increasing financial support, and the positive effect of children's financial support was greater than the negative effect of intergenerational care. In addition, intergenerational care also exerted a positive chain mediating effect by affecting children's financial support; that is, children's financial support could mitigate the negative effects of intergenerational care on parents' health.

This study also found that there were obvious heterogeneous effects on gender, the number of children, and region. Children's migration improved fathers' health but did not improve mothers' health. There are two possible reasons: One is female health is more fragile and easily affected by changes in the external environment; the other is the female has an advantage in the role of caregiver, and mothers are more likely to bear family labor and the task of caring for grandchildren when their children go out to work. Therefore, compared to fathers, mothers' health is more severely negatively affected. We found that there is an adverse effect on parents who are living in western rural China. The possible reason is that in the western regions of China, the labor usually migrates to the eastern coastal areas to work, and the family income may improve after the children migrate. However, due to the distance, the frequency of children returning to their hometown is generally relatively low. Parents lack care and spiritual support and need to undertake more family labor. The income effect of migration cannot compensate for the time allocation effect. Meanwhile, in western rural China, public resources, such as medical and elderly support, are relatively insufficient. Parents need more support from their children.

TABLE 6 Mediating effect of grandparenting time and children's financial support.

	SRH	IADL	Physical activity ability	CES–D	SWB
Independent mediation effect of grandparenting time	−0.005	−0.013	−0.046	0.039	−0.071
Independent mediation effect of remittance	0.008	0.127	0.164	−0.178	0.218
Chain mediation effect of grandparenting time	0.007	0.109	0.140	−0.152	0.186

Conclusion

In this study, we found that adult children migration can improve parents' physical health, mainly thanks to the income effect. We also found although the income effect has a positive effect on parents' health, the time allocation effect has a negative effect on parents' health because of the lack of care and increased working hours of parents. Meanwhile, the positive income effect can partly offset such negative effects in health caused by the absence of migrant children.

The findings of this study have important implications. First, it is of great importance to promote the free movement of migrant workers. Rural labor mobility can optimize resource allocation, transfer surplus labor, significantly increase farmers' income, and subsequently, has a positive effect on the physical health of the rural elderly population through the income effect. Therefore, the policy needs to be improved to promote rural surplus labor transfer, including enhancing labor training, rights and interest protection, and welfare and household registration system reform. Second, intergenerational communication and relevant social care services for the rural left-behind elderly population should be enhanced furtherly. Although the transfer payment from migrant children can mitigate the negative effect of children's migration, it is quite limited to parents' mental health. Currently, the mental health of the rural left-behind elderly population in China is easily overlooked, this population's mental health problems are more serious. Giving financial support cannot completely substitute for the absence of children, and the communication between migrate children and left-behind parents should be enhanced with the application of modern information technology. Moreover, the social care system also should be constructed to provide excellent care service for the left-behind parents in rural areas.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

ChiZ designed the study, carried out the data collection and analysis, and participated in drafting the manuscript. ChoZ was involved in data analysis and drafting the manuscript. KL and XC participated in drafting the manuscript. All authors contributed to reviewing the manuscript and have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Association of social support with cognition among older adults in China: A cross-sectional study

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Objective: This study aimed to examine the relationship between social support and its sub-domains and cognitive performance, and the association with cognitive impairment among older adults in China.

Design: A cross-sectional study.

Setting and participants: We included 865 community-based individuals aged 65 and above from Hubei province, China.

Methods: The level of social support was evaluated using the social support rating scale (SSRC). The Mini-Mental State Examination was adopted to assess cognitive function, and its cut-offs were used to determine cognitive impairment among the participants. Multiple linear regression models and logistic regression models were used to estimate the β and odds ratios (*ORs*) and their 95% CIs, respectively.

Results: The participants were divided into quartiles 1–4 (Q1–Q4), according to the total scores of SSRC. After adjusting for sociodemographic characteristics, lifestyle factors, and history of diseases, for MMSE scores, compared to these in Q1, the β of Q2–Q4 were −0.22 (−0.88, 0.43), 0.29 (−0.35, 0.94), and 0.86 (0.19, 1.53), respectively; For cognitive impairment, the *ORs* of Q2–Q4 were 1.21 (0.80, 1.82), 0.62 (0.40, 0.94), and 0.50 (0.32, 0.80), respectively. Considering SSRC scores as the continuous variable, per 1-unit increase, the β was 0.05 (0.02, 0.09) for the cognitive score, and the *OR* was 0.95 (0.92, 0.98) for cognitive impairment. In addition, higher levels of both subjective support and support utilization were related to better MMSE performance and lower risks of cognitive impairment.

Conclusion and implications: Among the older adults in China, as expected, there is a positive relationship between social support and cognitive performance, and high levels of social support, particularly in support utilization, were related to low risks of cognitive impairment. More social support should be provided in this population to improve cognitive function and reduce the risks of cognitive impairment.

KEYWORDS

cognitive function, cognitive impairment, older adults, social support, cross-sectional study

Introduction

With the rapid aging of the population over the world, the diseases of cognitive impairment, including mild cognitive impairment (MCI) and dementia, are causing a tremendous burden on the economy and health (1, 2). MCI is a disorder characterized by impairment of memory, learning difficulties, and reduced ability to concentrate on a task for more than brief periods, and has a high risk of progressing to dementia (3). It is estimated that there are 15.07 million people with dementia and 38.77 million people with MCI in China (4). Given no effective treatment for dementia, the efforts on modifiable influencing factors are important for improving cognitive function and preventing diseases of cognitive impairment among older adults.

For an individual, social support is the composition of material and spiritual support from various people and organizations, including family members, friends, neighbors, colleagues, and governmental and non-governmental organizations. Given that the resources to keep alive, such as food, daily supplies, and emotional support, largely depend on the family members and other for older adults, social support may play a crucial role in the health outcomes of older adults. In addition, a previous study showed that common comorbidities, such as hypertension, diabetes, glycemic variability, and dyslipidemia were linked to cognitive decline (5–7). Social support in the older adult may be beneficial to controlling blood pressure and lipids well and keeping blood glucose stable (8–11). Several studies have explored the associations of emotional and instrumental support with cognitive function and brain image among adults in the US (12–15), UK (16), Dutch (17), Mexican (18), and South Africa (19). The results from these studies (12–23) were conflicting due to the heterogeneities in study design, sample size, and study population. In addition, social support was often divided into different aspects (24), such as objective support from living materials, subjective support from emotional networks, and support utilization indicating the ability to get others' support. However, there were limited studies investigating the relationship between social support and cognition in China.

In this study, by a specialized questionnaire for assessing different aspects of social support, we conducted a cross-sectional study and examined the association of social support and its sub-domains with cognition among older adults aged 65 and above in China.

Methods

Study population and data collection

Participants were recruited from Wuhan city, China. Eligible participants aged 65 and above volunteered to participate in this study and could provide informed consent and did not have severe physical diseases and were able to go to community health service centers. The following exclusion criteria were applied: (1) Hearing or language disorders and inability to communicate. (2) Severe diseases, such as mental illness, motor impairment, or history of stroke within two months. (3) Missing information on social support, cognitive test, or other covariates. We used following method to calculate the sample size, $n = Z_{a/2}^{2} * P * (1\text{-}P) / \delta^{2}$. According to previous studies (25, 26) on cognitive function among older adults in Hubei province, China, the prevalence of cognitive impairment was set as 25% in this study. In addition, $Z_{a/2}$ was set as 1.96, δ (allowable error) was set as 3%, and the required sample size was calculated to be 800. Cluster sampling methods were used for the survey. We first performed random sampling methods to select three community health service centers in Wuhan city, the residents whose health records were registered in health service centers were recruited. With the inclusion and exclusion criteria, a total of 865 older adults aged 65 and above were used as the final analytic sample. The detailed flowchart was presented in Figure 1.

Baseline data on socio-demographic and background variables (including general demographic characteristics, lifestyle factors, and history of diseases) were collected using a self-made questionnaire. The interviewers underwent extensive training as well as periodic certification. One-to-one interview in a quiet room was employed to complete all questionnaires. This study was approved by the Medical Ethics Committee of Medical College, Wuhan University of Science and Technology (No. WUSTMC-201942). Written informed consent was obtained from all participants.

Assessment of cognitive function

Mini-Mental State Examination (MMSE) originated from Folstein et al. in 1975 (27), and has 13 items, including orientation, attention, language, immediate recall, delayed recall, and construction, and the scores range from 0 to 30 points. High scores indicate good cognitive performance. The Chinese version of MMSE was employed to assess the cognitive function of participants in this study. The previous study has shown good reliability (28) and validity (29) of the Chinese version of the Mini-Mental State Examination. According to a previous validation study on the Chinese version of MMSE (29), the cut-off points of dementia and MCI were set as 16/17 and 19/20 for illiteracy, 19/20 and 24/25 for primary school, and 23/24 and 27/28 for junior high school and above in this population. The participants screened with dementia and MCI were considered to be with cognitive impairment.

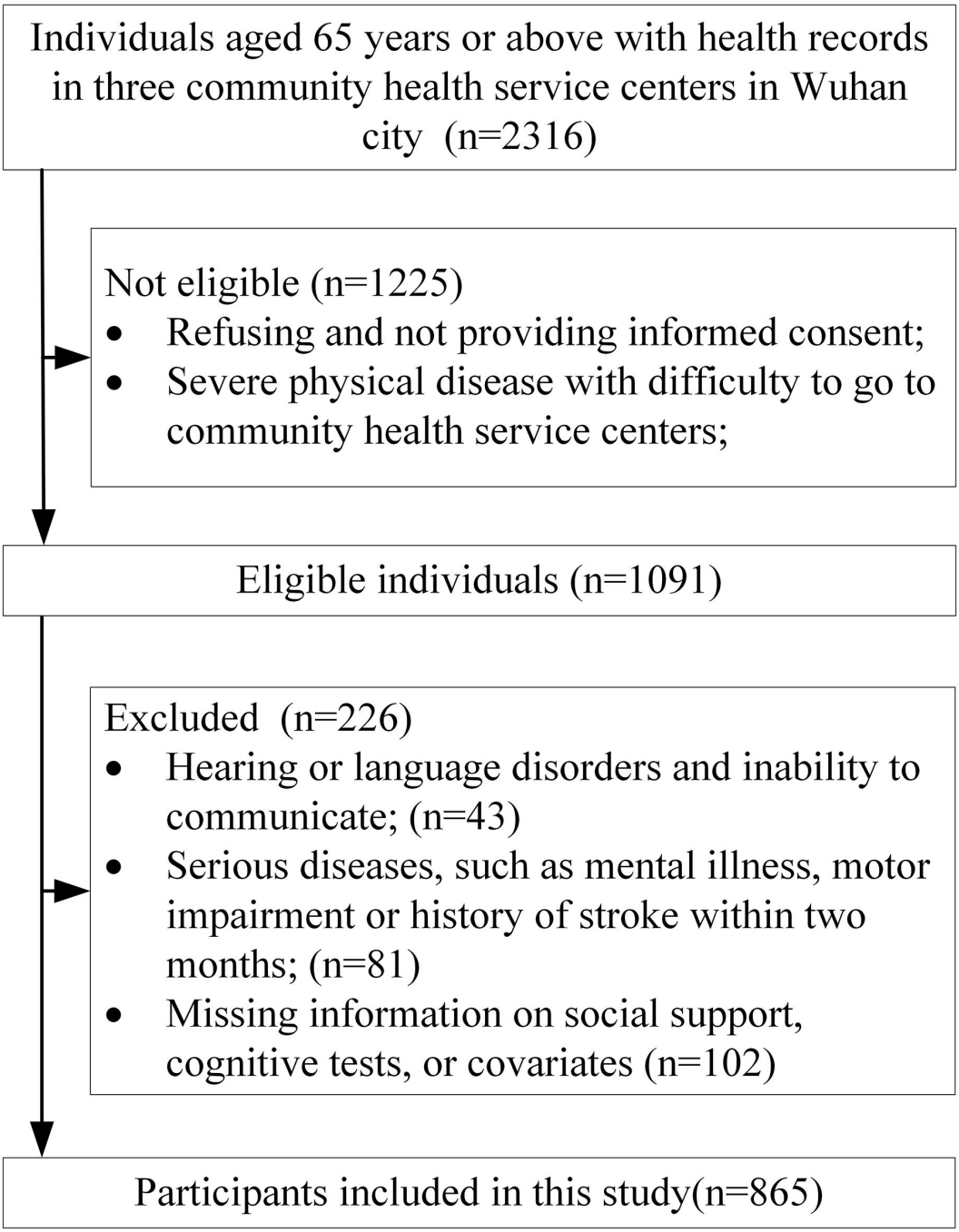

FIGURE 1
The flow chart of the inclusion and exclusion of study population.

Measurement of social support score

The score of social support was measured by the social support rating scale (SSRS) (24). As shown in Table 1, the SSRS consists of three sub-domains such as objective support, subjective support, and support utilization, its total scores range from 12 to 66, and higher scores indicate better social support. Cronbach's a coefficient, split-half correlation coefficient, and test-retest correlation coefficient of SSRS were 0.821, 0.875, and 0.829, respectively, indicating high reliability (30). A previous study also showed high-construct validity and content validity (31). As a questionnaire to evaluate social support, SSRC has

TABLE 1 The questions, options, and points of social support rating scale (SSRC)[a].

Questions	Options	Single/multiple, points
1. What number of friends who could provide the support you have now?	1. Nobody 2. 1–2 people 3. 3–5 people 4. 6 people or above	Single, 1–4 points
2. In the past year, you are	1. Living far from family member, and living along 2. No fixed shelter and living with strangers frequently 3. Living with friends, colleagues, and classmates 4. Living with family numbers	Single, 1–4 points
3. The relationship between you and neighborhoods	1. Never care 2. A little of concern 3. Obvious concern from some neighborhoods 4. Lots of concern from many neighborhoods	Single, 1–4 points
4. The relationship between you and colleagues	1. Never care 2. A little of concern 3. Obvious concern from some colleagues 4. Lots of concern from many colleagues	Single, 1–4 points
5.1 The support and care from		
(1) Spouse	1. No 2. Rare 3. General 5. Complete	Single, 1–4 points
(2) Parents	1. No 2. Rare 3. General 6. Complete	Single, 1–4 points
(3) Kids	1. No 2. Rare 3. General 7. Complete	Single, 1–4 points
(4) Brothers and sister	1. No 2. Rare 3. General 8. Complete	Single, 1–4 points
(5) Other family members, such as the brother's wife	1. No 2. Rare 3. General 4. Complete	Single, 1–4 points
6. The resources of financial support and solving questions when you are in trouble	1. No any source 2. Spouse 3. Other family members 4. Friends 5. Relatives 6. Colleagues 7. Organizations in work 8. Organizations from parties and other governmental organizations 9. Religious and social organizations 10. Others	Multiple, 0–9 points
7. The resources of care and comfort when you are in trouble	1. No source 2. Spouse 3. Other family members 4. Friends 5. Relatives 6. Colleagues 7. Organizations in work 8. Organizations from parties and other governmental organizations 9. Religious and social organizations 10. Others	Multiple, 0–9 points
8. The ways of pouring out when you are annoyed	1. Never pouring out to others 2. Pouring out to one or two close people 3. Pouring out when friends talk with me for initiative 4. Pouring out to others for the initiative to get support and understanding	Single, 1–4 points
9. The ways of asking for help when you are annoyed	1. Never asking for help from others 2. Rarely asking for help from others 3. Sometimes asking for help from others 4. Often asking for help from others	Single, 1–4 points
10. How often to participate in activities from all kinds of organizations, including working organizations, organizations from parties and other governmental organizations, religious and social organizations, and others	1. Never 2. Rarely 3. Sometimes 4. Often	Single, 1–4 points

[a] The SSRS was divided into three domains: objective support (questions 2, 6, and 7), subjective support (questions 1, 3, 4, and 5), and level of support utilization (questions 8, 9, and 10).

been widely accepted and used in epidemiological studies across China (32).

Socio-demographic characteristics, lifestyle factors, and history of diseases

According to the previous studies (33, 34), the socio-demographic characteristics, lifestyle factors, and history of diseases were considered covariates. Socio-demographic characteristics included age, sex, education level, and marital status. Education levels were divided into three categories: 0–6 years, 7–9 years, and ≥10 years. Marital status was categorized as married and non-married (single, divorced, or widowed). Lifestyle factors included smoking status and alcohol intake, which were defined as yes or no based on self-reported information. History of disease included obesity, hypertension, and diabetes. Body mass index (BMI)

was calculated using weight to divide the square of height, and participants with a BMI <18.5 kg/m^2 were considered underweight, between 18.5 and 23.9 kg/m^2 were considered normal, between 24 and 27.9 kg/m^2 were considered overweight, and ≥ 28 kg/m^2 were considered obese (35). Hypertension was defined as at least one of followed conditions: self-reported history of diagnosed hypertension, having anti-hypertension drugs or measured systolic blood pressure ≥140 mm Hg, or diastolic blood pressure ≥90 mm Hg (36). Diabetes was defined as at least one of the following conditions: self-reported history of diagnosed diabetes, having glucose-lowering medications or fasting blood glucose level of ≥7 mmol/L (37).

Statistical analysis

Differences between groups in demographic variables were examined using ANOVA analysis for continuous variables, and Pearson's chi-square test for categorical variables. Multiple linear regressions were performed to calculate the partial regression coefficient between the social support and MMSE scores. Unconditional logistic regression models were used to examine the association of social support with cognitive impairment by evaluating the odds ratio. Besides, the linear relationship and odds ratio between scores of three domains of social support were also examined. The covariates were controlled in model 1: adjusted for age and sex; model 2, further adjusted for education level, marriage, smoking, and drink; model 3, further adjusted for BMI categories, hypertension, and diabetes. All reported *P*–values were two-tail, and $P < 0.05$ was considered to be statistically significant. All statistical analyses were performed using SPSS 19.0 (SPSS Inc., Chicago, IL, USA).

Results

Characteristics of participants

The mean age in this study was 70.44 years old, and 53.18% were women. There were 264 participants with cognitive impairment, with a 30.52% of cognitive impairment prevalence. The demographic data and lifestyle factors were presented in Table 2 according to the participants with the quartiles 1–4 of social support scores. The participants with higher support scores were more likely to have lower age, higher MMSE scores, higher education levels, and be married. There was no significant difference in sex, smoking, drinking, BMI, hypertension, and diabetes among these groups.

The relationship between social support and cognitive function

As shown in Table 3, in multiple linear regression analysis of controlling the demographic characteristics, lifestyle, and history of diseases, compared to the participants with the lowest quartile of social support score (Q1), those with the highest quartile of social support score (Q4) was positively related to MMSE score ($\beta = 0.86$, 95% *CI*: 0.19, 1.53). The β for 1-unit increment of social support was 0.05 (95% *CI*: 0.02, 0.09; $P < 0.001$) for MMSE, showing a positive relationship between social support and MMSE scores. In addition, objective support and subjective support scores were not related to the MMSE scores. The support utilization score was positively related to MMSE scores, and the β was 0.14 (95% *CI*: 0.04, 0.24) for 1-unit increment (Table 4).

Association of social support with cognitive impairment

As shown in Table 5, by the logistic regression model, the associations of social support with cognitive impairment were examined after adjusting the covariates. In the analysis of adjusted model 3, compared to the participants with Q1, those with Q4 have a reduced odds ratio (*OR* = 0.50, 95% *CI*: 0.32, 0.80). With the 1-unit increment of social support score, there was a 5% decreased risk (*OR* = 0.95, 95% *CI*: 0.92, 0.98; $P = 0.003$) for cognitive impairment. Moreover, the higher scores in support utilization were associated with lower risks of CI, with a 10% decreased risk (*OR* = 0.90, 95% *CI*: 0.84, 0.96) for a 1-unit increment (Table 6).

Discussion

We examined the relationship between social support and cognition among older adults in China, and found that the level of social support, particularly in support utilization, was positively associated with cognitive function. In addition, higher levels of social support, subjective support, and support utilization were associated with reduced risks of cognitive impairment, after controlling the socio-demographic characteristics, lifestyle factors, and history of diseases.

Our results are in accordance with previous studies (12, 17–22), investigating the link between social support and cognitive function. A cohort study of 624 older adults using the structural equation model showed that social support at baseline was negatively related to cognitive function 2 years later (22). A longitudinal study, including 2,255 participants aged 55–85 over 6 years of follow-up, found that high levels of emotional and instrumental support were related to better cognitive performance (17). A cross-sectional study also showed

TABLE 2 Baseline characteristics of study population according to quartiles of social support scores[a].

Characteristic	Social support				F/χ^2	*P*-value
	Quartile 1 (12–28)	Quartile 2 (29–32)	Quartile 3 (33–36)	Quartile 4 (37–53)		
Sample size (*n*)	223	197	234	211		
Support, *mean* (*SD*)	25.2 (2.9)	30.5 (1.1)	34.5 (1.2)	40.8 (3.5)	1603.16	<0.001
MMSE, *mean* (*SD*)	25.8 (4.2)	25.9 (4.3)	26.8 (3.8)	27.5 (2.7)	9.49	<0.001
Age, *mean* (*SD*)	71.6 (5.2)	70.8 (5.2)	69.9 (4.3)	69.4 (4.6)	9.08	<0.001
Sex, *n* (%)	3.11	0.375				
Male	107 (50.0)	94 (47.7)	116 (49.6)	88 (41.7)		
Female	116 (52.0)	103 (52.3)	118 (50.4)	123 (58.3)		
Educational level, *n* (%)	24.36	<0.001				
0–6 years	114 (51.2)	85 (43.2)	82 (35.0)	66 (31.3)		
7–9 years	65 (29.2))	66 (33.5)	82 (35.0)	73 (34.6)		
≥10 years	44 (19.7)	46 (23.4)	70 (29.9)	72 (34.1)		
Marital status, *n* (%)	83.53	<0.001				
Married	138 (61.9)	153 (77.7)	211 (90.2)	195 (92.4)		
Non–married[b]	85 (38.1)	44 (22.3)	23 (9.8)	16 (7.6)		
Smoking status, *n* (%)	1.16	0.762				
Smoking	48 (21.5)	45 (22.8)	58 (24.8)	44 (20.9)		
Non–smoker	175 (78.5)	152 (77.2)	176 (75.2)	167 (79.1)		
Alcohol intake, *n* (%)	0.11	0.991				
Drinking	43 (19.2)	36 (18.3)	45 (19.2)	41 (19.4)		
Non–drinker	180 (80.7)	161 (81.7)	189 (80.8)	170 (80.6)		
BMI, *n* (%)	9.51	0.392				
<18.5	8 (3.6)	99 (44.4)	93 (41.7)	23 (10.3)		
18.5–23.9	10 (5.1)	85 (43.2)	80 (40.6)	22 (11.2)		
24.0–27.9	11 (4.7)	115 (49.2)	73 (31.2)	35 (15.0)		
≥28.0	6 (2.8)	104 (49.3)	76 (36.0)	25 (11.9)		
Hypertension, *n* (%)	5.82	0.121				
Yes	157 (70.4)	144 (73.1)	147 (62.8)	143 (67.8)		
No	66 (29.6)	53 (26.9)	87 (37.2)	68 (32.2)		
Diabetes, *n* (%)	1.39	0.707				
Yes	45 (20.2)	33 (16.8)	45 (19.2)	35 (16.6)		
No	178 (79.8)	164 (83.3)	189 (80.8)	176 (83.4)		

[a] Data are n (%) unless indicated otherwise; MMSE, mini–mental state examination; BMI, body mass index.
[b] non–married means single, divorced, or widowed.

the positive relationship between social support and cognitive function in middle-aged African Americans (12), older adults in China (20), Mexican adults aged 50 and older (18), and middle-aged and older adults in rural South Africa (19). Another study, consisting of 623 middle-aged adults with a family history of Alzheimer's disease, reported that a higher level of social support was associated with better performance on tests of speed and flexibility (21). A large-scale brain image study found that individuals with social isolation had lower gray matter volumes in several brain regions temporal, such as the temporal lobe, frontal lobe, and hippocampus, and the gray matter volumes partly explained the association of baseline social isolation with cognition (16). However, several studies indicated different results from this study. Prospective studies (13, 23) have explored the temporal associations between cognitive function and social support and showed that poor cognitive function might have a negative effect on social support, and social support in mid-life was not associated with outcomes of cognitive impairment in late life. Further interventional studies and long-term observational studies are needed to prove the causal association and temporal relationship between social support and cognitive function.

The present study also indicated the inverse relationship between cognitive impairment and both subjective support and support utilization in older adults. The items of subjective support reflected the magnitude of emotional support from

TABLE 3 Relationship between the social support and score in MMSE in multiple linear regression analysis[a].

	Social support				1 unit increment	*P* for 1 unit increment
	Quartile 1	Quartile 2	Quartile 3	Quartile 4		
Model 1[b]	0 (ref.)	0.04 (−0.66, 0.73)	**0.78 (0.10, 1.45)**	**1.59 (0.90, 2.28)**	**0.10 (0.06, 0.14)**	<0.001
Model 2[c]	0 (ref.)	−0.20 (−0.86, 0.44)	0.27 (−0.37, 0.91)	**0.86 (0.19, 1.53)**	**0.06 (0.02, 0.10)**	<0.001
Model 3[d]	0 (ref.)	−0.22 (−0.88, 0.43)	0.29 (−0.35, 0.94)	**0.86 (0.19, 1.53)**	**0.05 (0.02, 0.09)**	<0.001

[a] Data are multivariate β (95% confidence interval); support score range of quartile 1–4 corresponds to 12–28, 29–32, 33–36, and 37–53, respectively.
[b] Model 1: adjusted for age and sex.
[c] Model 2: adjusted for model 1+ education level, marital status, smoking status, and alcohol intake.
[d] Model 3: adjusted for model 2+ body mass index, hypertension, and diabetes.
Bold values means $P < 0.05$.

TABLE 4 The relationship between three domains of social support and MMSE score in multiple linear regression[a].

Domains	*β* of 1 unit increment	*P* for 1 unit increment
Objective support		
Model 1[b]	**0.13 (0.03, 0.23)**	0.013
Model 2[c]	0.05 (−0.04, 0.15)	0.293
Model 3[d]	0.05 (−0.05, 0.14)	0.355
Subjective support		
Model 1[b]	**0.10 (0.04, 0.16)**	0.002
Model 2[c]	0.06 (−0.04, 0.11)	0.067
Model 3[d]	0.06 (−0.04, 0.11)	0.067
Support utilization		
Model 1[b]	**0.22 (0.12, 0.33)**	<0.001
Model 2[c]	**0.14 (0.04, 0.24)**	0.005
Model 3[d]	**0.14 (0.04, 0.24)**	0.005

[a] Data are multivariate β (95% confidence interval).
[b] Model 1: adjusted for age and sex.
[c] Model 2: adjusted for model 1+ education level, marital status, smoking status, and alcohol intake.
[d] Model 3: adjusted for model 2+ body mass index, hypertension, and diabetes.
Bold values means $P < 0.05$.

friends, neighbors colleagues, and family members (38). Consistent with our results, a longitudinal study with over 7.5 years of follow-up found a significant relationship between the high level of emotional support and change in global cognitive function. The aforementioned longitudinal (17) and cross-sectional (12, 19) studies also showed similar associations between emotional support with cognitive function. The items of support utilization describe the degree of voluntarily seeking others' help and understanding and attending social activities, which may involve the willingness to communicate and collaborate with others. In addition, the objective support was not related to cognition function. These associations of the sub-domain of social support and cognitive function highlighted the importance of emotional support and support utilization, suggesting that facilitating the emotional support and support utilization of participants may be beneficial to the prevention of poor cognitive performance and cognitive impairment.

Some interpretations may increase the understanding of the relationship between social support and cognitive function. Accumulating evidence demonstrated that social support was associated with a reduced risk of depression (39, 40) and well-being (41). Several large prospective studies proved that these improvements in mental health might delay the progression of cognitive impairment and Alzheimer's disease (42). Moreover, social support also means the degree of feedback when older adults ask for needs and help. For instance, foods to eat and drugs to perform always need to be provided and prepared for older adults. The loss of these may cause accelerating cognitive decline. Importantly, as vulnerable people, older adults have more benefits from social support than younger. In addition, social support could reflect long-term care from others, which may increase the management of blood lipids and glucose (8–11) and reduce the risk of Alzheimer's disease and dementia in late life for the benefit of controlling blood glucose and lipids well.

The biological mechanisms that social support is beneficial to cognitive function are feasible. Social interaction was considered as a pathway of mental stimulation, which could contribute to cognitive reserves by activating and strengthening neurobiological activities (18, 43). Animal studies also indicated that the level of brain-derived neurotrophic factor (BDNF) playing a beneficial role in the brain was related to social support in rats (44, 45). Interestingly, another human study showed that social support from others was associated with BDNF, which alleviates the stress response (46). The evidence from human studies and animal experiments suggested that tDNF may explain the links between social support and cognitive function.

In addition, the specialized questionnaire was important to evaluate the level of social support. This study used the SSRC to assess the social support of participants. The items of SSRC consist of objective support, perceived social support, and support utilization, which comprehensively represent the level of social support. SSRC was confirmed with good reliability and α's coefficient (47, 48). Epidemiological studies among the Chinese population have widely used SSRC to examine the relationship between social support and diseases (32, 49). Over past decades, studies across the world have employed various tests to determine social support. However, there

TABLE 5 Association between the social support and cognitive impairment in logistic regression.

	Social support				1 unit increment	*P* for 1 unit increment
	Quartile 1	Quartile 2	Quartile 3	Quartile 4		
NC/CI, *n* / *n*	140/83	118/79	176/58	167/44		
Model 1[b]	1.00 (ref.)	1.19 (0.80, 1.78)	**0.62 (0.41, 0.93)**	**0.50 (0.32, 0.77)**	**0.95 (0.93, 0.97)**	<0.001
Model 2[c]	1.00 (ref.)	1.20 (0.80, 1.80)	**0.62 (0.41, 0.96)**	**0.50 (0.32, 0.80)**	**0.95 (0.92, 0.98)**	0.003
Model 3[d]	1.00 (ref.)	1.21 (0.80, 1.82)	**0.62 (0.40, 0.94)**	**0.50 (0.32, 0.80)**	**0.95 (0.92, 0.98)**	0.003

[a] Data are odds ratio (95% confidence interval); support score range of quartile 1–4 corresponds to 12–28, 29–32, 33–36, and 37–53, respectively; NC, normal cognition; CI, cognitive impairment.
[b] Model 1: adjusted for age and sex.
[c] Model 2: adjusted for model 1+ education level, marital status, smoking status, and alcohol intake.
[d] Model 3: adjusted for model 2+ body mass index, hypertension, and diabetes.
Bold values means $P < 0.05$.

TABLE 6 The association of three domains of social support with cognitive impairment in logistic regression[a].

Domains	*OR* of 1 unit increment	*P* for 1 unit increment
Objective support		
Model 1[b]	0.94 (0.89, 1.00)	0.063
Model 2[c]	0.96 (0.90, 1.02)	0.158
Model 3[d]	0.96 (0.90, 1.02)	0.213
Subjective support		
Model 1[b]	**0.94 (0.91, 0.98)**	0.001
Model 2[c]	**0.94 (0.91, 0.98)**	0.003
Model 3[d]	**0.94 (0.91, 0.98)**	0.003
Support utilization		
Model 1[b]	**0.90 (0.80, 0.96)**	0.002
Model 2[c]	**0.90 (0.84, 0.96)**	0.002
Model 3[d]	**0.90 (0.84, 0.96)**	0.002

[a] Data are odds ratio (95% confidence interval).
[b] Model 1: adjusted for age and sex.
[c] Model 2: adjusted for model 1+ education level, marital status, smoking status, and alcohol intake.
[d] Model 3: adjusted for model 2+ body mass index, hypertension, and diabetes.
Bold values means $P < 0.05$.

are some differences between the various versions of social support due to the distinction of culture and language among different countries and areas (13, 17, 19). Thus, future studies using approximate questionnaires will contribute to providing empirical evidence to evaluate the association of social support with diseases.

This study has several limitations to report. First, given the cross-sectional nature of this study, we could not examine the temporal association between social support and cognitive function. Second, the MMSE, as the assessment of cognitive function, was used in this study. Further epidemiological studies employing a battery of multi-domain cognitive tests and clinical diagnosis of MCI and dementia as outcomes are promising. Third, all participants in this study were recruited from Hubei province, and the results may not apply to older adults in other parts of China. Fourth, we did not test the biomarkers associated with support and cognition, such as BDNF. Further studies based on blood or brain biomarkers are needed to confirm the findings in this study. Fifth, although we have adjusted for many potential confounders in this study, we are unable to completely rule out residual confounders from unmeasured factors.

Conclusions and implications

In this cross-sectional study, we found that social support and support utilization were positively related to cognitive function. In addition, social support, subjective support, and support utilization were negatively associated with the risk of cognitive impairment. The improvement of social support, particularly in support utilization, from health care policies, society, and family numbers may have a protective effect on late-life cognition among old adults in China.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Medical Ethics Committee of Medical College, Wuhan University of Science and Technology. The patients/participants provided their written informed consent to participate in this study.

Author contributions

SR and XL proposed and designed the study. SR and BL drafted this article. YG and BL completed the statistical analysis. SR supervised the data acquisition, statistical analysis, and interpretation of results. All authors critically revised the manuscript for important intellectual content.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The impact of socioeconomic status and sleep quality on the prevalence of multimorbidity in older adults

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Introduction: Multimorbidity has become a global public health concern that can cause serious damage to the health status of older adults. This study aimed to investigate the impact of socioeconomic status (SES) and sleep quality on the prevalence of multimorbidity in older adults, thus providing a reference for reducing the risk of the prevalence of multimorbidity and improving the health of older adults.

Methods: A multi-stage random sampling method was used to conduct a questionnaire survey on 3,250 older adults aged 60 years and above in Shanxi Province, China. The chi-square test and multiple logistic regression models were used to analyze the association of SES and sleep quality with the prevalence of multimorbidity of older adults.

Results: The prevalence of multimorbidity was 30.31% in older adults aged 60 years and above in Shanxi Province, China. After adjusting for confounders, very low SES (OR = 1.440, 95% CI: 1.083–1.913) and poor sleep quality (OR = 2.445, 95% CI: 2.043–2.927) were associated with the prevalence of multimorbidity. Older adults with low SES and poor sleep quality had the highest risk of the prevalence of multimorbidity (OR = 3.139, 95% CI: 2.288–4.307).

Conclusions: SES and sleep quality are associated with the prevalence of multimorbidity in older adults, and older adults with lower SES and poorer sleep quality are at higher risk for the prevalence of multimorbidity.

KEYWORDS

older adults, socioeconomic status, sleep quality, multimorbidity, prevalence

Introduction

Aging is one of the most prominent features in recent population dynamics around the world. Owing to the declines in both fertility and mortality, the proportion of older adults in the population has increased substantially both in developed and developing countries (1). China has experienced rapid population aging in the past decades (2). According to the seventh national census, the population aged 60 and above has exceeded 264 million, accounting for 18.70% of the total population of China (3). The population aging brings a series of socioeconomical challenges to the current healthcare system in China (4).

Multimorbidity is defined as the condition of co-existence of two or more chronic conditions in a person (5). It is becoming more and more common in older adults. A systematic review (41 articles were included) indicated that the prevalence of multimorbidity in older adults ranges from 55.0 to 98.0% (6). Multimorbidity can lead to adverse health consequences for older adults. A study revealed the risk of death was 1.73 and 2.72 times for older adults with 2+ and 3+ morbidities, respectively, compared to those without multimorbidity (7). Multimorbidity is influenced by several factors. Studies found a strong association between multimorbidity and age (8, 9). Compared with men, women are at higher risk of multimorbidity (10). In addition, several factors, such as low education level, smoking, alcohol consumption, obesity, high waist circumference, and family history of chronic conditions, are associated with multimorbidity (10–12). Focusing on multimorbidity of older adults is of great significance to protect their health and cope with population aging.

Among various health-related factors, SES holds an important position. In terms of relationships between SES, health, and social causality, there is a common view among scholars that the lower the individual's SES, the worse the health status (13). Scholars found that SES is one of the strongest and most consistent predictors of morbidity and mortality (14–16). This finding applies to all diseases with few exceptions, and SES continues throughout the entire life span (14). However, is the effect of SES on multimorbidity in older adults the same? Based on this, we hypothesize that there is a significant association between SES and the prevalence of multimorbidity in older adults.

Sleep, as a life behavior occupying a significant portion of our lives, plays an important role in maintaining human health (17). But sleep disorder has become one of the major health issues of older adults (18, 19). Epidemiological studies have shown an association between poor sleep quality and perennial chronic diseases in older adults, such as type 2 diabetes, hypertension, coronary heart disease, and chronic obstructive pulmonary disease (20, 21). Sleep quality is also associated with psychological distress, and older adults who have poor sleep quality are more likely to experience various mental health problems (22). Therefore, we hypothesize that poor sleep quality is related to the prevalence of multimorbidity in older adults. Different SES will greatly affect people's behavior and lifestyle (23). Several studies have found that people with low SES has worse sleep than those with high SES (24–26). While improving sleep quality is an effective way to protect health, whether this is effective for older adults with any SES and the effect of different sleep qualities on the prevalence of multimorbidity in older adults with different SES are unclear. Therefore, this study assumed that different combinations of SES and sleep quality have different effects on the prevalence of multimorbidity in older adults to analyze the combined association of SES and sleep quality.

The purpose of this study was to investigate the impact of SES and sleep quality on the prevalence of multimorbidity in older adults. In the context of population aging, the health of older adults is receiving increasing attention. It is believed that the results of this study would contribute to reducing the risk of the prevalence of multimorbidity and improving their health.

Materials and methods

Sample and participants

A cross-sectional study based on a structured questionnaire was conducted in Shanxi Province from June to August 2019, and a multi-stage random sampling method was used to select participants. In the first stage, all 11 prefecture-level cities in Shanxi Province were included as sampling units, and the districts (counties and county-level cities) of each prefecture-level city were numbered according to the order published on the government website. In the second stage, two districts (counties and county-level cities) were randomly selected from each prefecture-level city using the random number table method. In the third stage, two communities (administrative villages) were selected from each district (county and county-level city) using the same method. In the fourth stage, considering the different population sizes of each community (administrative village), one or two residential communities (natural villages) were selected from each community (administrative village), from which older adults were randomly selected as study subjects.

The inclusion criteria were as follows: permanent residents of Shanxi Province aged 60 years and above, without serious cognitive impairment, with no communication impairment, and voluntarily participation in the survey. A total of 3,266 questionnaires were distributed, and 3,250 valid questionnaires were recovered, with an effective recovery rate of 99.51%.

All the participants were informed of the purpose and procedure of the investigation, after which they signed consent. After providing consent, the participants were invited by trained investigators to respond to questionnaires. All questionnaires were anonymous. The study procedures were approved by the University Ethics Committee.

Measures

Socioeconomic status

Factors such as education level, occupation, income, wealth, and deprivation are often used to reflect SES (2). This study selected educational level, occupation before retirement, and personal monthly income to measure the SES of older adults with reference to a previous study (23). Educational level is divided into the following four categories: no formal education, primary education, secondary education, and higher education. Occupation before retirement is divided into the following five groups: unemployed, peasant, worker, professional technicians, and enterprise/institution personnel. Personal monthly income (RMB) is divided into three levels: less than 1,000, 1,000–2,999, and 3,000 and above. Principal component analysis (PCA) was used to construct the SES index to comprehensively evaluate the SES of the older adults. Quartiles were used to classify the SES index into four categories: very high, high, low, and very low.

Sleep quality

The Pittsburgh Sleep Quality Index (PSQI) was used to measure sleep quality of older adults (27). It contains seven component scores: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medications, and daytime dysfunction. The seven component scores were added to yield a global PSQI score, and the range of the global score was 0–21. The higher the score, the worse the sleep quality. In this study, the global PSQI scores of <5 and ≥ 5 were defined as "good sleep quality" and "poor sleep quality", respectively (28). Cronbach's α was 0.758 for the PSQI in this study.

Multimorbidity

A total of 26 chronic diseases were included in the questionnaire in this study (e.g., hypertension, diabetes, coronary heart disease, atherosclerosis, chronic obstructive pulmonary disease, chronic nephritis, stroke, osteoporosis). The number of chronic diseases for older adults was self-reported and verified with the diagnostic evidence of medical records or the prescriptions from doctors (29). Multimorbidity was established when older adults suffer from two or more chronic diseases.

Covariates

Sociodemographic and lifestyle variables of older adults were recorded through the questionnaire. Sociodemographic variables included gender (male or female), age (60-, 70-, or 80- years), marital status (married, unmarried or other), empty nest status (not-empty nest, empty nest, or no children), family history of diseases (no or yes), and BMI categories (underweight [<18.5 kg/m^2], normal weight [18.5- kg/m^2], overweight [24- kg/m^2], or obesity [≥ 28 kg/m^2]). Lifestyle variables included physical activity level (low, middle, or high), drinking status (not-drinking, past-drinking, or now-drinking), and smoking status (not-smoking, past-smoking, or now-smoking). Physical activity level was measured using the Chinese version of the International Physical Activity Questionnaire, long form (IPAQ-LC), and the IPAQ-LC has demonstrated adequate reliability and showed sufficient evidence of validity (30). The results were classified into low, middle, and high categories according to the criteria accordingly (31).

Statistical analysis

Continuous variables were presented as mean ± SE, and categorical variables as frequency (%). PCA was used to construct the SES index. The chi-square test was used to compare the prevalence of multimorbidity among older adults with different sociodemographic variables, lifestyle variables, sleep quality, and SES. The multiple logistic regression models were used to analyze the association of SES and sleep quality with the prevalence of multimorbidity, and the association of different combinations of SES and sleep quality with the prevalence of multimorbidity in older adults. SPSS 22.0 (IBM, New York, USA) was used for all the statistical analyses in this study. All tests were two-tailed, and $P < 0.05$ was considered statistically significant.

Results

Basic characteristics of older adults

Among the 3,250 older adults, 1,515 (46.62%) were male and 1,735 (53.38%) were female. The largest number [1,769 (54.43%)] of older adults aged 60–70 years. A total of 985 (30.31%) participants suffered from multimorbidity, and 1,587 (48.83%) participants were recognized as having poor sleep quality. The distribution of the sociodemographic variables of older adults is shown in Table 1.

Multimorbidity with different characteristics

The results showed that there were significant differences in gender, age, marital status, empty nest status, family history of diseases, BMI categories, physical activity level, drinking status, smoking status, and sleep quality in different types of chronic diseases ($P < 0.05$). The factors female, age 80 years and above, unmarried or others, empty nest, have a family history of diseases, obesity, low physical activity level, past-drinking,

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TABLE 1 Multimorbidity with sociodemographic, lifestyles, and sleep quality in older adults.

Factors	N	Types of chronic diseases [*N* (%)]			χ^2	*P*
		None	1	≥2 (multimorbidity)		
Gender					6.890	0.032
Male	1,515	652 (43.04)	438 (28.91)	425 (28.05)		
Female	1,735	697 (40.17)	478 (27.55)	560 (32.28)		
Age					127.342	<0.001
60-	1,769	872 (49.29)	468 (26.46)	429 (24.25)		
70-	1,164	386 (33.16)	372 (31.96)	406 (34.88)		
80-	317	91 (28.71)	76 (23.97)	150 (47.32)		
Marital status					11.459	0.003
Married	2,842	1,061 (42.75)	705 (28.40)	716 (28.85)		
Unmarried or others	768	288 (37.50)	211 (27.47)	269 (35.03)		
Empty nest status					42.610	<0.001
Not-empty nest	1,599	703 (43.96)	424 (26.52)	472 (29.52)		
Empty nest	1,581	595 (37.63)	483 (30.55)	503 (31.82)		
No children	70	51 (72.86)	9 (12.86)	10 (14.28)		
Family history of diseases					88.183	<0.001
No	3,084	1,334 (43.26)	860 (27.89)	890 (28.86)		
Yes	166	15 (9.04)	56 (33.73)	95 (57.23)		
BMI categories					35.434	<0.001
Underweight	452	202 (44.69)	111 (24.56)	139 (30.75)		
Normal weight	1,719	771 (44.85)	451 (26.24)	497 (28.91)		
Overweight	843	301 (35.71)	280 (33.21)	262 (31.08)		
Obesity	236	75 (31.78)	74 (31.36)	87 (36.86)		
Physical activity level					20.474	<0.001
Low	723	317 (43.85)	162 (22.41)	244 (33.74)		
Middle	1,321	527 (39.89)	382 (28.92)	412 (31.19)		
High	1,206	505 (41.87)	372 (20.85)	329 (27.78)		
Drinking status					49.057	<0.001
Not-drinking	2,389	1,025 (42.90)	650 (27.21)	714 (29.89)		
Past-drinking	279	62 (22.22)	102 (36.56)	115 (41.22)		
Now-drinking	582	262 (45.02)	164 (28.18)	156 (26.80)		
Smoking status					60.782	<0.001
Not-smoking	2,264	987 (43.60)	601 (26.55)	676 (29.85)		
Past- smoking	357	81 (22.68)	138 (38.66)	138 (38.66)		
Now-smoking	629	281 (44.67)	177 (28.14)	171 (27.19)		
Sleep quality					150.266	<0.001
Good	1,663	854 (51.35)	431 (25.92)	378 (22.73)		
Poor	1,587	495 (31.19)	485 (30.56)	607 (38.25)		
Total		1,349 (41.51)	916 (28.18)	985 (30.31)		

past-smoking, and poor sleep quality had a higher prevalence of multimorbidity (Table 1).

SES of older adults

Among the 3,250 older adults, 577 (17.75%) had no formal education, while 1,062 (32.68%), 1,324 (40.74%), and 287 (8.83%) had primary, secondary, and higher education, respectively. In terms of occupation before retirement, the largest number [1,466 (45.11%)] of older adults were peasants, while the smallest number [221 (6.80%)] were unemployed. Of all older adults, 1,691 (52.03%) had a personal monthly income <1,000, followed by 808 (24.86%) with 3,000 and above and 751 (23.11%) with 1,000-2,999. PCA was used to construct the SES index. The results showed that the KMO coefficient was 0.680, and Bartlett's test showed $P < 0.001$. Based on the principle that the eigenvalue is more than 1 or the cumulative contribution rate is more than 80%, the principal component was determined and the SES index was calculated. Then, the SES index was divided

TABLE 2 Multimorbidity with SES in older adults.

Factors	N	Types of chronic diseases [*N* (%)]			χ^2	*P*
		None	1	≥2 (multimorbidity)		
Educational level					67.211	<0.001
No formal education	577	198 (34.32)	162 (28.08)	217 (37.60)		
Primary education	1,062	389 (36.63)	329 (30.98)	344 (32.39)		
Secondary education	1,324	596 (45.02)	364 (27.49)	364 (27.49)		
Higher education	287	166 (57.84)	61 (21.25)	60 (20.91)		
Occupation before retirement					15.608	0.048
Unemployed	221	98 (44.34)	59 (26.70)	64 (28.96)		
Peasant	1,466	560 (38.20)	428 (29.20)	478 (32.60)		
Worker	538	237 (44.05)	155 (28.81)	146 (27.14)		
Professional technicians	272	124 (45.59)	64 (23.53)	84 (30.88)		
Enterprise/institution personnel	753	330 (43.82)	210 (27.89)	213 (28.29)		
Personal monthly income (RMB)					20.963	<0.001
<1,000	1,691	654 (38.68)	476 (28.15)	561 (33.17)		
1,000–2,999	751	353 (47.00)	211 (28.10)	187 (24.90)		
≥3,000	808	342 (42.33)	229 (28.34)	237 (29.33)		
SES					30.696	<0.001
Very high	873	389 (44.56)	237 (27.15)	247 (28.29)		
High	753	349 (46.35)	203 (26.96)	201 (26.69)		
Low	1,063	419 (39.42)	318 (29.92)	326 (30.66)		
Very low	561	192 (34.22)	158 (28.16)	211 (37.62)		
Total		1,349 (41.51)	916 (28.18)	985 (30.31)		

into four categories based on quartiles: very high, high, low, and very low. The number of older adults in each category was 873 (26.86%), 753 (23.17%), 1,063 (32.71%), and 561 (17.26%), respectively (Table 2).

Multimorbidity with different SES

The results showed that there were significant differences in educational level, occupation before retirement, personal monthly income, and SES in different types of chronic diseases ($P < 0.05$). The prevalence of multimorbidity was higher among older adults for the factors no formal education, peasant, personal monthly income <1,000, and very low SES (Table 2).

The association of SES and sleep quality with multimorbidity

The association of SES and sleep quality with the prevalence of multimorbidity was analyzed using the multiple logistic regression model. After adjusting for confounders, compared with very high SES, the risk of the prevalence of multimorbidity of high SES, low SES, and very low SES was 0.920 (95% CI: 0.713–1.188), 1.195 (95% CI: 0.943–1.515), and 1.440 (95% CI: 1.083–1.913), respectively. Compared with good sleep quality, the risk of the prevalence of multimorbidity was 2.445 (95% CI: 2.043–2.927) for poor sleep quality (Table 3).

The association of different combinations of SES and sleep quality with multimorbidity

The group with very high SES and good sleep quality was used as the reference group, after adjusting for confounders. The combinations of each type of SES and poor sleep quality and the combination of very low SES and good sleep quality were significantly associated with the prevalence of multimorbidity. Among these groups, older adults with low SES and poor sleep quality had the highest risk of the prevalence of multimorbidity (OR = 3.139, 95% CI: 2.288–4.307) (Table 4).

Discussion

In this study, the prevalence of multimorbidity was 30.31% in older adults. Studies on multimorbidity have been conducted

TABLE 3 Association of SES and sleep quality with multimorbidity in older adults.

Factors	N	Types of chronic diseases							
		0 vs. 1				0 vs. ≥2 (multimorbidity)			
		UOR (95% CI)	*P*	AOR (95% CI)	*P*	UOR (95% CI)	*P*	AOR (95% CI)	*P*
SES									
Very high	873	Reference	–	Reference	–	Reference	–	Reference	–
High	753	0.927 (0.730–1.177)	0.534	0.982 (0.765–1.260)	0.884	0.866 (0.681–1.102)	0.242	0.920 (0.713–1.188)	0.523
Low	1,063	1.154 (0.926–1.438)	0.203	1.276 (1.010–1.613)	0.041	1.089 (0.873–1.358)	0.450	1.195 (0.943–1.515)	0.140
Very low	561	1.225 (0.937–1.603)	0.138	1.340 (1.002–1.792)	0.049	1.490 (1.150–1.930)	0.003	1.440 (1.083–1.913)	0.012
Sleep quality									
Good	1,663	Reference	–	Reference	–	Reference	–	Reference	–
Poor	1,587	1.901 (1.601–2.258)	<0.001	1.824 (1.526–2.181)	<0.001	2.687 (2.265–3.188)	<0.001	2.445 (2.043–2.927)	<0.001

UOR, unadjusted odd ratios; AOR, adjusted odd ratios. CI, confidence interval.
AOR adjusted for gender, age, marital status, empty nest status, family history of diseases, BMI categories, physical activity level, drinking status, and smoking status.

TABLE 4 Association of different combinations of SES and sleep quality with multimorbidity in older adults.

SES	Sleep quality	N	Types of chronic diseases							
			0 vs. 1				0 vs. ≥2 (multimorbidity)			
			UOR (95%CI)	*P*	AOR (95%CI)	*P*	UOR (95%CI)	*P*	AOR (95%CI)	*P*
Very high	Good	517	Reference	–	Reference	–	Reference	–	Reference	–
	Poor	356	1.932 (1.383–2.699)	<0.001	1.706 (1.204–2.418)	0.003	2.441 (1.755–3.394)	<0.001	2.031 (1.433–2.880)	<0.001
High	Good	415	0.990 (0.725–1.352)	0.949	1.001 (0.724–1.385)	0.995	0.796 (0.570–1.111)	0.181	0.829 (0.583–1.177)	0.294
	Poor	338	1.674 (1.190–2.353)	0.003	1.678 (1.175–2.396)	0.004	2.269 (1.628–3.161)	<0.001	2.098 (1.474–2.987)	<0.001
Low	Good	495	1.100 (0.818–1.479)	0.529	1.154 (0.845–1.575)	0.368	0.918 (0.671–1.256)	0.594	0.920 (0.660–1.283)	0.624
	Poor	568	2.396 (1.778–3.228)	<0.001	2.529 (1.847–3.464)	<0.001	3.109 (2.313–4.180)	<0.001	3.139 (2.288–4.307)	<0.001
Very low	Good	236	1.321 (0.903–1.933)	0.152	1.409 (0.943–2.107)	0.095	1.719 (1.188–2.487)	0.004	1.629 (1.097–2.418)	0.015
	Poor	325	2.177 (1.528–3.103)	<0.001	2.203 (1.509–3.216)	<0.001	3.318 (2.360–4.665)	<0.001	2.787 (1.926–4.034)	<0.001

UOR, unadjusted odd ratios; AOR, adjusted odd ratios. CI, confidence interval.
AOR adjusted for gender, age, marital status, empty nest status, family history of diseases, BMI categories, physical activity level, drinking status, and smoking status.

extensively in China and worldwide, but the estimate for the prevalence of multimorbidity varies widely in different studies. A cross-sectional study conducted in northeastern China showed that the prevalence of multimorbidity was 24.7% in adults, with the prevalence increasing with age, and up to 51.2% in older adults aged 60–79 years (32). In Yunnan Province, China, the prevalence of multimorbidity among rural older adults aged 60 and above was 16.1% (33). This large variation has been observed in studies from other countries and regions, for example, in South Asia, the prevalence of multimorbidity ranges from 4.5 to 83% (34). The inconsistency of the prevalence of multimorbidity may be related to the differences in the characteristics of participants and types of chronic disease in different studies. Although the prevalence of multimorbidity was inconsistent, it remained at a high level in this study. In the context of increasing aging, it is important to pay more attention to the prevalence of multimorbidity of older adults to improve their health and ensure that they enjoy their old age.

This study found that there was a negative correlation between SES and the prevalence of multimorbidity; very low SES increased the risk of the prevalence of multimorbidity in older adults. Kivimäki et al. (35) found that low SES was associated with 18 of 56 specific diseases or health conditions, including diabetes, heart failure, and obesity, suggesting that SES has an influence on the development and prevalence of multimorbidity (36). A systematic evaluation (24 articles were included) found that low education level and high deprivation were associated with an increased risk of multimorbidity (5). Older adults with lower SES in this study tend have lower educational level, poorer occupation before retirement, or lower income, and these factors are associated with multimorbidity prevalence (5, 37, 38). Kuo et al. (39) confirmed inequities in healthcare utilization among people with different occupations and income levels. Older

adults with lower SES have difficulty accessing quality healthcare services, which adversely affects their health. Meanwhile, the lower SES group may adopt unhealthy lifestyles, such as smoking, risky drinking, and insufficient physical activity, which are not conducive to maintaining health (11, 40, 41). In addition, the knowledge and awareness of chronic disease prevention and control of less educated people may be even lower (42), increasing the risk of developing multimorbidity.

The older adults with poor sleep quality accounted for 48.83% in this study, and the results also found that poor sleep quality was related to the prevalence of multimorbidity in older adults. A cross-sectional study in Cypriot found that people with poor sleep quality had a higher risk of developing two, three, or more than three morbidities (43). Moreover, Sindi et al. (44) confirmed that moderate to severe sleep disturbances were associated with a higher speed of chronic disease accumulation in older adults without multimorbidity at baseline, including neuropsychiatric and musculoskeletal diseases. With the onset of aging, sleep quality of the older adults gradually decreases, which may be due to the fact that circadian oscillations become less pronounced in older adults and melatonin levels decrease, making older adults go to sleep earlier and wake up earlier than younger adults, as well as making it more difficult for them to fall asleep and stay asleep (18).

In addition to poor sleep quality due to aging, several studies have found that lower SES is associated with poorer sleep quality (24–26). Habitual attaining of adequate sleep is one of key components of a healthy lifestyle (45), and Xue et al. (23) indicated that there was a significant positive correlation between SES and health promoting lifestyle of the older adults. Older adults with lower SES may not give their lifestyles much attention, which may make it difficult for them to get a good night sleep. Older adults with lower SES may live in adverse material circumstances, such as crowded rooms, excessive noise, and bad public security, which can have direct effects on sleep quality (46). In addition, social isolation is particularly frequent in disadvantaged socioeconomic groups, and older adults with social isolation may experience sleep problems that affect sleep quality (47, 48).

The association of different combinations of SES and sleep quality with the prevalence of multimorbidity was analyzed after analyzing the association of them with the prevalence of multimorbidity separately. Older adults with very high SES and good sleep quality were used as the reference group. When the association between SES and the prevalence of multimorbidity was analyzed separately, only very low SES was significantly associated with the prevalence of multimorbidity. However, when poor sleep quality was combined, the risk of the prevalence of multimorbidity was significantly higher in every SES group. Meanwhile, very low SES was significantly associated with the prevalence of multimorbidity, regardless of whether the sleep quality was good or poor. The results suggested that it is necessary for older adults to pay more attention to their sleep status and ensure better sleep quality, in order to reduce the risk of the prevalence of multimorbidity. Meanwhile, for older adults with very low SES, more comprehensive measures should be given to protect their health, considering that the negative impact of very low SES on their health may outweigh the positive impact of good sleep quality.

Limination

This study has several limitations to mention. First, we used a cross-sectional design for investigating the impact of SES and sleep quality on the prevalence of multimorbidity, so it is not possible to establish causal relationships. Second, the sample is not sufficiently representative. All the participants were older adults and were from the same province, which means that the results may be unique. In addition, we used the PSQI to measure sleep quality in older adults, and the results did not constitute a clinical diagnosis of poor sleep quality.

Conclusion

This study investigated the impact of SES and sleep quality on the prevalence of multimorbidity in older adults through a survey among 3,250 older adults. The results showed that the risk of the prevalence of multimorbidity in older adults increased significantly with decreasing SES and sleep quality. The combined association of SES and sleep quality suggested that improving sleep quality is an effective health promotion modality for most older adults, while those at the bottom of the society may require more comprehensive measures to protect their health.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Shanxi Medical University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

CZ designed and organized this survey. BX, YX, FD, SX, and JZ collected and cleaned the data. BX, YX, and FD analyzed the data and wrote the manuscript. XZ, LS, WO, and QW revised and edited the manuscript. All authors have read and approved the final manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Can leisure and entertainment lifestyle promote health among older people living alone in China?—A simultaneous equation approach

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Objectives: With the surging number of older people living alone, their lifestyles and health status have aroused increasing concern. This study aims to investigate whether a leisure and entertainment lifestyle (LEL) can improve the multidimensional health among older people living alone and try to identify the latent mechanisms among them.

Method: For this purpose, we extracted data from the Chinese General Social Survey (CGSS) and established a simultaneous equations model, comprising ordinary least square regression (OLS), two-stage least squares (2SLS), and the mediating effect model.

Results: Older people living alone in China reported relatively better mental health status (3.64 ± 1.07), followed by physical health (3.41 ± 1.26) and social health (2.75 ± 1.18). In the OLS model, LEL significantly improved the social health of older people living alone ($\beta = 0.054$, $P < 0.01$), followed by physical health ($\beta = 0.042$, $P < 0.01$) and mental health ($\beta = 0.027$, $P < 0.01$). After endogenous tests from 2SLS model and robustness tests, we found that more active LEL was associated with higher levels of physical health and mental health. However, LEL had no significant effect on the improvement of the social health of the older people living alone. Using the mediation analysis, exercise efficacy partially mediated the relationship of LEL with physical health and mental health, and the ratios were 19.75 and 24.85%, respectively. Similarly, positive life attitudes partially mediated the relationship between LEL and physical health, and LEL and mental health, with ratios of 10.65 and 26.83%, respectively.

Conclusion: Our findings suggested that LEL is significantly associated with better physical and mental health for older people living alone in China, and

the association is mediated by exercise efficacy and positive attitudes toward life. Promoting more leisure and recreational activities, upgrading exercise efficacy, and encouraging positive life attitudes are necessary health promotion measures in active aging policies for the wellbeing of older people living alone.

KEYWORDS

leisure and entertainment life, older people living alone, multidimensional health, simultaneous equations approach, China

Background

The world is witnessing a rapid demographic shift toward population aging. Therefore, investigating and understanding the health and well-being of older people is of priority, especially in China. As home to one-fifth of the global population, China is a typical example of a country with an aging trend, with older people accounting for 14.2% of the total population in 2021 (1). With the implementation of the family planning policy in China, the traditional nuclear family structure has changed, and the family sizes have reduced, thus breaking the traditional Chinese family model of three or even four generations living together. Economic development and urbanization have pushed young people to work away from home (2–4). Moreover, the older people and children in modern society demand their own "free space" influenced by the Western culture. Because of these reasons, there is an increasing number of empty-nest older people living alone in China (5–7). However, older people living alone are different from empty-nest older people. The latter generally refers to older couples living together and taking care of and helping each other. In contrast, for older people living alone, not only have their children left home but they have also experienced widowhood or divorce or have always been single, this makes them more vulnerable than empty-nest older people (8). In China, where filial piety prevails, due to the absence or limitation in the quantity of family interactions, the older people living alone are at greater risk of long-term exclusion from social relations and are more likely to experience limited access to health services, which may pose a potential risk to their physical and mental health (9–12).

It is well-established that age-related conditions and, in particular, physical health, functional health, mental health, and psychosocial vulnerability are burdens for older people (13–16). This is related to multiple factors, including objective and subjective indicators, respectively (17). Although objective functional health is the main predictor of perceived health, empirical results on the associations between functional health and subjective health are often inconsistent, ranging from low and non-significant associations to highly significant associations (16, 18–22). Part of this heterogeneity may be based on the assessment of the expanded function in functional health, mainly leisure activities (23). The later stage of the life course is broadly signified by an increase in free time, opportunities to maximize the utility of one's free time, and enjoyment of leisure activities that are socially structured (24). The aging activity theory postulates that older people who maintain active social activities have a higher quality of life in later life and a more successful aging process than those who do not (25, 26). Active lifestyle arrangements among older people highlight the potential of leisure activities in improving subjective health in later life (4, 10, 27, 28).

Although previous studies have analyzed the impact of a leisure and entertainment lifestyle (LEL) on health, they are limited to the role of certain types of LEL or focus on only a single dimension of health; moreover, rare studies focus on older people living alone in China (29–31). Leisure activity has been proven to moderate the relationship between living alone and poor physical health, mental health, and social health among Japanese, Korean, Singaporean, and American, older adults living alone (32–34). Therefore, based on the previous literature mentioned above, we proposed the hypothesis that LEL significantly improves the multidimensional health of older people living alone in China.

How does LEL affect the multidimensional health of older people living alone? Some scholars pointed out that leisure and entertainment life are a means to improve the efficacy of physical exercise, and effective exercise can improve health promotion (35–37). Studies have shown that a rich life of leisure and social interaction increases positive life attitudes such as happiness and enthusiasm for life, relieves loneliness, and increases subjective health perception (38–40). From the perspective of social capital, active leisure and entertainment life would enhance personal social trust and social adaptability (41, 42). This means that leisure and entertainment life can positively affect the health of older adults living alone through exercise efficacy, positive life attitudes, and social trust. However, these hypotheses have not been explored fully in the currently limited literature, especially in China.

To sum up, this study explores the effects of LEL on the health of older people living alone from the following aspects. First, ordinary least square regression (OLS) was adopted to analyze the influence of LEL on multidimensional health. However, the limited studies on this topic identify critical challenges in terms of the potential for residual

confounding due to omitted variables, differential measurement error, or a possible causal relationship between LEL and multidimensional health. We should further address the endogenous problem. Hence, under considering endogeneity, we adopted a simultaneous equations model consisting of OLS and two-stage least squares (2SLS), as well as an instrumental variable introduced in the 2SLS model to correct the results. This will help to more robustly estimate the effect of LEL on the multidimensional health of older people living alone. Finally, we adopted a mediating effect model to explore the mechanism of this effect.

Methods

Study design

We obtained data from the Chinese General Social Survey 2017 (CGSS). The CGSS is a national, comprehensive, and continuous academic survey project for Chinese residents conducted by the China Survey and Data Center of Renmin University of China. These data are representative of the scientific research value recognized by academia at present. The survey adopted a multi-stage stratified sampling method, collecting 12,582 representative valid sample data from 125 counties in 31 province-level regions of mainland China (43).

The 2017 CGSS data include comprehensive information on the population and social attributes, health, family, work, leisure and entertainment life, and social attitudes of Chinese residents of all age groups over 18 years of age. Following the purpose of our research, we filtered the age variable as "over 60 years old" and the residence status as "live alone." Finally, 865 samples were included in the analysis after deleting the missing values and outliers of the sample.

Variables and measures

Multidimensional health

According to the World Health Organization, health is a state of physical, mental, and social well-being (44). Health is dynamic, multidimensional, and continuous. Some scholars regard health as a state of personal experience and reflect health status through subjective health evaluation indicators (45, 46). The physical health spectrum can be categorized as ranging from a minimum state defined by an inability to work or care for personal needs, to an optimal state expressed by no complaints and a high level of energy (47, 48). This means that the level of physical health is related to the degree of physical function and activity limitation brought about by diseases (49). Mental health includes positive emotions and positive functioning, and the measurement of negative or positive emotions can reflect an individual's mental health status (50, 51). Social health is defined in terms of social participation in activities and interpersonal interactions (52). The dimensions we choose for the multidimensional health of older people living alone included physical health, mental health, and social health. According to previous research, multidimensional health was measured by three questions in the CGSS 2017: "How often has your work or daily activities been affected by health problems?" "How often did you feel depressed or depressed?," and "How often did you participate in social activities in your free time?," respectively (3, 53, 54). A five-point Likert scale was used to evaluate the levels of each dimension. The higher the score, the better the health status.

Leisure and entertainment life (LEL)

LEL was measured by the question "The frequency of engaging in the following activities in your free time." The answers included watching television, watching movies, shopping, reading, watching performances, gathering with relatives, gathering with friends, listening to music, physical exercise, watching sports, doing crafts, and surfing the Internet. The answers to each question ranged from 1 to 5. 1 = never, 2 = a few times a year, 3 = a few times a month, 4 = a few times a week, and 5 = every day. The LEL index was calculated by adding up the scores of all the responses. A higher score indicated a higher level of leisure and entertainment. The Cronbach's α of LEL was 0.812, and the KOM value was 0.701.

Mediating variables

Exercise efficacy, positive life attitudes, and social trust as mediating variables were further examined as potential mechanisms by which LEL affects multidimensional health in the mediating effect model. A large body of evidence suggested that a physically active lifestyle is associated with a reduced risk of chronic disease, all-cause mortality, and cognitive health (55). Public health recommendations in many countries emphasize regular participation in moderate-intensity physical activity (at least 5 days per week, 30 min or more per day) (56). Some studies asked respondents to report activities that "make you sweat at least" to measure exercise efficacy by combining light-intensity physical activity and moderate-to-vigorous physical activity for this domain across different ages and genders (57–59). This measure of exercise efficacy is also applicable in Chinese health life study, and it is expressed as "the frequency of physical activity that lasts more than 30 min and makes you sweat" in CGSS 2017.

Happiness is commonly understood as how much one likes one's life or, more formally, the degree to which one positively evaluates one's life as a whole. A central element in the definition is subjective "evaluation" or "liking" of life. The set-point theory considers evaluation as a stable attitude toward life. Happiness is also considered a happy disposition and positive attitude

toward life (60, 61). This definition of happiness as an attitude toward life stresses the consistency in affective response, while others see it as a belief system, especially for older people (40, 62). Therefore, we used the evaluation of happiness of older people living alone as their positive attitude toward life, which is evaluated by the "degree of happiness in life" in CGSS 2017.

Social trust refers to trust in people in general, and it is a widely used social capital variable. Standard trust is measured by the share of a population that answers that most people can be trusted when asked the question "In general, do you think most people can be trusted?" (63, 64). Although this question has been criticized for being vague and difficult to answer without specific knowledge of whom to trust, it is acceptable because social trust is in essence trust without specific information (65). Likewise, social trust is expressed by the "degree of trust in others in society" in CGSS 2017, which is easier for Chinese people to understand (66).

The answers for three variables were divided into five grades with 1–5 points. A higher score indicated a higher degree of exercise efficacy, positive life attitude, and social trust of the survey respondents.

Control variables

Some studies indicated that sociodemographic characteristics and socioeconomic status would influence the health of older people (13, 28, 42, 67). With reference to previous studies, the following variables were considered: household registration, gender, age, education level, marital status, work status, the number of children, socioeconomic status (1 = well below average, 2 = below average, 3 = average, 4= above average, and 5 = well above average), and cognitive ability (1 = very poor, 2 = relatively poor, 3 = ordinary, 4 = better, and 5 = very good). Table 1 shows the details of the settings and measurements of the above variables.

Analytical strategy

Descriptive statistics were used to present the means and standard deviations of the main study variables in the model. Variance inflation factor (VIF) was used as the multicollinearity diagnosis index for variables, VIF<3.

The relationship between LEL and multidimensional health was established based on a simultaneous equation. First, the OLS model was used to estimate the correlation between the three outcome healthy indicators and all explanatory variables of older people living alone. The model's equation can be set as follows:

$$Y_i = \beta_0 + \beta_1 L_i + \delta X_i + \varepsilon_i \quad (1)$$

where Y_i is the health level (physical health, mental health, and social health), L_i is the LEL, X_i is the control variable, and β_1 is the estimated parameter reflecting the effect of LEL on the health status of older people living alone.

Second, we considered the empirical results caused by the yield biased from the OLS model. Therefore, we also used the average score of the LEL of the older people living alone at the provincial level (*LELm*) as an instrumental variable to solve the endogeneity problem. Furthermore, the 2SLS model, presented in equations (2) and (3), was adopted to estimate the result. Similar strategies were adopted in other studies (45, 68, 69).

$$\text{The first stage}: L_i = \alpha_0 + \alpha_1 Lm_i + \delta X_i + \nu_i \quad (2)$$

$$\text{The second stage}: Y_i = \lambda_0 + \lambda_1 \hat{L}_i + \delta X_i + \varepsilon_i \quad (3)$$

Equation (2) is the estimation equation of the first stage, where Lm_i represents the selected instrumental variable *LELm*, α_1 is the estimated parameter, and ν_i is the linear random error. Equation (3) is the estimation equation of the second stage, where $\hat{L}_i$ is the predicted value of L_i in equation (2), and λ_1 is the estimated parameter that represented the predictive effect of the first-stage regression result. The other variables have the same meanings as in equation (1).

Finally, we set up the mediating effect model to explore the mechanism of LEL affecting multidimensional health (54, 70). The equation used is as follows:

$$Y_i = \alpha L_i + \delta X_i + \varepsilon_i \quad (4)$$

$$M_i = \theta L_i + \delta X_i + \mu_i \quad (5)$$

$$Y_i = \alpha' L_i + \gamma M_i + \delta X_i + \nu_i \quad (6)$$

where α is the total effect of L_i (LEL) on Y_i (multidimensional health), θ is the effect of LEL on mediating variable M_i (exercise efficacy, positive life attitude, and social trust), α' is the direct effect of L_i on health after controlling for mediating variable M_i, and γ is the effect of mediating variable M_i on Y_i. The ratio of indirect effect to total effect is calculated as $\theta\gamma/\alpha$.

Model estimates may be inconsistent due to sample bias or causal relationships between variables; therefore, we used the substitution variable and model for the robustness test. We used the total score of the respondents' answers to the frequency of using media tools and entertainment with relatives and friends in the CGSS 2017 as a substitution variable (*LELs*) for LEL, and self-rated general health level as a substitution variable for multidimensional health. Some studies showed that the estimated effects of using OLS and the ordered probit model are virtually identical; therefore, we also adopted the ordered probit model to test the robustness of the OLS estimation results (68, 71, 72). Detailed test results are provided in Supplementary Table S1. All data were analyzed using Stata version 17.0.

TABLE 1 OLS estimation of the correlation of LEL and multidimensional health ($N = 865$).

Variables	Model 1 physical health			Model 2 mental health			Model 3 social health		
	β	95% CI		β	95% CI		β	95% CI	
LEL	0.042***	0.028	0.055	0.027***	0.012	0.042	0.054***	0.038	0.070
	(0.007)			(0.007)			(0.008)		
Sex (ref: female)	0.215***	0.061	0.369	0.133*	−0.011	0.277	−0.174**	−0.331	−0.017
	(0.079)			(0.073)			(0.080)		
Age	0.002	−0.009	0.012	0.012**	0.002	0.022	0.006	−0.005	0.018
	(0.005)			(0.005)			(0.006)		
Household registration (ref: Urban)	−0.322***	−0.535	−0.109	−0.131	−0.347	0.085	0.590***	0.383	0.798
	(0.108)			(0.110)			(0.106)		
Marital status (ref: married)	0.017	−0.163	0.196	0.025	−0.151	0.202	0.056	−0.141	0.253
	(0.091)			(0.090)			(0.100)		
Education	−0.035	−0.123	0.052	−0.019	−0.105	0.067	−0.150***	−0.240	−0.059
	(0.044)			(0.044)			(0.046)		
Working status (ref: no)	0.314***	0.129	0.498	0.031	−0.141	0.202	−0.111	−0.305	0.084
	(0.094)			(0.087)			(0.099)		
Number of children	−0.015	−0.053	0.023	−0.021	−0.061	0.018	−0.032	−0.070	0.006
	(0.019)			(0.020)			(0.019)		
Socioeconomic status	0.127***	0.031	0.223	0.160***	0.080	0.240	0.162***	0.072	0.253
	(0.049)			(0.041)			(0.046)		
Hospital experience (ref: not hospitalized)	−0.837***	−0.999	−0.675	−0.285***	−0.438	−0.132	−0.113	−0.276	0.050
	(0.083)			(0.078)			(0.083)		
Cognitive ability	0.061	−0.021	0.142	0.073**	0.001	0.144	0.041	−0.038	0.121
	(0.042)			(0.037)			(0.040)		
Intercept	2.228***	1.273	3.184	1.720***	0.760	2.68	0.754	−0.242	1.749
	(0.487)			(0.489)			(0.507)		
N	865			865			865		
F	32.15***			11.94***			9.18***		
R^2	0.257			0.127			0.104		

Robust standard errors in parentheses. *P < 0.1, **P < 0.05, and ***P < 0.01.

Result

Descriptive statistics

Figure 1 shows the levels of multidimensional health and the LEL index. In terms of physical health, 28.21% of the older people living alone thought they were relatively healthy, and 23.58% were very healthy. Regarding mental health, 33.18% of the older people living alone reported being relatively healthy, and 24.39% reported they were very healthy. Regarding social health, 22.08% of the older people living alone reported they were relatively healthy, and only 7.63% were very healthy. The study calculated the average level of health in each dimension: Physical health score was 3.41 ± 1.26, mental health score was 3.64 ± 1.07, and social health score was 2.75 ± 1.18. Overall, older people living alone in China rated mental health the highest, followed by physical health and social health. Moreover, the LEL index of older people living alone was 23.46 ± 6.53.

Detailed information on other explanatory indicators is shown in Figure 2. Among the 865 respondents, the average age was 72.01, and 54.91% of respondents were women. The proportion of agricultural household registrations was 52.95%. Furthermore, 79% of the overall sample were non-marital status (unmarried, divorced, or widowed). Finally, they had 2.48 children on average.

Results of the OLS model

Table 1 and Figure 2 show the OLS estimation correlations between the explanatory variables and the multidimensional health of the older people living alone. LEL significantly improved the social health of older people living alone ($\beta = 0.054$, $P < 0.01$), followed by physical health ($\beta = 0.042$, $P < 0.01$) and mental health ($\beta = 0.027$, $P < 0.01$).

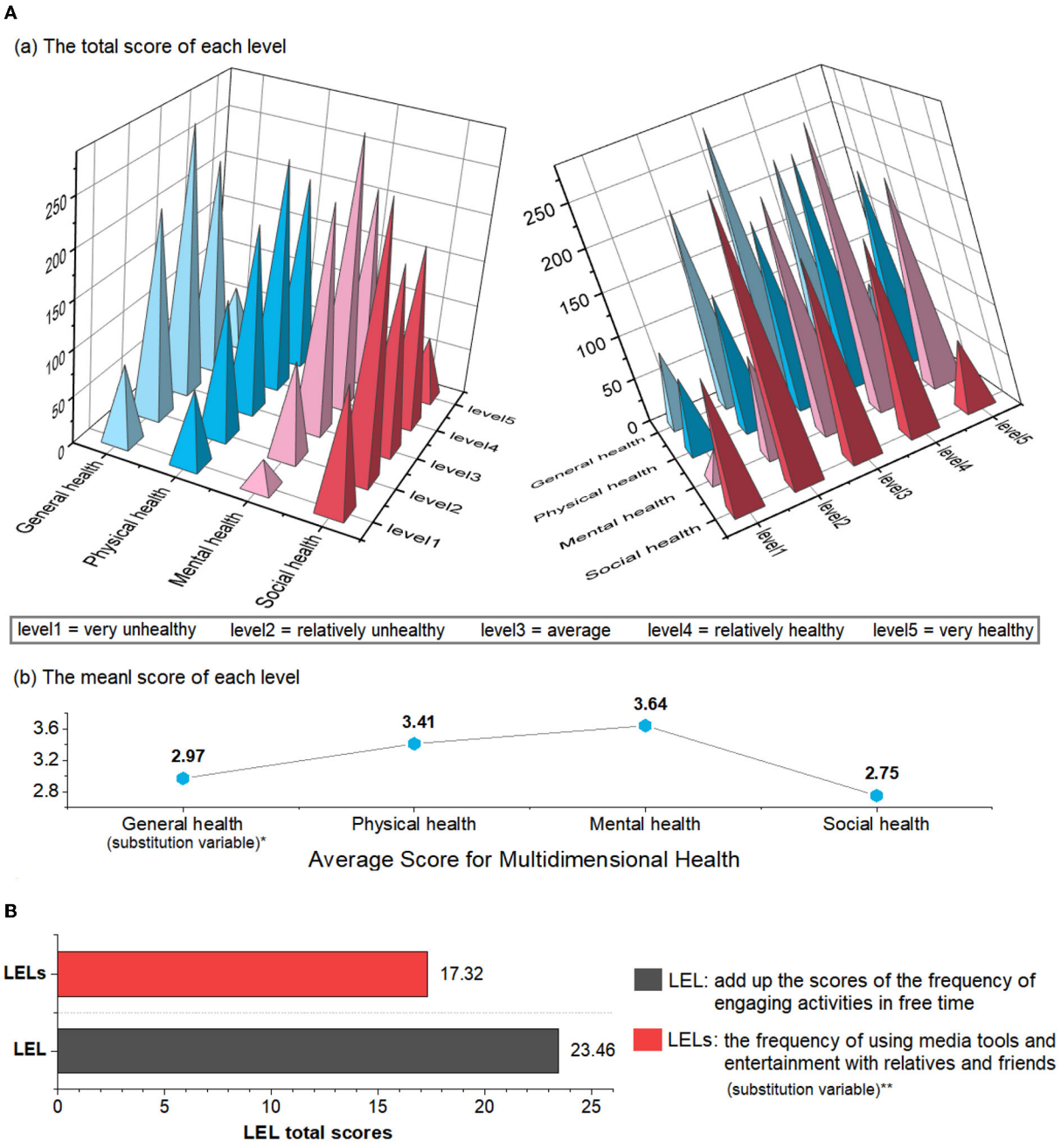

FIGURE 1
(A) Multi-dimensional health level and **(B)** leisure and entertainment life (LEL) level of older people living alone in China. *General health level as substitution variable for multi-dimensional health is examined for robustness check of the model robustness test. **The frequency of using media tools and entertainment with relatives and friends as substitution variable for leisure and entertainment life is examined for robustness check of the model robustness test.

Among sociodemographic characteristics, older men living alone had a higher level of physical health than women ($\beta = 0.215$, $P < 0.01$), but the opposite effect was observed in predicting social health ($\beta = -0.174$, $P < 0.05$). Older people living alone with agricultural household registration had a lower level of physical health than those with urban household registration ($\beta = -0.322$, $P < 0.01$), but the opposite effect was observed in predicting social health ($\beta = 0.590$, $P < 0.01$). Interestingly, the level of mental health has improved significantly with age, and there was no significant effect on physical health and social health. However, there was a significant negative correlation between education level and

Description of variables

Variable	Categories or Ranges	Mean ± SD or N(%)
Sex	0=Female	475(54.913)
	1=Male	390(45.086)
Age	60~93	72.01±7.842
Household registration	0=Urban	407(47.052)
	1=Agricultural	458(52.947)
Marital status	0=Married	171(19.768)
	1=Unmarried, divorced, widowed	694(80.231)
Education	1=no education	241(27.861)
	2=primary school level	299(34.566)
	3=junior high school	187(21.618)
	4=senior high school	90(10.404)
	5=junior college or above	48(5.5491)
Working status	0=no	664(76.763)
	1=yes	201(23.236)
Hospital experience	0 = not hospitalized within one year	577(66.705)
	1 = hospitalized within one year	288(33.294)
Number of children	0~24	2.479±1.908
Socioeconomic status	Ordered classification variables, 1~5	2.098±0.915
Cognitive ability	Ordered classification variables, 1~5	3.295±1.091
Exercise efficacy	Ordered classification variables, 1~5	2.171±1.681
Positive attitude	Ordered classification variables, 1~5	3.825±0.905
Social trust	Ordered classification variables, 1~5	3.071±1.080

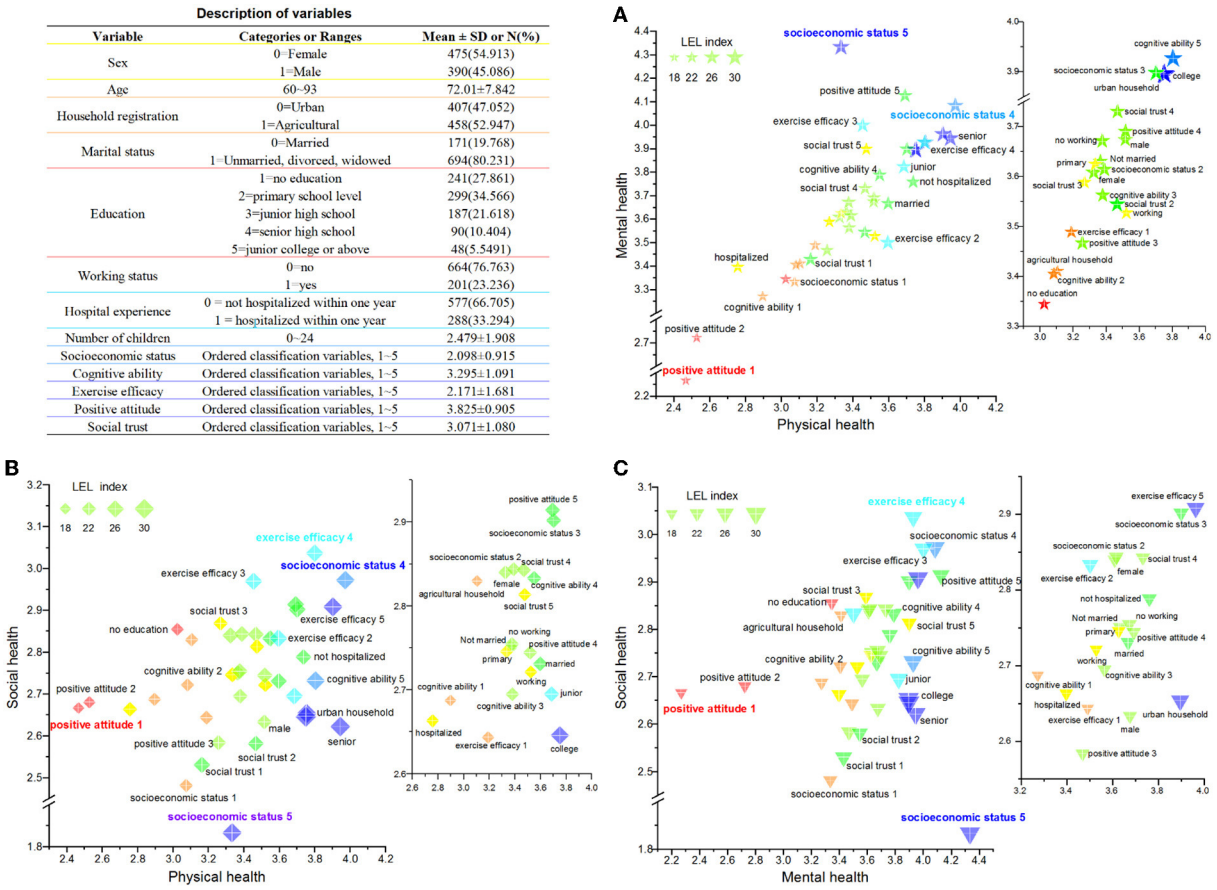

FIGURE 2
Variable distribution differences in multi-dimensional health and leisure and entertainment life (LEL) of older people living alone in China. **(A)** Variable distribution differences in physical health—mental health—LEL. **(B)** Variable distribution differences in physical health—social health—LEL. **(C)** Variable distribution differences in mental health—social health—LEL.

social health, which means that the level of social health declined as education level increased.

In addition, according to the current state of older people living alone, those who still worked had better physical health ($\beta = 0.314$, $P < 0.01$). Old people who were not hospitalized had better physical and mental health than those who were hospitalized within the past 1 year ($\beta_{physicalhealth} = -0.837$, $\beta_{mentalhealth} = -0.285$, $P < 0.01$). The cognitive ability of older people was significantly positively correlated with their mental health ($\beta = 0.073$, $P < 0.05$). Moreover, socioeconomic status was positively correlated with the three dimensions of health (($\beta_{physicalhealth} = 0.127$, $\beta_{mentalhealth} = 0.160$, $\beta_{socialhealth} = 0.162$, $P < 0.01$).

Results of the 2SLS model

The OLS model confirmed significant correlations between LEL and the three dimensions of health in older people living alone, but any observed causal relationship must be interpreted with caution. We used the LEL's average scores of the older people at the provincial level as instrumental variables and conducted 2SLS estimation for endogeneity. To further confirm the validity of the instrumental variable, a weak instrumental variable test was needed before the estimation of the 2SLS model. According to Angrist and Pischke, when the F-value of the minimum eigenvalue statistic is > 10, the instrumental variables are not weak (73). After the weak instrumental variable test, the minimum eigenvalue statistic was 80.30, which was far > 10, and the partial R-squared was 0.086, suggesting there was no problem of weak instruments. The relevance assumption was thus satisfied, and we can use the *LELm* as an instrumental variable, as it was not part of the error term of the second-stage regression.

According to Table 2, the empirical results of the 2SLS confirmed that the active LEL of the older people living alone had a positive impact on their health, which was similar to the OLS model. Except for social health, the regression coefficients

TABLE 2 2SLS estimation of the effect of LEL on multidimensional health.

Variables	1st stage LEL			2nd stage Physical health			2nd stage Mental health			2nd stage Social health		
	β	95% CI		β	95% CI		β	95% CI		β	95% CI	
LELm	0.543***	0.410	0.675									
	(0.0606)											
LEL				0.098***	0.048	0.149	0.051**	0.004	0.097	0.001	−0.051	0.053
				(0.026)			(0.024)			(0.027)		
Other variables	Controlled			Controlled			Controlled			Controlled		
Intercept	13.94***	8.935	18.944	0.740	−0.877	2.357	1.099	−0.409	2.607	2.131**	0.445	3.816
	(2.441)			(0.825)			(0.769)			(0.860)		
N	865			865			865			865		
R^2	0.451			0.204			0.114			0.053		
Durbin chi2				5.749**			1.172			4.633**		
F /Wu–Hausman *F*	68.20***			5.700**			1.156			4.588**		

Robust standard errors in parentheses. *P < 0.1, **P < 0.05, and ***P < 0.01.

of LEL had a significant impact on physical health (β = 0.098, $P < 0.05$) and mental health (β = 0.051, $P < 0.05$). The high regression coefficient of LEL indicated that, without introducing the instrumental variable, OLS underestimated the impact of the LEL of older people living alone on their physical health and mental health.

How LEL affects multidimensional health of older people living alone

Table 3 shows the mediating effects of exercise efficacy, positive life attitudes, and social trust. According to equation (5), the results showed that LEL and exercise efficacy were positively correlated, with a regression coefficient of 0.122 at the 0.01 level, as shown in column (1) of Table 3. When LEL and exercise efficacy were both included in equation (6), the direct impact of LEL on physical health was 0.033 and significant at the 0.01 level, as shown in column (2) of Table 3. Meanwhile, the regression coefficient of exercise efficacy was 0.068 and significant at the 0.01 level. Combining the results of the total effect (coefficient = 0.042, $P < 0.01$) of LEL on physical health in Table 1, exercise efficacy was considered to play a partial mediating role between LEL and physical health; the ratio of the intermediary effect in the total effect was 19.75%. Similarly, exercise efficacy was considered to play a partial mediating role between LEL and mental health; the ratio of the intermediary effect to the total effect was 24.85%. A positive life attitude was considered to play a partial mediating role between LEL and physical health, and LEL and mental health; the ratio of the intermediary effect to the total effect was 10.65and 26.83%, respectively. However, according to the mediation effect test procedure, after the bootstrap test (5000 samples), the indirect effect of exercise efficacy was not significant between LEL and social health, so did the indirect effect of positive life attitudes was not significant between LEL and social health. Likewise, the indirect effect of social trust was not significant, as no mediating role of social trust was found between LEL and multidimensional health.

Discussion

Based on the theory and results from the OLS model, active LEL is significantly associated with better health for older people living alone. Using the simultaneous OLS and 2SLS equation models, we obtained unbiased estimators of the outcome. After endogeneity and robustness tests, we found that more active LEL was associated with 0.098% higher physical health and 0.051% higher mental health; the OLS results may have underestimated the LEL's positive effect. Our positive results were similar to those found in other studies that did not consider endogeneity (74–76). The results robustly confirmed that LEL can promote the physical health and mental health of older people living alone. Furthermore, through mediation analysis, we confirmed a partial mediating effect of exercise efficacy between LEL and physical and mental health, and a similar mediating effect of active life attitudes between LEL and physical and mental health.

According to the disengagement theory and activity theory state, the majority of older people are not willing to withdraw from the social systems to which they belong (77, 78). Disengagement theory argues that as an inevitable disengagement process, aging is associated with social isolation and reduced social participation (79). Retirement, the departure of children, and the beloved gone gradually shape the "passive state" of older people living alone. With the separation from the original work roles and family roles, there is a loss of role function in older people, resulting in their physical and mental imbalances (80). Older people living alone experience greater

TABLE 3 Results of the mediation test.

Variables	(1) Exercise efficacy			(2) Physical health			(3) Mental health			(4) Social health		
	β	95% CI		β	95% CI		β	95% CI		β	95% CI	
LEL	0.122***	0.99	0.145	0.033***	0.19	0.48	0.020**	0.04	0.36	0.050***	0.33	0.67
	(0.012)			(0.007)			(0.008)			(0.009)		
Exercise efficacy				0.068***	0.19	0.117	0.055**	0.08	0.102	0.035	−0.20	0.90
				(0.025)			(0.024)			(0.028)		
Other variables	Controlled			Controlled			Controlled			Controlled		
Intercept	0.282	−10.44	1.608	2.209***	1.262	3.157	1.705***	0.749	2.66	0.744	−0.249	1.736
	(0.676)			(0.483)			(0.487)			(0.506)		
N	865			865			865			865		
R^2	0.258			0.263			0.132			0.106		
Variables	**(5) Positive life attitude**			**(6) Physical health**			**(7) Mental health**			**(8) Social health**		
	β	95% CI		β	95% CI		β	95% CI		β	95% CI	
LEL	0.021***	0.11	0.32	0.037***	0.23	0.51	0.020***	0.05	0.34	0.054***	0.38	0.70
	(0.005)			(0.007)			(0.007)			(0.008)		
Positive life attitude				0.213***	0.122	0.304	0.345***	0.259	0.431	−0.005	−0.099	0.089
				(0.046)			(0.044)			(0.048)		
Other variables	Controlled			Controlled			Controlled			Controlled		
Intercept	1.750***	10.16	2.483	1.856***	0.901	2.81	1.116**	0.170	20.62	0.762	−0.247	1.772
	(0.374)			(0.486)			(0.482)			(0.514)		
N	865			865			865			865		
R^2	0.161			0.277			0.198			0.104		
Variables	**(9) Social trust**			**(10) Physical health**			**(11) Mental health**			**(12) Social health**		
	β	95% CI		β	95% CI		β	95% CI		β	95% CI	
LEL	−0.005	−0.019	0.09	0.042***	0.28	0.55	0.027***	0.13	0.42	0.054***	0.39	0.70
	(0.007)			(0.007)			(0.008)			(0.008)		
Social trust				0.063*	−0.009	0.136	0.112***	0.046	0.179	0.081**	0.008	0.154
				(0.037)			(0.034)			(0.037)		
Other variables	Controlled			Controlled			Controlled			Controlled		
Intercept	2.454***	1.480	3.429	20.73***	1.107	30.38	1.444***	0.473	2.416	0.554	−0.439	1.548
	(0.497)			(0.492)			(0.495)			(0.506)		
N	865			865			865			865		
R^2	0.029			0.260			0.139			0.109		

Robust standard errors in parentheses. *P < 0.1, **P < 0.05, and ***P < 0.01.

social isolation if they withdraw from social structure. Successful aging is a dynamic process of transition from passive aging to active aging. Therefore, as a representative view of successful aging, activity theory claims that social activities with alternative compensation functions are necessary to achieve successful aging (79, 81). Activity theory argues against sedentary lifestyles, arguing that maintaining active physical and social activity in older adults is critical to their health and well-being (82). Older people living alone retain psychological and social needs similar to younger adults, and their way to resist social withdrawal is to stay socially active in leisure and entertainment to enhance self-adaptation and social integration. Older people living alone gain more advantages by engaging in leisure time because they may not have family obligations such as caring for a spouse or grandchildren compared with older people living together. Environmental infrastructure support in public settings, such as seniors' outdoor exercise venues (playgrounds and exercise parks) and chess rooms in the community, provides

opportunities for physical activity and social connectedness for older people. Except for traditional media, the Internet and smart media provide broader information environment support to promote the activeness of older people living alone. In recent years, there has been a boom in short videos and live broadcasts, such as on square dancing, singing, and physical exercise, on the Internet in China, which may promote positive life attitudes and motivation to exercise effectively among seniors living alone. Leisure styles, such as sports participation and watching of performances and games, may promote positive emotional states and enhance social interaction of them.

There are several possible explanations for the lack of a relationship between leisure and entertainment and the social health of older people living alone. One explanation is that the number and structure of recreational activities among older people living alone, such as home activities and outdoor activities, may offset one another's effects on social health (75, 83, 84). In the context of rapid urbanization and modernization in China, as people gradually move to different regions, the relatives and neighbors of the older people living alone will become estranged due to geographic locations, and members of the new community are also relatively unfamiliar. At present, the older generation in China can communicate with the outside world through mobile phones and the Internet, which may reduce the intimate association between leisure, entertainment, and social health. Therefore, the LEL of older people living alone may increase the possibility of social interaction, but there are still challenges in prompting them to actively improve their social health premised on social trust or social reciprocity in a short period (85).

This study measured the multidimensional health differences among older people living alone at the sociodemographic level. Older women were shown to have poorer physical health; this is likely because of women's vulnerability due to a higher risk of chronic illnesses stemming from longer life expectancy and less access to appropriate healthcare (2, 86–88). Nevertheless, older Chinese women may have active social participation because they are more likely to chat, share, shop, and participate in square dancing (88–91). Another interesting finding is that older people living alone had better mental health as their age increased. One possible explanation is that older individuals living alone may have lower expectations from life as they age (92).

Compared with urban older people, older people living alone in rural areas reported lower physical health but higher social health. A similar result about lower physical health was reported in previous studies (93, 94). Limited economic resources, backward infrastructure, and limited access to health information all hinder health-promoting activities among older people living in rural areas (29). However, neighbors in rural China are closer, especially the older generation, as they are affected by the clan system and blood ties. Thus, they have more opportunities and willingness to participate in human relations activities in villages (95, 96). A further interesting finding is that education was significantly negatively associated with social health, which is the opposite of other studies showing that older people with higher education are significantly more likely to participate in social activities (97, 98). This may be because older people with high education living alone are more dependent on new media for information than on social participation (99).

These findings have important implications in making active aging policies to ensure the well-being of older people living alone. First, installing and supporting age-friendly and suitable outdoor exercise equipment are necessary health promotion measures in the location and settings where seniors live alone, especially for vulnerable seniors living alone in Chinese rural communities, with multiple diseases and low incomes. The two-way linkage between online sharing on the Internet and offline leisure activities is a way of health promotion that keeps pace with the times against the background of the popularization of network media. Propagating health information through new media, such as the Internet, WeChat, Douyin, and other mobile apps, can help expand the life cycle of older people living alone.

Conclusion

Health problems of older people living alone in China have aroused widespread concern in the society. We explored the relationship and mechanism between LEL and multidimensional health of older people living alone in China for the first time using simultaneous equations. We obtained unbiased estimators of the significant positive outcome between LEL and the multidimensional health of older people living alone by using the model of OLS and 2SLS models. We robustly confirmed that active LEL can improve the multidimensional health of older people living alone. Furthermore, a mediation analysis indicated partial mediating effects of exercise efficacy between LEL-physical health and LEL-mental health, among others, on the effects of active life attitudes between LEL-physical health and LEL-mental health. These findings have important implications in making active aging policies for the well-being of older people living alone.

Limitation

Our results must be considered with caution, due to some study limitations that must be acknowledged. First, although our study sample may be fairly representative of the older population living alone in China and our research comprises a cross-sectional, relevant survey, we cannot rule out the possibility of reverse causation. Hence, future prospective studies are necessary (100). Furthermore, even though referring to the previous research experience, there is still a little limitation when adopting the question in CGSS2017 to measure physical health that the participant might consider mental issues as a

health problem impacting on work or daily activities and answer accordingly. In addition, health outcomes of older adults living alone are not only affected by their short-term leisure lifestyle in later life, but also by a combination of factors such as the long-term living environment, social welfare, early life experiences, and household spending (101–106). Due to the selection of sample in this study, we did not conduct an in-depth analysis of these factors, and the living arrangements of older people living alone during different survey follow-up periods need to be explored in future research (10). Finally, although this study used the latest 2017 CGSS data, considering the past 2 years, COVID-19 might have an impact on the leisure lifestyles of the older population. Thus, it is necessary to follow up with the latest data and fully consider the relationship between the lifestyle and health status of older people living alone during the pandemic (28).

Data availability statement

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Author contributions

QHW was responsible for the overall design of the research and revised the paper. YHQ conducted, analyzed the results, and drafted the manuscript. SCJ, PFG, and JCL substantially contributed to data acquisition. RZW and XYQ assisted with the literature review. JJL contributed to the interpretation of results and in writing the manuscript. All authors contributed to this manuscript. All authors approved of the current version of this manuscript for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.967170/full#supplementary-material

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Association between community-level social trust and the risk of dementia: A retrospective cohort study in the Republic of Korea

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Introduction: It is known that biological risk factors and lifestyle behaviors are important determinants of dementia. However, there has been yet to be sufficient evidence to prove that community-level social capital is one of the determinants of dementia. This retrospective cohort study is a large, long-term, population-based study that investigated the association between community-level social trust and the risk of dementia in the Republic of Korea.

Methods: Data came from the Korean National Health Insurance Service database. The community-level social trust values were determined by the Korean Community Health Survey. The study population consisted of 1,974,944 participants over 50 years of age and was followed up from 1 January 2012 to 31 December 2019 with a latent period of 5 years from 1 January 2012 to 31 December 2016. Cox proportional hazards regression was utilized to obtain the adjusted hazard ratios (aHRs) and 95% confidence intervals (CIs) for the risk of dementia according to social trust quintiles.

Results: Participants within the highest quintile of community-level social trust had a lower risk for overall dementia (aHR, 0.90; 95% CI, 0.86–0.94) and Alzheimer's disease (aHR, 0.90; 95% CI, 0.85–0.94) compared to those within the lowest quintile of community-level social trust. The alleviating trend association of high community-level social trust on dementia risk was maintained regardless of whether the participants had health examinations.

Conclusions: Our findings suggest that higher community-level social trust is associated with a reduced risk of dementia. Community-level social trust is a crucial indicator of dementia and improving community-level social trust may lead to a lower risk of dementia.

KEYWORDS

community-level social trust, dementia, cohort study, Alzheimer's disease, Republic of Korea

Introduction

Dementia is a disease with high prevalence and high societal burden (1). In 2019, there were 57.4 (95% CI 50.4–65.1) million cases of dementia worldwide (2). By 2050, the Republic of Korea is expected to have 3.02 million cases of dementia among people over 65 years of age, up from 830,000 cases in 2020 (3). The typical risk factors of dementia are biological factors and lifestyle behaviors. Previous studies have demonstrated that community-level social capital is one of the determinants of dementia, but there has yet to be sufficient evidence to prove that such is the case (4, 5).

Social capital can be broadly defined as a "collective asset in the form of shared norms, values, beliefs, trust, networks, social relations, and institutions that facilitate cooperation and collective action for mutual benefits" (6). While the definition of social capital can be controversial, it can be distinguished into two main types: structural and cognitive dimensions. Structural dimensions are the external behaviors of individuals within the groups and may include "networks, relationships, and institutions" (7). On the other hand, cognitive dimensions are the perceptions of individuals "of the level of interpersonal trust and norms of reciprocity within the group" (8) and may include "values, attitudes, trust, confidence, and norms" (7). Both dimensions may be conceived or studied on either individual or collective levels (8).

Among the various cognitive dimensions of social capital, social trust has been recognized as an important factor on people's health outcomes. Subramanian et al. (9) investigated the association between social trust and self-rated health in the United States. The study found that higher community social trust levels led to a lower probability of poor health reports (9). In addition, Kuroki (10) in Japan showed that social trust is causally associated with individual happiness. Additionally, one study studied a relationship between community-level social capital, including community-level social trust, and sexual behaviors on adolescents in Tanzania (11). As investigated in previous studies, individual and community-level social trust are both influential on health outcomes. However, our study focused on community-level social trust because trust is a collective feature of groups, typically conceptualized by aggregating individual responses of people (12), and may be able to independently impact health outcomes.

There are other studies from the Republic of Korea which also investigated the association between community-level social trust and various health outcomes such as metabolic syndrome (MetS), cardiovascular disease (CVD), and mortality. In those studies, higher community-level social trust was associated with better health status (13–15). Meanwhile, there is limited research regarding the association of community-level social trust with the risk of dementia in the Republic of Korea. One study from the American Association for Geriatric Psychiatry found that cognitive decline may be a pathological marker of Alzheimer's disease, the most common type of dementia (16), highlighting the importance of studying a relationship between cognitive factors and dementia. In this respect, it is crucial to investigate the relationship between community-level social trust, a cognitive dimension of social capital, and the risk of dementia–thus calling for a need to investigate the association between community-level social trust and the risk of dementia among a large population in the Republic of Korea.

Methods

Data source

The study population was obtained from the Korean National Health Insurance Service (NHIS) database (NHIS-2021-1-755). NHIS is an institution that provides compulsory health insurance and corresponding services for all Korean citizens (17). For all relevant individuals aged 40 years or older, NHIS further offers health screening examinations that consist of a self-reported questionnaire on health-related behaviors, anthropometric measurements, and laboratory tests for blood and urine. For claims purposes, the NHIS congregates health service exploitation information on all insured health services, including inpatient and outpatient hospitalizations, health screening examinations, diagnostic and treatment-related procedures, and pharmaceutical prescriptions. Several previous extensive epidemiological studies utilizing the NHIS database have been studied, and its validity can be accounted for (17).

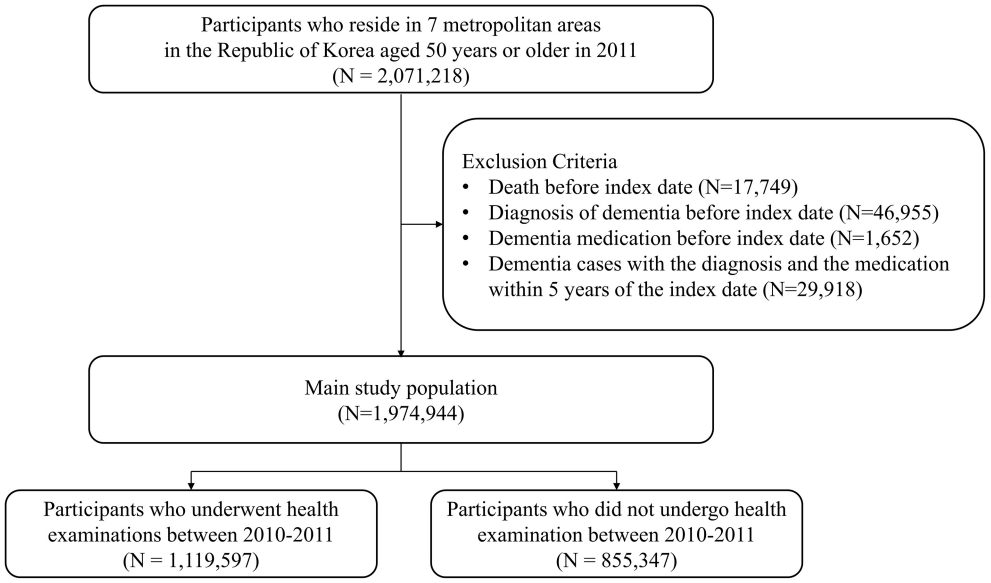

FIGURE 1
Study sample selection.

Study population

Study sample selection is presented in Figure 1. Among 2,071,218 initial participants from seven metropolitan areas in the Republic of Korea aged 50 years or older in 2011, 17,749 participants were excluded as they passed away before 2012, and 46,955 participants with the diagnosis of dementia before the index date of 1 January 2012 were excluded. 1,652 participants were also excluded as they were prescribed medication for dementia before the index date. Additionally, 29,918 participants were excluded because of dementia cases with the diagnosis and medication within 5 years of the index date. This led the main study population to consist of 1,974,944 participants who followed up on their diagnosis and prescription for dementia to define incident dementia from 1 January 2012 to 31 December 2019. Among the main study population, 1,119,597 participants underwent health examinations between 2010 and 2011, and 855,347 participants did not.

Key variables

We obtained community-level social trust values based on the Korean Community Health Survey (KCHS) (18), coordinated by the Korea Disease Control and Prevention Agency in 2011. KCHS is a nationally representative community-based cross-sectional survey with community-level information corresponding to administrative district areas. All survey participants were asked, "Do you trust members of your community?" as a social trust measure (19). The proportion of participants who answered "yes" to each administrative district area's social trust question was utilized to calculate the social trust value. The social trust values in 2011 were combined according to each participant's area of residence, which is also assigned to the same administrative district area. Study participants were divided into quintiles based on social trust values, with the lowest social trust values appearing in the first quintile.

The attending physician has a duty to put the International Classification of Diseases, Tenth Revision (ICD-10) codes for the primary cause of hospitalization upon hospital admission. Dementia was measured using both medications (tacrine, donepezil, rivastigmine, and galantamine) and diagnosis for dementia (ICD-10 code F00, F01, F02, F03, or G30), Alzheimer's disease (AD; ICD-10 code F00, G30) and vascular dementia (VD; ICD-10 code F01) (20). Since dementia is a slowly progressing disease over time, all analyses were conducted based on a 5-year wash-out period that did not consider new cases of dementia diagnosis from 1 January 2012 to 31 December 2016.

Potential confounders including age in years (continuous), sex (categorical, men or women), categorical area of residence (capital-Seoul, or metropolitan city–Busan, Daegu, Incheon, Gwangju, Daejeon, and Ulsan), categorical household income in first, second, third, and fourth quartiles, and Charlson comorbidity index (continuous) were adjusted. The household income was calculated from the insurance premium. The individual-level confounding variables such as depression diagnosis (categorical, no or yes), diabetes diagnosis (categorical,

TABLE 1 Descriptive characteristics of the main study population.

	Social trust (Quintiles)					*P*-value
	1st (Lowest)	2nd	3rd	4th	5th (Highest)	
Range, %	41.54–52.83	53.08–58.32	58.33–60.20	60.21–67.62	67.92–88.46	
Number of people	394,114	383,687	407,270	398,640	391,233	
Age, years, mean (SD)	55.53 (10.49)	55.23 (10.25)	55.52 (10.53)	56.00 (10.62)	55.24 (10.44)	<0.001
Sex, *N* (%)						<0.001
Men	190,207 (48.26)	184,018 (47.96)	195,833 (48.08)	191,379 (48.01)	189,254 (48.37)	
Women	203,907 (51.74)	199,669 (52.04)	211,437 (51.92)	207,261 (51.99)	201,979 (51.63)	
Area of residence, *N* (%)						<0.001
Capital	243,157 (61.70)	156,964 (40.91)	267,368 (65.65)	142,960 (35.86)	55,666 (14.23)	
Metropolitan city	150,957 (38.30)	226,723 (59.09)	139,902 (34.35)	255,680 (64.14)	335,567 (85.77)	
Household income, quartiles, *N* (%)						<0.001
1st (highest)	127,115 (32.25)	136,461 (35.57)	154,668 (37.98)	137,046 (34.38)	151,115 (38.63)	
2nd	91,330 (23.17)	86,839 (22.63)	86,818 (21.32)	90,877 (22.80)	87,420 (22.34)	
3rd	79,290 (20.12)	70,348 (18.33)	70,159 (17.23)	72,097 (18.09)	64,666 (16.53)	
4th (lowest)	96,379 (24.45)	90,039 (23.47)	95,625 (23.48)	98,620 (24.74)	88,032 (22.50)	
Charlson comorbidity index, *N* (%)						<0.001
0	76,235 (19.34)	72,063 (18.78)	78,797 (19.35)	73,157 (18.35)	70,357 (17.98)	
1	86,823 (22.03)	86,304 (22.49)	90,559 (22.24)	85,542 (21.46)	87,265 (22.31)	
≥2	231,056 (58.63)	225,320 (58.72)	237,914 (58.42)	239,941 (60.19)	233,611 (59.71)	
Previous depression, *N* (%)						<0.001
No	358,761 (91.03)	348,171 (90.74)	368,796 (90.55)	360,923 (90.54)	354,155 (90.52)	
Yes	35,353 (8.97)	35,516 (9.26)	38,474 (9.45)	37,717 (9.46)	37,078 (9.48)	
Previous cardiovascular disease, *N* (%)						<0.001
No	318,912 (80.92)	311,196 (81.11)	327,778 (80.48)	318,616 (79.93)	319,818 (81.75)	
Yes	75,202 (19.08)	72,491 (18.89)	79,492 (19.52)	80,024 (20.07)	71,415 (18.25)	
Previous diabetes, *N* (%)						<0.001
No	307,341 (77.98)	303,645 (79.14)	320,770 (78.76)	308,730 (77.45)	309,899 (79.21)	
Yes	86,773 (22.02)	80,042 (20.86)	86,500 (21.24)	89,910 (22.55)	81,334 (20.79)	

P-value calculated by Chi-squared test for categorical variables and analysis of variance for continuous variables. SD, standard deviation; N, number of people.

no or yes), or cardiovascular disease diagnosis (categorical, no or yes) before 1 January 2012 were adjusted additionally.

Statistical analysis

As criteria for determining the qualities of the study population, the Chi-squared test was exploited for categorical variables, and the analysis of variance was used for continuous variables. For dementia risk in accordance with social trust quintiles, the adjusted hazard ratios (aHRs) and 95% confidence intervals (CIs) were calculated using multivariate Cox proportional hazards regression. The relationship between social trust and the risk of dementia was stratified according to age, sex, household income, Charlson comorbidity index, depression, cardiovascular disease, and diabetes. We also conducted analyses of the risk of dementia according to social trust considering participation in health examinations. Finally, we provided the aHRs per one interquartile range increase of the community-level social trust to show that the results align with the result from the adjusted hazard ratios using quintiles of the community-level social trust values.

We defined statistical significance as a p-value of <0.05 on a two-sided basis. The data collection and statistical analysis were carried out using SAS 9.4 (SAS Institute, Cary, NC, USA).

Results

Table 1 summarizes the descriptive qualities of the study population. The ranges for social trust were 41.54–52.83, 53.08–58.32, 58.33–60.20, 60.21–67.62, and 67.92–88.46%. Social trust in the highest quintile was associated with more metropolitan residents, a higher income, and fewer comorbidities (all p-values < 0.001). The number of participants who previously

TABLE 2 Hazard ratios for dementia according to social trust.

	Social trust (Quintiles)				
	1st (Lowest)	2nd	3rd	4th	5th (Highest)
Number of people	394,114	383,687	407,270	398,640	391,233
Overall dementia					
Events	5,040	4,606	5,391	5,675	5,127
Person-years	3,048,525	2,975,285	3,155,512	3,077,398	3,030,278
aHR (95% CI)[a]	1.00 (reference)	0.91 (0.87–0.95)	0.98 (0.94–1.02)	0.95 (0.91–0.99)	0.90 (0.86–0.94)
aHR (95% CI)[b]	1.02 (0.98–1.07)	0.93 (0.89–0.97)	1.00 (reference)	0.97 (0.93–1.01)	0.92 (0.88–0.96)
Alzheimer's disease					
Events	4,476	4,151	4,790	5,092	4,661
Person-years	3,049,351	2,975,958	3,156,393	3,078,293	3,030,984
aHR (95% CI)[a]	1.00 (reference)	0.91 (0.87–0.95)	0.96 (0.92–1.01)	0.94 (0.90–0.98)	0.90 (0.85–0.94)
aHR (95% CI)[b]	1.04 (0.99–1.09)	0.95 (0.91–0.99)	1.00 (reference)	0.98 (0.94–1.02)	0.93 (0.89–0.98)
Vascular dementia					
Events	511	381	516	518	453
Person-years	3,054,289	2,980,716	3,161,951	3,084,016	3,036,179
aHR (95% CI)[a]	1.00 (reference)	0.80 (0.70–0.93)	1.03 (0.90–1.18)	0.98 (0.85–1.13)	0.90 (0.77–1.05)
aHR (95% CI)[b]	0.97 (0.85–1.11)	0.78 (0.68–0.90)	1.00 (reference)	0.95 (0.83–1.08)	0.87 (0.75–1.004)

The aHRs were calculated by Cox proportional hazards regression after adjustments for age, sex, area of residence, household income, Charlson comorbidity index, depression, cardiovascular disease, and diabetes. aHR (95% CI)[a]: First quintile group is the reference group for all adjusted hazard ratios. aHR (95% CI)[b]: Third quintile group is the reference group for all adjusted hazard ratios. aHR, adjusted hazard ratio; CI, confidence interval.

had depression, cardiovascular disease, or diabetes was also measured, and there were significant differences in the distribution of all confounders (all p-values < 0.001).

Table 2 depicts the association of community-level social trust with dementia. Compared to those in the lowest quintile of social trust, those in the highest quintile had a lower risk for overall dementia (aHR, 0.90; 95% CI, 0.86–0.94). There was an alleviating trend with higher levels of social trust for overall dementia. Participants in the highest social trust quintile experienced a lower risk of Alzheimer's disease than those in the lowest social trust quintile (aHR, 0.90; 95% CI, 0.85–0.94). Though the results were not statistically significant, vascular dementia showed a similar trend to overall dementia or Alzheimer's disease. The trend was unchanged when the third quintile of social trust value group was the reference group. The risk of dementia was the lowest in the highest social trust quintile group for overall dementia (aHR, 0.92; 95% CI, 0.88–0.96), Alzheimer's disease (aHR, 0.93; 95% CI, 0.89–0.98), and vascular dementia (aHR, 0.87; 95% CI, 0.75–1.004). Supplementary Table S1 shows the adjusted hazard ratio for dementia per 1 Interquartile Range (IQR) increase in the social trust index. As social trust index increased by 1 IQR value, the risk of overall dementia (aHR, 0.98; 95% CI, 0.96–0.99; p-value, 0.005) and Alzheimer's disease (aHR, 0.98; 95% CI, 0.96–0.99; p-value, 0.003) decreased.

Table 3 illustrates the association between social trust and dementia according to age, sex, household income, and Charlson comorbidity index. In most of the stratification, consistent associations were discovered. Among participants with age <65 years (aHR, 0.89; 95% CI, 0.77–0.995) or ≥65 years (aHR, 0.92; 95% CI, 0.87–0.97), participants in the highest quintile of social trust had a lower risk of overall dementia. Similarly, lower overall dementia was seen among men (aHR, 0.88; 95% CI, 0.81–0.95) as well as women (aHR, 0.91; 95% CI, 0.86–0.96) within the highest social trust quintile. In most subgroups divided by household income and Charlson comorbidity index, an alleviating association for those with higher social trust on overall dementia was discovered. The stratified results on the relationship between social trust and dementia according to depression, cardiovascular disease, and diabetes are represented in Supplementary Table S2. After the stratified analysis, the risk-reducing trend of high social trust in dementia was maintained.

Table 4 demonstrates the risk of dementia according to social trust among participants who received health examinations and who did not receive health examinations. Among the final study population, 1,119,597 participants underwent health examinations. After additional adjustments for dementia risk factors, participants in the highest quintile of social trust were at a lower risk of overall dementia (aHR, 0.93; 95% CI, 0.87–0.996) and Alzheimer's disease (aHR, 0.91; 95% CI, 0.85–0.98) than those in the lowest quintile of social trust. A similar trend was maintained when the reference group was changed to the third quintile of the social trust values. Among participants who did not undergo health examinations (855,347 participants in total),

TABLE 3 Stratified analysis on the association of social trust with dementia according to age, sex, household income, and Charlson comorbidity index.

	aHR (95% CI)					*P*-value for trend
	Social trust (Quintiles)					
	1st (Lowest)	2nd	3rd	4th	5th (Highest)	
Overall dementia						
Age, years						
<65	1.00 (reference)	0.82 (0.73–0.91)	0.99 (0.89–1.10)	0.90 (0.79–1.01)	0.89 (0.77–0.995)	0.841
≥65	1.00 (reference)	0.95 (0.91–1.001)	0.995 (0.95–1.04)	0.97 (0.92–1.01)	0.92 (0.87–0.97)	0.019
Sex						
Men	1.00 (reference)	0.93 (0.86–0.998)	0.95 (0.89–1.02)	0.98 (0.91–1.05)	0.88 (0.81–0.95)	0.044
Women	1.00 (reference)	0.90 (0.85–0.95)	0.99 (0.94–1.05)	0.93 (0.88–0.99)	0.91 (0.86–0.96)	0.056
Household income						
Upper half	1.00 (reference)	0.92 (0.87–0.98)	1.03 (0.97–1.09)	0.98 (0.92–1.03)	0.92 (0.87–0.98)	0.314
Lower half	1.00 (reference)	0.90 (0.84–0.96)	0.92 (0.86–0.98)	0.92 (0.86–0.98)	0.86 (0.80–0.93)	0.002
Charlson comorbidity index						
0	1.00 (reference)	0.79 (0.67–0.93)	0.98 (0.84–1.15)	0.86 (0.73–1.02)	0.83 (0.70–0.99)	0.245
1	1.00 (reference)	0.85 (0.74–0.97)	1.03 (0.91–1.16)	0.94 (0.82–1.07)	0.90 (0.78–1.03)	0.528
≥ 2	1.00 (reference)	0.93 (0.88–0.98)	0.97 (0.93–1.02)	0.96 (0.91–1.01)	0.90 (0.86–0.95)	0.013
Alzheimer's disease						
Age, years						
<65	1.00 (reference)	0.80 (0.71–0.90)	0.94 (0.83–1.05)	0.89 (0.79–1.01)	0.86 (0.76–0.98)	0.498
≥65	1.00 (reference)	0.96 (0.91–1.01)	0.98 (0.94–1.03)	0.96 (0.91–1.004)	0.92 (0.88–0.98)	0.025
Sex						
Men	1.00 (reference)	0.93 (0.86–1.002)	0.94 (0.87–1.01)	0.96 (0.89–1.04)	0.87 (0.80–0.95)	0.038
Women	1.00 (reference)	0.90 (0.85–0.96)	0.97 (0.92–1.03)	0.92 (0.87–0.98)	0.91 (0.86–0.97)	0.047
Household income						
Upper half	1.00 (reference)	0.92 (0.86–0.98)	1.01 (0.95–1.07)	0.97 (0.91–1.03)	0.93 (0.87–0.99)	0.384
Lower half	1.00 (reference)	0.90 (0.84–0.97)	0.90 (0.84–0.97)	0.90 (0.84–0.97)	0.86 (0.79–0.93)	<0.001
Charlson comorbidity index						
0	1.00 (reference)	0.81 (0.67–0.96)	1.02 (0.87–1.21)	0.84 (0.70–0.996)	0.82 (0.68–0.996)	0.209
1	1.00 (reference)	0.86 (0.75–0.99)	1.04 (0.91–1.19)	0.95 (0.83–1.09)	0.91 (0.78–1.05)	0.648
≥ 2	1.00 (reference)	0.93 (0.88–0.98)	0.94 (0.90–0.99)	0.94 (0.90–0.99)	0.90 (0.85–0.95)	0.008
Vascular dementia						
Age, years						
<65	1.00 (reference)	0.74 (0.56–0.997)	1.12 (0.85–1.47)	0.85 (0.63–1.14)	0.99 (0.73–1.35)	0.241
≥65	1.00 (reference)	0.84 (0.71–0.995)	1.02 (0.87–1.19)	1.03 (0.88–1.21)	0.88 (0.73–1.05)	0.973
Sex						
Men	1.00 (reference)	0.92 (0.75–1.14)	1.01 (0.82–1.24)	1.05 (0.86–1.30)	0.95 (0.76–1.20)	0.778
Women	1.00 (reference)	0.72 (0.59–0.87)	1.05 (0.87–1.25)	0.92 (0.76–1.11)	0.85 (0.69–1.05)	0.757
Household income						
Upper half	1.00 (reference)	0.80 (0.65–0.97)	1.09 (0.91–1.31)	0.94 (0.78–1.13)	0.88 (0.72–1.08)	0.839
Lower half	1.00 (reference)	0.81 (0.65–1.01)	0.95 (0.77–1.17)	1.04 (0.84–1.27)	0.92 (0.73–1.16)	0.656
Charlson comorbidity index						
0	1.00 (reference)	0.54 (0.32–0.91)	0.50 (0.31–0.83)	0.78 (0.49–1.24)	0.72 (0.43–1.22)	0.533
1	1.00 (reference)	0.80 (0.53–1.20)	1.04 (0.71–1.53)	0.87 (0.58–1.32)	0.94 (0.61–1.45)	0.814
≥2	1.00 (reference)	0.84 (0.72–0.99)	1.10 (0.95–1.29)	1.03 (0.88–1.20)	0.92 (0.77–1.09)	0.549

The aHRs were calculated by Cox proportional hazards regression after adjustments for age, sex, area of residence, household income, Charlson comorbidity index, depression, cardiovascular disease, and diabetes. aHR, adjusted hazard ratio; CI, confidence interval.

TABLE 4 Risk for dementia according to social trust considering participation in health examinations.

	Total	Events	Social trust (Quintiles)				
			1st (Lowest)	2nd	3rd	4th	5th (Highest)
Participants who underwent health examinations							
Overall dementia							
aHR (95% CI)[a]	1,119,597	13,044	1.00 (reference)	0.94 (0.88–0.996)	1.01 (0.95–1.07)	0.95 (0.89–1.01)	0.93 (0.87–0.996)
aHR (95% CI)[b]	1,119,597	13,044	0.99 (0.93–1.06)	0.93 (0.88–0.99)	1.00 (reference)	0.95 (0.90–0.999)	0.93 (0.87–0.98)
Alzheimer's disease							
aHR (95% CI)[a]	1,119,597	11,673	1.00 (reference)	0.92 (0.86–0.99)	0.97 (0.90–1.03)	0.93 (0.87–0.999)	0.91 (0.85–0.98)
aHR (95% CI)[b]	1,119,597	11,673	1.04 (0.97–1.11)	0.95 (0.90–1.02)	1.00 (reference)	0.97 (0.91–1.03)	0.95 (0.89–1.01)
Vascular dementia							
aHR (95% CI)[a]	1,119,597	1,191	1.00 (reference)	0.92 (0.74–1.13)	1.23 (1.01–1.49)	1.01 (0.82–1.24)	1.08 (0.86–1.34)
aHR (95% CI)[b]	1,119,597	1,191	0.82 (0.67–0.995)	0.75 (0.62–0.91)	1.00 (reference)	0.82 (0.69–0.99)	0.88 (0.72–1.07)
Participants who did not undergo health examinations							
Overall dementia							
aHR (95% CI)[a]	855,347	12,795	1.00 (reference)	0.90 (0.84–0.95)	0.95 (0.90–1.01)	0.95 (0.89–1.01)	0.87 (0.81–0.93)
aHR (95% CI)[b]	855,347	12,795	1.05 (0.99–1.11)	0.94 (0.88–0.996)	1.00 (reference)	0.99 (0.94–1.05)	0.91 (0.85–0.97)
Alzheimer's disease							
aHR (95% CI)[a]	855,347	11,497	1.00 (reference)	0.91 (0.85–0.97)	0.96 (0.90–1.02)	0.94 (0.88–0.999)	0.88 (0.82–0.95)
aHR (95% CI)[b]	855,347	11,497	1.05 (0.98–1.11)	0.95 (0.89–1.01)	1.00 (reference)	0.98 (0.92–1.04)	0.92 (0.86–0.98)
Vascular dementia							
aHR (95% CI)[a]	855,347	1,188	1.00 (reference)	0.72 (0.59–0.88)	0.89 (0.74–1.07)	0.97 (0.80–1.17)	0.76 (0.61–0.94)
aHR (95% CI)[b]	855,347	1,188	1.13 (0.93–1.36)	0.81 (0.67–0.995)	1.00 (reference)	1.09 (0.91–1.30)	0.85 (0.69–1.06)

The aHRs were calculated by Cox proportional hazards regression after adjustments for age, sex, area of residence, household income, Charlson comorbidity index, depression, cardiovascular disease, and diabetes. aHR (95% CI)[a]: First quintile group is the reference group for all adjusted hazard ratios. aHR (95% CI)[b]: Third quintile group is the reference group for all adjusted hazard ratios. aHR, adjusted hazard ratio; CI, confidence interval.

reduced risks of overall dementia (aHR 0.87; 95% CI, 0.81–0.93), Alzheimer's disease (aHR 0.88; 95% CI, 0.82–0.95), and vascular dementia (aHR, 0.76; 95% CI, 0.61–0.94) were observed when the first quintile of social trust was the reference group. The trend was unchanged when the third quintile of social trust was used as a reference group. A description of the qualities of participants who had health examinations is shown in Supplementary Table S3, and a description of the characteristics of individuals who did not undergo health examinations is represented in Supplementary Table S4.

Discussion

In this large, long-term, population-based retrospective cohort study, higher community-level social trust was related to a lower risk of dementia. Among the three categories of dementia–overall dementia, Alzheimer's disease, and vascular dementia–the risk of overall dementia and Alzheimer's disease was reduced with higher community-level social trust. Even after additional adjustments with risk factors such as comorbidities, depression, diabetes, and cardiovascular disease, the results were preserved and statistically significant. Based on our information, this is the first countrywide cohort study to show an association of community-level social trust with dementia risk for an extensive general population worldwide.

Previously, other studies explored the association of various components of social capital, including social relationships, support, and community engagement with dementia. Kuiper et al. (21) performed a meta-analysis of longitudinal cohort studies on the association of social relationships with the risk of dementia. They concluded that social relationship factors that characterize a lack of social interaction are related to incident dementia (21). Since the study only included two studies from Asia, it is yet unclear about the relationship between social capital and incident dementia among the Asian population. However, our study provides significant results proving that there may be a negative association between high community-level social capital (trust aspect) and a lower risk of dementia using large population-based data. Also, a longitudinal study in Australia showed that low social support is associated with incident dementia (22). The study investigated both genders, but the results were only significant among women [Hazard Ratio (HR) = 1.79]. In contrast, the results in our study were not gender-specific, meaning the results were similar for men and women. Moreover, an English national cohort study presented

that community engagement may be protective against the risk of dementia onset (23). This study consists of a relatively small number of participants—9,550 participants in total. The study also measured dementia with mixed definitions, including self-reported informant-reported scores above a certain threshold of IQCODE (Informant Questionnaire on Cognitive Decline in the Elderly). Instead, our study utilized the ICD-10 code definition of dementia with three categories–overall dementia, Alzheimer's disease, and vascular dementia. Consequently, unlike previous studies, our study presents compelling evidence that social trust in a community has a dementia-risk-reducing effect among older adults in the Korean population regardless of sex with an objective definition of dementia and a large study population.

Moreover, current literature suggests that depression is one of the influential determinants of dementia (Alzheimer's disease, vascular dementia, or any dementia) (24, 25). There has been substantial research regarding the association between social capital and depression as well. For instance, a cross-sectional study in China showed that social capital mediates depression (26). Another study from Indonesia proved that social trust is related to the severity of depressive symptoms (27). In this respect, it is vital to consider the possible confounding effect of depression on the association between social capital and the risk of dementia. In our study, this effect was considered by involving depression with ICD-10 diagnosis as one of the confounding variables. This makes our study more compelling that there is an association between social capital and the risk of dementia.

Recently, a cross-sectional study from Japan discovered that community-level social capital, including social trust, is associated with dementia (4). Although this study showed that higher community-level social trust is associated with a lower risk of dementia, it used the self-administered dementia checklist to measure subjective dementia symptoms. In other words, it used a limited definition to measure incident dementia. By contrast, our study provides more robust evidence than the previous study on the association between community-level social trust and the risk of dementia by having a direct measure of dementia. In addition, our study population was obtained from a nationwide cohort database, and the social trust value was calculated from a district representative sample and converted into the area-level value for all populations, which is different from the recent Japanese cross-sectional study that only consisted of 75,338 participants in total. In our study, a null association was discovered between social trust level and vascular dementia. However, though not statistically significant, there was an association with vascular dementia in our several results. Further studies considering enough vascular dementia cases are needed.

Various mechanisms have been proposed to explain the significant association of social capital, including community-level social trust, with dementia. First, social relationship engagement in districts with a high social trust may delay the incidence of dementia with cognitive stimulation and effective stress management by alleviating harmful stress nervous system responses (16). Second, the "use it or lose it" theory, which says that the brain can be considered as a muscle and various activities, including social activities that stimulate the brain (28), may be applied to explain the relationship between social trust and the risk of dementia. Reshadi (29) showed that social trust and social participation have a significant relationship. In this respect, participating more in social activities in districts with high social trust leads to frequent stimulation of the brain, which may delay the incidence of dementia. Third, low levels of social trust may increase social stress and anxiety, which may result in the stimulation of the hypothalamic-pituitary-adrenal axis (HPA axis) (15). The stimulation of the HPA axis leads to high blood cortisol levels, which can cause detrimental diseases such as dementia (30, 31). By decreasing social stress and anxiety, a high social trust may help reduce the risk of dementia. Finally, by promoting health awareness, communities with a higher community-level social trust may reduce unhealthy lifestyle behaviors (32). Instead of healthy lifestyle pathways, this study focuses on the psychosocial pathway, health service utilization pathway, and other possible undetermined mechanisms.

Several limitations were discovered in this study. First, the social trust index was calculated at one point so that the possible change in the social trust level at various points was not contemplated. This can be considered a minor limitation since communities in a country participate in the same social activities, which may affect the change in social trust, and it has been demonstrated that the trust values return to the primary levels (33). Second, our retrospective cohort study could be biased by omitted variables. The factors that we could not observe or measure in the database, not social trust level, may affect dementia risk. However, it is hard to control omitted variable bias in any retrospective database (34). Third, this study only considered participants living within seven metropolitan cities, without participants living within rural areas. Further studies may be needed to determine the influence of social trust on dementia in older adults within rural areas. Fourth, we could not consider all risk factors modeled by the 2020 *Lancet* Commission, like education level and air pollution (35), as covariates due to a lack of information. However, we accounted for income level, which might be a proxy for education level. Future studies that consider other risk factors, which were not included in our analysis, are required to validate our findings. Finally, since the NHIS database does not include imaging data and screening examinations, the operational definition of dementia was based on the ICD-10 codes and the prescription of dementia-related medications. Specifically, the severity and stage of dementia were not considered in the analyses due to the lack of information.

Despite these limitations, this study has significant strengths. Based on our information, this is the first study to investigate community-level social trust and dementia risk in Korea. Our study consists of a large cohort population of nearly 2

million participants with the minimal exclusion of the study population. Second, we excluded the area-level confounders such as urbanization by limiting the study population to seven metropolitan areas of the Republic of Korea. Third, our study's result was significant in both men and women. This is notable because some previous studies showed different results by gender of the study participants. Fourth, our study divides dementia into overall dementia, Alzheimer's disease, and vascular dementia with ICD-10 code diagnosis and prescription of anti-dementia drugs. Reliable medical claims records support the validation of dementia events. Lastly, we accounted for various confounding variables such as comorbidities in the analysis.

Findings in our study suggest that higher social trust at the community level is associated with a lower risk of dementia. The association is preserved with additional adjustments for dementia risk factors such as comorbidities, depression, diabetes, and cardiovascular disease. This proposes that social trust, as part of social capital, is a significant indicator of dementia. Therefore, having a health care policy that can improve community-level social trust may help reduce the risk of dementia, especially among individuals over 50 years of age.

Data availability statement

The datasets are not publicly available as they are protected by the Korean National Health Insurance Service. Anonymized versions can be made available upon institutional approval. Further information is available via https://nhiss.nhis.or.kr and queries should be directed to the corresponding author(s).

Ethics statement

The studies involving human participants were reviewed and approved by Seoul National University Hospital Institutional Review Board (IRB number: E-1806-076-951). Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

Study concept and design: JH, SJP, J-KL, HJJ, and SMP. Acquisition of data: J-KL and SMP. Analysis and interpretation of data and critical revision of the manuscript for important intellectual content: JH, SJP, J-KL, HJJ, JO, SC, SJ, KHK, JSS, and SMP. Drafting of the manuscript: JH, SJP, J-KL, and SMP. Statistical analysis: JH and SJP. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.913319/full#supplementary-material

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Predicting death quality from life prior to death among older Chinese in a retrospective cohort study

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Background: The pursuit of a good death is crucial in aging societies. This retrospective cohort study investigated the relation between life prior to death and quality of death among older Chinese.

Methods: End-of-life data reported by relatives of participants (aged 54 and over) from the Chinese Longitudinal Healthy Longevity Survey (CLHLS) who deceased between January 2011 and June 2019 were utilized. Life prior to death included health condition (morbid or not) and physical functioning (a latent factor with six indicators). Quality of death was assessed by painlessness and consciousness at death. Confirmatory Factor Analysis was employed to examine the factor structure of physical functioning and Structural Equation Modeling to explore associations between life prior to death and death quality based on sex and residence location.

Results: Freedom from chronic diseases was found to contribute to high-quality deaths (i.e., being painless and conscious) both directly and indirectly by enhancing physical functioning. Men and women diverged toward end-of-life: women were moderately less liable to illnesses and thus less painful at death. Yet, men functioned much better, and more often remained conscious when dying. Location's effect was weaker: although rural residents were more prone to painful deaths than urban dwellers, this urban-rural divide was slightly narrowed by rural settlers' relative health, which also indirectly led to their slight advantage in consciousness at death.

Conclusions: The results suggested that different dimensions of life prior to death predicted quality of death. Additionally, morbidity's effect on functioning and death quality stresses health management's role in improving end-of-life experiences.

KEYWORDS

life prior to death, death quality, morbidity, activities of daily living (ADL), retrospective design, CLHLS, sex difference, socioeconomic factor

Introduction

Improving end-of-life experiences is essential to successful aging (1). According to practitioners and health researchers, high quality of life prior to death emphasizes healthier survival (freedom from illness or management of pain and other unpleasant symptoms from chronic diseases) and satisfactory functional status (autonomy in activities of daily living, or ADLs) given expected proximity to death (2–4). Additionally, to "die well" is increasingly considered crucial in aging societies (5–7). Quality markers of a good death identified in empirical studies include freedom from pain or discomfort, being conscious and alert, and feeling dignified and prepared, among others (1, 3, 5, 8). So far, much end-of-life research has centered on patients diagnosed with terminal illnesses (2, 9). Despite providing substantial clinical and policy implications, this line of inquiry neglects older people who are relatively healthy and functionally capable.

Instead, research on late life in China has examined experiences of older adults in general to promote healthy longevity for all. After all, this is a particular challenge for the country given that the proportion of its older population (aged 60 or more) is projected to increase by 28% (402 million) by 2040, a faster rate than most countries across the world (10). Consistent with previous research conducted elsewhere, indicators for healthy aging in China also comprise being disease-free and able to perform ADLs independently, among others (11, 12). Moreover, older Chinese females appear relatively disadvantaged in health and functioning, a phenomenon prevailing in contemporary human societies (13), although some studies conducted in China did detect male disadvantages in certain diseases (14) or equal functional statuses for men and women (15). Furthermore, adopting urban-rural residence as a proxy for socioeconomic status (SES) in China, scholars have found that urban settlers are more likely to be morbid or multimorbid, while rural residents face greater risks of functional disability (11, 12, 16, 17). Such urban-rural disparities seem paradoxical, as morbidity or comorbidity is repeatedly found to be correlated with functional limitation (15, 18). Reasons for these sex- and residence-related nuances might be nosologic, methodological, or substantive: definitions and classifications of diseases might affect the measure of morbidity (13), the approximation of functional limitation by observed scores (e.g., difficulties in one or more ADL items, or sums of scores from ADL items) can be inaccurate because of measurement error in ADL items (12, 18), and the unequal distribution of medical resources across regions may lead to the under-report and underdiagnosis of diseases in rural villages (14).

Instrumental in promoting understanding of late life, the abovementioned works in China hardly ever associated life prior to death to quality of death. The few exceptions either focused on adverse health conditions at end-of-life or limited their examination of death statuses to death location or level of pain experienced (7, 19, 20). The effects of health conditions (single disease or comorbidity) on physical functioning given proximity to death, and how they both could have influenced the quality of death, remain inconclusive. Whether sex or urban-rural residence plays a role toward end-of-life is also largely unclear. Thus, to address these gaps, the current study analyzed end-of-life data collected from relatives of older adults (aged 54 and over) participating in the Chinese Longitudinal Healthy Longevity Survey (CLHLS) who deceased between 2011 and 2019. This is the first known retrospective design to capture the mechanisms between life prior to death and death quality and to explore sex and urban-rural disparities drawing on nationwide data from older Chinese.

Materials and methods

Data source

The CLHLS aimed to understand factors associated with mortality and healthy longevity (17). The baseline survey was conducted in 1998 in one-half of the cities and counties randomly selected from 22 out of 31 provinces throughout mainland China (21). The ∼985 million people in these participating provinces accounted for 85% of the Chinese population, revealing the wide coverage of the CLHLS. The target respondents were older people aged 65 and over, although the oldest old (80-year-olds and older) and males were oversampled to achieve adequate representation (22). Seven follow-up surveys were conducted in 2000, 2002, 2005, 2008–09, 2011–12, 2014, and 2017–18, with replacements for those who deceased between waves. Detailed information on sampling procedures and survey protocols is available from Peking University Open Access Research Database (http://opendata.pku.edu.cn/), and ethical approval was gained from the Ethics Committees of Peking University and Duke University (17, 23). Assessments of data (accuracy of age, consistency, and validity of various measures, etc.) yielded proof of high data quality (22).

After participants had died between waves, a close contact (often a family member, but occasionally, a friend, social worker, or others) was interviewed in the next immediate wave about the decedents' pre-death and dying experiences. The information gathered included medical history and functional capacities prior to death, cause of death, and death statuses, among others. Data on the 9,778 deaths during the 2011–12 ($n = 5,642$), 2014 ($n = 2,589$), and 2017–18 ($n = 1,547$) waves were utilized in this research, because the questions on medical history were changed since the 2011–12 wave, rendering it unfeasible to incorporate the data from earlier waves.

Measurement

Life prior to death

Life prior to death consisted of health condition and physical functioning (20, 21). Health condition was measured by the number of known diseases the departed had ~3 months or less prior to death, where a code of 0 stood for no disease at all, 1 for one disease, and 2 for two diseases and more (i.e., comorbidity). The diseases reported were common chronic illnesses among older Chinese, which included hypertension, diabetes, heart diseases, cerebrovascular disease (CVD), pneumonia, tuberculosis, cancer, glaucoma, gastric or duodenal ulcer, Parkinson's Disease, bedsores, dementia, and arthritis.

To account for measurement errors in observed variables, physical functioning was conceptualized as a latent factor with six indicators, all of which corresponded to the decedents' ability to perform six ADLs (bathing/showering, dressing, getting to the toilet, indoor mobility, continence, and eating) within 3 months before their deaths. The answers from the surrogate respondents (relatives or other close contacts) were dichotomized into "dependent (=0)" and "independent (=1)."

Quality of death

Quality of death was assessed by two items from the CLHLS: whether the older adults seemed painful at death, and whether they lost consciousness when dying. The former was evaluated by a five-point Likert scale ranging from 1 ("very painful") to 5 ("peaceful"). The latter had two categories: 1 for being conscious and 2 if otherwise. During data analyses, responses to both items were re-coded as 0 when they were negative ("very painful" and "relatively painful"; "unconscious") and 1 when positive ("all right", "relatively peaceful" and "peaceful'; "conscious").

Covariates

Sex and residence location were the covariates in this study. Both variables were dichotomous: (a) sex (0 = "male," 1 = "female"), and (b) residence location (0 = "rural areas," 1 = "urban areas").

Analytic plan

Confirmatory Factor Analysis (CFA) was adopted to examine the factor structure of the latent construct—physical functioning. The following indices were utilized to determine the model fit: statistical non-significance of model chi-square (α at.05), the comparative fit index (CFI) $\geq$0.95, the Tucker-Lewis Index (TLI) $\geq$0.95, the standardized root mean residual (SRMR) $\leq$0.08, the root mean square error of approximation (RMSEA) $<$0.07 (24).

Subsequently, to isolate the effects of sex and urban-rural residence at the observed level (i.e., in each of the six indicators of physical functioning), the 'multiple indicators, multiple causes' (MIMIC) method was applied (25, 26). To the original CFA model, a hypothesized path linking a covariate (sex or residence) and one indicator of physical functioning (bathing, dressing, etc.) was added, while holding constant the level of physical functioning as a latent factor. This procedure was repeated for all six indicators one-by-one, and for both covariates (sex and residence). A good overall model fit, in addition to a statistically significant regression coefficient for the added path, would provide evidence of the covariate's effect irrespective of the latent construct. Any path satisfying both criteria would be retained in the model for subsequent analysis.

Finally, Structural Equation Modeling (SEM) was employed to identify associations between life prior to death and quality of death based on sex and residence. Both CFA and SEM were conducted with Mplus 8.3, the software program designed for latent variable modeling (27).

Results

Descriptive statistics

Table 1 below exhibits the socio-demographic characteristics of the decedents. Age at death ranged from 54 to 121 (M = 94.33, SD = 7.95), with six participants aged between 54 and 64. Women comprised 58.75% of the sample. On average, the participants received 1.48 years of schooling (SD = 2.91). Toward end-of-life, over half (58.68%) lived in rural regions, while the rest resided in urban areas, such as cities or towns. Most subjects (87.03%) were community-dwelling, and about 90% were primarily cared for by their family. Additionally, as far as the available data have implied, nine out of ten responses were from a next of kin. Given that information on end-of-life status tends to be accurate when provided by family members (7, 28), the proxy responses from the CLHLS were considered reliable.

Table 2 here describes health condition, six indicators of physical functioning, and two items representing quality of death among participants. Over half of the total sample were morbid (n = 5,425, 57.43%). To be more specific, 31.0% (n = 2,932) reported one illness, 14.7% lived with two diseases (n = 1,394), 6.7% with three conditions (n = 636), and the rest with four or more (4.9%, n = 468). On average, this sample had 1.04 chronic illnesses (SD = 1.26). Difficulties with performing ADLs were prevalent (between 65.62 and 79.64%) in five out of six activities except for continence, with which slightly less than half (48.10%) had trouble. Almost two fifths of the deaths were of less-than-satisfactory qualities, featured by feelings of pain (38.59%) and unconsciousness (36.09%).

Sex differences emerged toward end-of-life. Women were relatively heathier, as the proportion of women whose close

TABLE 1 Socio-demographic characteristics of subjects ($N = 9,778$).

Characteristics	*N*	%	Characteristics	*N*	%
Age at death (years)			Relationship between the proxy and the deceased[a]		
Mean (*SD*)	94.35 (*9.03*)		Relative	1,106	90.07
Minimum–maximum	54–121		Non-relative	122	9.93
Sex			Months between the last interview and death		
Male	4,033	41.25	Mean (*SD*)	18.33 (*11.29*)	
Female	5,745	58.75	Minimum–maximum	0–61.70	
Education (years)			Primary caregiver		
Mean (*SD*)	1.48 (*2.91*)		No caregiver needed	233	2.42
Minimum–maximum	0–25		Lack of a caregiver	66	0.69
Residence location prior to death			Spouse	751	7.80
Rural areas	5,738	58.68	Children/grandchildren	7,899	82.08
Urban areas	4,040	41.32	Other relatives/friends	239	2.48
Marital status prior to death			Others	435	4.52
Unmarried	7,719	80.11	Place of death		
Married	1,916	19.89	Home	8,544	88.74
Living arrangement prior to death			Hospital	812	8.43
Alone	1,245	12.97	Nursing homes	215	2.23
With others	8,352	87.03	Others	57	0.59

SD, standard deviation. [a] Information was only available for the 2018 wave. The italic values are standard deviations.

contacts recalled having no disease (46.21%) was larger than that of men (37.38%), while a higher percentage of men were believed to be morbid. On the other hand, men functioned much better, because a higher fraction of men than women could perform all ADLs without assistance: the sex gap regarding proportions varied between 2.62 and 7.68%. Discrepancies persisted till death. Painlessness was more often witnessed among female decedents (64.52% of women but 56.94% of men), while consciousness among male ones (66.96 vs. 61.78%).

Compared to sex disparities, residence-based divergences were not as pronounced. Urban dwellers were more often morbid: within 3 months prior to death, 31.44% of city-settlers lived with one disease and 29.79% with two or more, while the respective figures were 30.70 and 24.07% for rural residents. Circumstances with physical functioning (indicated by six ADL measures) were less straightforward. Higher percentages of older people in urban areas could perform three ADLs independently than their peers in rural locations (bathing/showering, indoor mobility, and continence), and the percentage differences ranged from 0.81 to 3.76%. By comparison, urban-rural divides in the remaining three ADLs (dressing, getting to the toilet, and eating) were minimal—percentage differences at 0.39% and lower. When dying, a larger share of urban decedents was painless (64.30 vs. 59.39%), but proportions of consciousness at death were substantially similar in urban and rural regions (62.52% in cities or towns and 64.88% in villages).

CFA and MIMIC-model method

CFA was carried out to determine whether a common factor, physical functioning, underlay the six items of ADLs (see the graphic representation in Figure 1, Panel A). All fit indices were optimal (CFI = 1.000; TLI = 1.000; RMSEA =0.038, 90% CI: [0.033, 0.044]; SRMR = 0.010), apart from the statistically significant chi-square statistics [χ^2 (df) = 135.319 (9), $p < 0.001$]. Because model chi-square tests the exact-fit hypothesis, which is sensitive to sample sizes larger than 300, the specified model was still recognized as a reasonably good fit for the data (29).

The MIMIC-method was then applied to identify the effect of covariates (sex and residence) at the observed level (i.e., in one or more indicators of physical functioning; see Figure 1, Panel B for an example) while holding constant the latent factor. The results were summed in Table 3 below (values of other path coefficients are substantially similar with the original CFA model and are thus omitted to save space but are available on request). The following trends emerged: proxy respondents of older women were more inclined to recall problems with bathing/showering and indoor mobility, but surrogates of older men were more liable to report issues with continence and feeding. In terms of location, surrogate respondents for rural settlers noticed more difficulties with dressing and getting to the toilet, while those for urban residents suggested more trouble with bathing/showering and continence. These four paths were retained in the subsequent SEM analysis.

TABLE 2 Descriptive statistics on health condition, physical functioning, and quality of death by sex and location.

	Sex		Residence location	
	Male *n* (%)	Female *n* (%)	Rural areas *n* (%)	Urban areas *n* (%)
Health condition (*n*; %)				
No disease (4,026; 42.58)	1,455 (37.38)	2,571 (46.21)	2,523 (45.22)	1,503 (38.77)
One disease (2,932; 31.01)	1,282 (32.94)	1,650 (29.65)	1,713 (30.70)	1,219 (31.44)
Two or more (2,498; 26.42)	1,155 (29.68)	1,343 (24.14)	1,343 (24.07)	1,155 (29.79)
Physical functioning (*n*; %)				
Bath/Shower				
Independent (1,944; 20.36)	977 (24.89)	967 (17.21)	1,204 (21.36)	740 (18.93)
Dependent (7,602; 79.64)	2,949 (75.11)	4,653 (82.79)	4,433 (78.64)	3,169 (81.07)
Getting dressed and undressed				
Independent (2,615; 27.39)	1,227 (31.20)	1,388 (24.72)	1,546 (27.45)	1,069 (27.31)
Dependent (6,932; 72.61)	2,706 (68.80)	4,226 (75.28)	4,087 (72.55)	2,845 (72.69)
Going to the toilet and cleaning				
Independent (2,469; 25.77)	1,176 (29.82)	1,293 (22.94)	1,457 (25.76)	1,012 (25.80)
Dependent (7,111; 74.23)	2,768 (70.18)	4,343 (77.06)	4,200 (74.24)	2,911 (74.20)
Indoor mobility				
Independent (2,395; 25.06)	1145 (29.13)	1,250 (22.21)	1,434 (25.39)	961 (24.58)
Dependent (7,162; 74.94)	2785 (70.87)	4,377 (77.79)	4,213 (74.61)	2,949 (75.42)
Controlling bladder/bowel functions				
Independent (4,966; 51.90)	2,102 (53.45)	2,864 (50.83)	3,019 (53.44)	1,947 (49.68)
Dependent (4,602; 48.10)	1,831 (46.55)	2,771 (49.17)	2,630 (46.56)	1,972 (50.32)
Feeding oneself				
Independent (3,284; 34.38)	1,483 (37.74)	1,801 (32.03)	1,949 (34.54)	1,335 (34.15)
Dependent (6,268; 65.62)	2,446 (62.26)	3,822 (67.97)	3,694 (65.46)	2,574 (65.85)
Quality of death (*n*; %)				
Freedom from pain				
Yes (5,475; 61.41)	2,087 (56.94)	3,388 (64.52)	3,121 (59.39)	2,354 (64.30)
No (3,441; 38.59)	1,578 (43.06)	1,863 (35.48)	2,134 (40.61)	1,307 (35.70)
Being conscious				
Yes (6,085; 63.91)	2,624 (66.96)	3,461 (61.78)	3,646 (64.88)	2,439 (62.52)
No (3,436; 36.09)	1,295 (33.04)	2,141 (38.22)	1,974 (35.12)	1,462 (37.48)

Percentages are proportions of non-missing values.

SEM

SEM was performed to analyze the associations between life prior to death and quality of death. As depicted in Figure 2, the model fitted the data well, χ^2 (df) = 293.502 (26), $p < 0.001$; CFI 0= 0.999; TLI = 0.999; RMSEA = 0.033, 90% CI: [0.029, 0.036]; SRMR = 0.015. Both unstandardized estimates (b) and standardized estimates (β) for the hypothesized paths are displayed in Tables 4, 5 summarizes the direct, indirect, and total effects between variables/factors in interest.

The results indicated that different dimensions of life prior to death predicted death qualities (i.e., painlessness and consciousness) to varying degrees. Freedom from diseases contributed to pain-free deaths to a moderately larger extent than to dying with consciousness ($|\beta|$s = 0.194 and 0.166, both ps < 0.001), but enhanced functioning capacity was associated more intensely with consciousness maintain rather than pain reduction ($|\beta|$s =0.387 and 0.082, both ps < 0.001). Notably, the abovementioned, morbidity's effects on both quality markers of death were mediated by functional limitations: morbid individuals' tendency toward painful deaths was aggravated by problems they had with ADLs ($|\beta| = 0.016$, $p < 0.001$), and the amplitude of negative mediation of consciousness loss was even stronger at end-of-life ($|\beta| = 0.077$, $p < 0.001$). Nonetheless, both mediatory effects were smaller compared to the direct association between morbidity and a less-than-satisfactory death: the indirect effect of health condition on pain through physical functioning was minimal

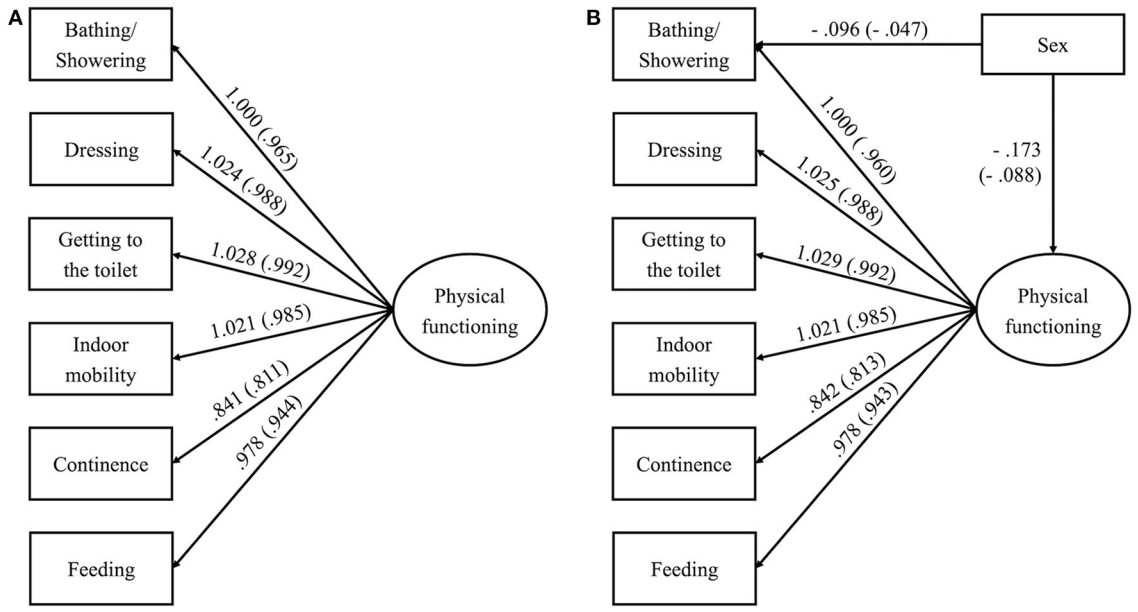

FIGURE 1
(A) Measurement model of physical functioning. Results for the Confirmatory Factor Analysis (standardized results in brackets), all *ps* < 0.001. χ^2 (df) = 135.319 (9), $p < 0.001$; CFI = 1.000; TLI = 1.000; RMSEA = 0.038, 90% CI: [0.033, 0.044]; SRMR = 0.010. **(B)** Example MIMIC model linking sex to bath/showering. Results for the MIMIC model (standardized results in brackets), all *ps* < 0.001. χ^2 (df) = 170.292 (13), $p < 0.001$; CFI = 1.000; TLI = 0.999; RMSEA = 0.036, 90% CI: [0.031, 0.040]; SRMR = 0.013.

TABLE 3 Fit indices and slope coefficients for MIMIC models testing sex-related or residence-based response differences on each indicator of physical functioning.

Indicator	χ^2_{SB}	*df*	RMSEA [90% CI]	CFI	TLI	*b*	*β*	*p*
Sex								
Bath/Shower	170.292***	13	0.036 [0.031, 0.040]	1.000	0.999	−0.096***	−0.047***	<0.001
Dressing	189.440***	13	0.038 [0.033, 0.042]	1.000	0.999	−0.002	−0.001	0.889
Going to toilet	187.955***	13	0.037 [0.033, 0.042]	1.000	0.999	−0.023	−0.011	0.065
Mobility	187.677***	13	0.037 [0.033, 0.042]	1.000	0.999	−0.029*	−0.014*	0.031
Continence	170.974***	13	0.036 [0.031, 0.040]	1.000	0.999	0.106***	0.052***	<0.001
Feeding	188.831***	13	0.038 [0.033, 0.042]	1.000	0.999	0.034*	0.017*	0.046
Residence location								
Bath/Shower	161.569***	13	0.035 [0.030, 0.039]	1.000	0.999	−0.060**	−0.029**	0.002
Dressing	162.569***	13	0.035 [0.030, 0.039]	1.000	0.999	0.040**	0.019**	0.004
Going to toilet	161.153***	13	0.034 [0.030, 0.039]	1.000	0.999	0.046***	0.023***	<0.001
Mobility	166.752***	13	0.035 [0.030, 0.040]	1.000	0.999	0.012	0.006	0.384
Continence	165.912***	13	0.035 [0.030, 0.040]	1.000	0.999	−0.075**	−0.037**	0.001
Feeding	166.747***	13	0.035 [0.030, 0.040]	1.000	0.999	0.029	0.014	0.090

χ2SB, model chi-square for Weighted Least Square Mean Variance (WLSMV) estimation; df, degree of freedom; CI, confidence interval; b, unstandardized estimates; β, standardized estimates.
*p < 0.05, **p < 0.01, ***p < 0.001.

($|\beta|$ = 0.016, $p < 0.001$) compared to the direct effect ($|\beta|$ = 0.177, $p < 0.001$), although the respective indirect effect on consciousness was only slightly weaker than the direct one (0.077 vs 0.089, both $|\beta|$s were statistically significant at $p = 0.001$).

Older men and women took divergent trajectories of dying. Sex influenced physical functioning directly and indirectly through health condition: reported incidence of chronic diseases was slightly lower among older women than men ($|\beta|$ = 0.096, $p < 0.001$), and this modest health advantage

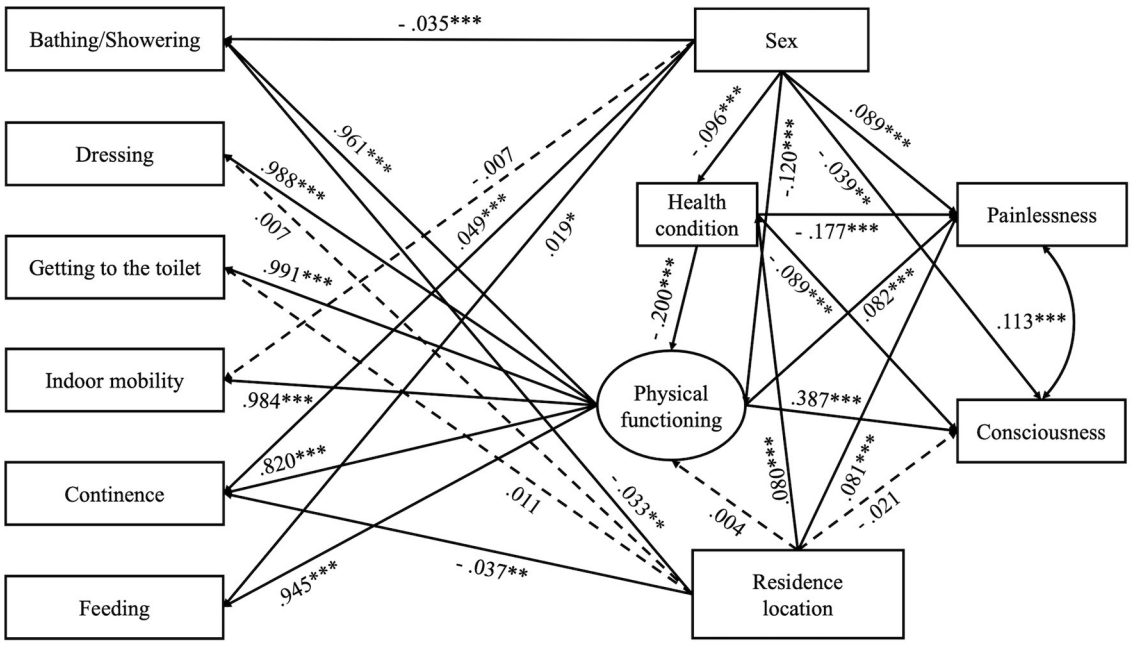

FIGURE 2
SEM model of associations between life prior to death and quality of death based on gender and residence location. All slope coefficients presented are standardized estimates, *$p < 0.05$, **$p < 0.01$, *** $p < 0.001$. χ^2 (df) = 293.502 (26), $p < 0.001$; CFI = 0.999; TLI = 0.999; RMSEA = 0.033, 90% CI: [0.029, 0.036]; SRMR = 0.015.

only improved women's physical functioning trivially ($|\beta| = 0.019$, $p < 0.001$). Given men's initial relatively pronounced advantage in functioning ($|\beta| = 0.120$, $p < 0.001$), women still functioned worse than men ($|\beta| = 0.101$, $p < 0.001$). These sex disparities indirectly impacted the quality of death: older women were less painful than men at death ($|\beta| = 0.098$, $p < 0.001$); yet men more often remained conscious ($|\beta| = 0.069$, $p < 0.001$).

Compared to sex, residence location played a much lesser role during end-of-life. The rural dwellers appeared healthier ($|\beta| = 0.080$, $p < 0.001$), which indirectly enhanced their functional capacities ($|\beta| = 0.016$, $p < 0.001$). However, location did not influence physical function directly ($|\beta| = 0.004$, $p = 0.778$). On death quality, location had both direct and indirect effects regarding pain: rural residents were more prone to painful deaths than urban settlers ($|\beta| = 0.081$, $p < 0.001$), but the former's better health marginally alleviated that effect to $|\beta| = 0.066$ ($p < 0.001$) because freedom from diseases marginally enhanced physical functioning, thereby relieving pain. Location did not directly affect consciousness when dying ($|\beta| = 0.021$, $p = 0.103$), but given its impact on morbidity, as well as morbidity's effect on functional limitations ($|\beta| = 0.012$, $p = 0.028$), deaths in villages were slightly more associated with consciousness ($|\beta| = 0.033$, $p = 0.012$).

Discussion

The current research was among the first known retrospective study investigating associations between life prior to death and quality of death based on sex and residence location among older Chinese. It was found that almost 40% of the deceased were reported to be painful or unconscious at death. High-quality deaths (being painless and conscious) were associated with freedom from chronic diseases and enhanced physical functioning during the final months of survival. In addition, men and women diverged toward end-of-life: older women were healthier than men and thus were less prone to painful deaths, while men functioned much better and thus more often died consciously. Finally, compared to rural residents, the urban ones were at a lower risk of dying in pain, although they tended to be more liable to lose consciousness at death due to morbidity.

First, almost two in every five older individuals in this research died less than satisfactorily, experiencing pain and/or loss of consciousness. Morbidity substantially increased the chances of experiencing pain and unconsciousness when dying, and functional limitations caused by diseases moderately exacerbated such tendencies. Therefore, fundamental and foremost among the potential strategies for improving end-of-life experiences *and* achieving 'a good death' is health

TABLE 4 Parameter estimates for the associations between life prior to death and quality of death.

Parameter	b	$S.E._b$	β	$S.E._\beta$	p
Path coefficient (regression)					
1. PF → B	1.000	0.000	0.961***	0.003	<0.001
2. PF → D	1.745***	0.147	0.988***	0.002	<0.001
3. PF → G	1.999***	0.241	0.991***	0.002	<0.001
4. PF → M	1.507***	0.107	0.984***	0.002	<0.001
5. PF → C	0.385***	0.018	0.820***	0.007	<0.001
6. PF → F	0.771***	0.039	0.945***	0.003	<0.001
7. HC → PF	−0.736***	0.061	−0.200***	0.014	<0.001
8. HC → FP	−0.181***	0.016	−0.177***	0.016	<0.001
9. HC → BC	−0.097***	0.017	−0.089***	0.015	<0.001
10. PF → FP	0.023***	0.005	0.082***	0.017	<0.001
11. PF → BC	0.115***	0.007	0.387***	0.015	<0.001
12. Sex → B	−0.278***	0.068	−0.035***	0.009	<0.001
13. Sex → M	−0.077	0.073	−0.007	0.006	0.292
14. Sex → C	0.172***	0.042	0.049***	0.012	<0.001
15. Sex → F	0.116*	0.055	0.019*	0.009	0.036
16. Sex → HC	−0.196***	0.024	−0.096***	0.012	<0.001
17. Sex → PF	−0.902***	0.108	−0.120***	0.013	<0.001
18. Sex → FP	0.187***	0.028	0.089***	0.013	<0.001
19. Sex → BC	−0.087**	0.030	−0.039**	0.013	0.003
20. Residence location → B	−0.261**	0.079	−0.033**	0.010	0.001
21. Residence location → D	0.093	0.102	0.007	0.008	0.362
22. Residence location → G	0.168	0.107	0.011	0.007	0.112
23. Residence location → C	−0.131**	0.040	−0.037**	0.011	0.001
24. Residence location → HC	0.164***	0.024	0.080***	0.012	<0.001
25. Residence location → PF	0.028	0.098	0.004	0.013	0.778
26. Residence location → FP	0.169***	0.028	0.081***	0.013	<0.001
27. Residence location → BC	−0.047	0.029	−0.021	0.013	0.103
Path coefficient (covariance)					
28. FP ↔ BC	0.113***	0.019	0.113***	0.019	<0.001

SE, standard error; b, unstandardized estimates; β, standardized estimates; B, bath/shower; D, dressing; G, going to toilet; M, indoor mobility; C, continence; F, feeding; HC, health condition; PF, physical functioning; FP, freedom from pain; BC, being conscious.
*$p < 0.05$, **$p < 0.001$, ***$p < 0.001$.

management. After all, reducing morbidity has been proposed as a promising intervening target in successful aging (21, 30). Because most older adults are community-dwelling in China, plausible measures to health management may include offering access to regular, community-based, and low-cost medical consultations and health examinations, as well as preventive home visits (7, 31). Additionally, provided that some older people already live with chronic diseases when facing proximity to death, reliable assistance in ADLs by professionals might be more beneficial to promoting their experiences during end-of-life. These findings on the dynamics of morbidity and functional difficulties, and their separate and joint impacts on death quality, should facilitate China's endeavor to improving its public healthcare reform, which is under strain due to a rapidly aging population. Of course, more research is required to address how community-based medical resources should be effectively utilized by those approaching death and their families, and how its budding end-of-life care services should be adequately developed.

Second, morbidity was moderately less prevalent among older women, which reduced their pain at death compared to men; older men's substantial advantage in physical functioning only mildly increased their likelihood of remaining conscious at death. This finding expounds the nuanced role sex plays given expected proximity to death, thus highlighting the need to consider sex-specific strategies when planning care and support for the aging population in China (13, 30, 32). Evidently, to improve end-of-life experiences, interventions that

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TABLE 5 Direct, indirect, and total effects of life prior to death on quality of death.

Effect	b	$S.E._b$	β	$S.E._\beta$	p
HC → FP					
1. Total	− 0.198***	0.016	−0.194***	0.015	<0.001
2. Direct	− 0.181***	0.016	−0.177***	0.016	<0.001
3. Indirect (HC → PF → FP)	− 0.017***	0.004	−0.016***	0.004	<0.001
HC → BC					
4. Total	− 0.181***	0.017	−0.166***	0.015	<0.001
5. Direct	− 0.097***	0.017	−0.089***	0.015	<0.001
6. Indirect (HC → PF → BC)	− 0.085***	0.007	−0.077***	0.006	<0.001
Sex → PF					
7. Total	− 0.757***	0.106	−0.101***	0.013	<0.001
8. Direct	− 0.902***	0.108	−0.120***	0.013	<0.001
9. Indirect (sex → HC → PF)	0.145***	0.021	0.019***	0.003	<0.001
Sex → FP					
10. Total	0.205***	0.028	0.098***	0.013	<0.001
11. Direct	0.187***	0.028	0.089***	0.013	<0.001
12. Indirect (total)	0.018*	0.007	0.009*	0.004	0.013
13. Indirect (sex → HC → FP)	0.036***	0.005	0.017***	0.003	<0.001
14. Indirect (sex → PF → FP)	− 0.021***	0.005	−0.010***	0.002	<0.001
15. Indirect (sex → HC → PF → FP)	0.003***	0.001	0.002***	0.000	<0.001
Sex → BC					
16. Total	− 0.155***	0.030	−0.069***	0.013	<0.001
17. Direct	−0.087**	0.030	−0.039**	0.013	0.003
18. Indirect (total)	− 0.068***	0.013	−0.030***	0.006	<0.001
19. Indirect (sex → HC → BC)	0.019***	0.004	0.008***	0.002	<0.001
20. Indirect (sex → PF → BC)	− 0.104***	0.012	−0.046***	0.005	<0.001
21. Indirect (sex → HC → PF → BC)	0.017***	0.002	0.007***	0.001	<0.001
Residence location → PF					
22. Total	−0.093	0.098	−0.012	0.013	0.343
23. Direct	0.028	0.098	−0.004	0.013	0.778
24. Indirect (residence location → HC → PF)	− 0.121***	0.020	−0.016***	0.003	<0.001
Residence location → FP					
25. Total	0.137***	0.028	0.066***	0.013	<0.001
26. Direct	0.169***	0.028	0.081***	0.013	<0.001
27. Indirect (total)	− 0.032***	0.006	−0.015***	0.003	<0.001
28. Indirect (residence location → HC → FP)	− 0.030***	0.005	−0.014***	0.002	<0.001
29. Indirect (residence location → PF → FP)	−0.001	0.002	0.000	0.001	0.778
30. Indirect (residence location → HC → PF → FP)	− 0.003***	0.001	−0.001***	0.000	<0.001
Residence location → BC					
31. Total	−0.074*	0.029	−0.033*	0.013	0.012
32. Direct	−0.047	0.029	−0.021	0.013	0.103
33. Indirect (total)	−0.027*	0.012	−0.012*	0.005	0.028
34. Indirect (residence location → HC → BC)	− 0.016***	0.004	−0.007***	0.002	<0.001
35. Indirect (residence location → PF → BC)	0.003	0.011	0.001	0.005	0.778
36. Indirect (residence location → HC → PF → BC)	− 0.014***	0.002	−0.006***	0.001	<0.001

S.E, standard error; b, unstandardized estimates; β, standardized estimates; B, bathing/showering; D, dressing; G, getting to the toilet; M, indoor mobility; C, continence; F, feeding; HC, health condition; PF, physical functioning; FP, freedom from pain; BC, being conscious. *$p < 0.05$, **$p < 0.001$, ***$p < 0.001$.

enhance functional capacity and lower incidence of chronic diseases should be, respectively useful for women and men (12, 20).

Third, using rural-urban residence as a proxy for SES, analyses showed that compared to urban dwellers, rural residents were more prone to painful deaths, although this urban-rural divide was slightly narrowed by rural settlers' relative health. In fact, rural residents' preferable health state also indirectly led to their modest advantage in consciousness at death. These findings should alert policymakers and practitioners to the urban-rural disparities in access to medical resources and end-of-life care services: despite the lower likelihood of reported morbidity in rural areas, the settlers there were still at a higher risk of painful deaths than their peers in cities, suggesting unmet needs for pain management and symptom control among rural residents approaching deaths (30, 33). Furthermore, the government should address their divergent needs when they approach death: the former might require measures and resources to pain and symptom management, and the latter should capitalize on health-enhancing interventions to reduce morbidity (6, 19, 30, 34).

This research had two limitations. First, the study utilized the end-of-life data in the CLHLS, which were confined to participants died between waves. Thereby, the level of representativeness of the sample for the target population (i.e., the deceased older adults across mainland China) was somewhat undetermined with regards to socio-demographic indicators. Nonetheless, the large size of this nationwide, observational sample should suffice to achieve the goal of revealing the mechanisms connecting life prior to death to quality of death. Second, the quality of death was ascertained by only two indicators reported by proxy respondents. Plausible disagreement between surrogate responses and those of the departed could have existed. Furthermore, the proxy respondent's pain evaluation might be subjective, and the decedent's medical history could exert an lingering impact on the proxy's recollections. Future research may adopt a prospective design to resolve this measurement issue. Should prospective studies be conducted by future scholars, it is also vital that they inspect how psychological aspects of older people affect their death quality as they deteriorate and reach proximity to death. Still, this study enhances understandings of how the medical and functional dimensions of life prior to death affected different dimensions of death quality.

In conclusion, this retrospective study found that morbidity (and comorbidity) and impaired physical functioning prior to death would curtail death quality. The finding that the former had a larger potential to increase pain when dying while the latter to reduce consciousness is essential, because it suggests that interventions addressing morbidity should be useful for older people at a higher risk of painful deaths (men and rural residents, for example) and those regarding functioning might be more needed by individuals prone to unconsciousness (such as women and urban dwellers).

Data availability statement

Publicly available data were analyzed in this study. This dataset can be found here: the Peking University Open Access Research Database (https://doi.org/10.18170/DVN/WBO7LK).

Ethics statement

The studies involving human participants were reviewed and approved by the Research Ethics Committee of Duke University (Pro00062871) and the Biomedical Ethics Committee of Peking University (IRB00001052–13074) jointly. The first author signed an online data use agreement to obtain data from the Chinese Longitudinal Healthy Longevity Survey (CLHLS) (accessed from http://opendata.pku.edu.cn/). The patients/participants provided their written informed consent to participate in this study.

Author contributions

JL analyzed the data and wrote the first draft of the paper. LS conceptualized the design and was a major contributor in writing the manuscript. XP assisted in data analysis, the writing of the results and discussion sections, and funding acquisition. ZH assisted in methodology and funding acquisition. All authors contributed to manuscript revision, read, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Self-medication and its typology in Chinese elderly population: A cross-sectional study

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Purpose: This paper aims to evaluate the prevalence of self-medication and its associated factors among the Chinese elderly. Also, according to whether the elderly communicate with doctors (no matter before or after self-medication), we aimed to categorize self-medication and explore the associated factors.

Methods: It was a cross-sectional study. Data were derived from the 2018 wave of the China Health and Retirement Longitudinal Study (CHARLS). According to whether communicate with doctors or not, self-medication was reclassified as "self-medicate and NOT communicating with a doctor," and "self-medicate and communicate with a doctor." A binary logistic regression was used to identify which elderly were more likely to self-medicate, and a multinomial logistic regression was applied to explore the associated influencing factors of self-medication classifications.

Results: A total of 17,445 individuals aged ≥45 years were enrolled. The prevalence of self-medication was 58.60%. Self-medication was strongly associated with sex, education level, pension, self-reported general health status, chronic illness, satisfaction with local medical services, and three province-level socioeconomic welfare variables. About 19.64% of self-medication populations had communicated with a doctor. Higher education level and younger age were significantly associated with a higher probability of "self-medication and communication with a doctor."

Conclusion: The prevalence of self-medication among the Chinese elderly is increasing over the year. Health education on appropriate medication use targeting elder adults with low education levels is highly recommended. The typology of self-medication and its factors are new research entry points and could be meaningful for future studies.

KEYWORDS

self-medication, typology, elderly, China, communication with a doctor, cross-sectional study

Introduction

Self-medication is defined as "the taking of any drug or medication on one's initiative, or on the advice of another person, for self-diagnosed illness without consulting a doctor" (1). It has some pros and cons. Responsible self-medication can not only empower the public to cure minor ailments themselves, but also save time and money (2). However, many people don't have a clear picture of themselves and self-medicate inappropriately (3). What's more, compared to the medications used with health professionals' prescriptions, self-medication to a certain extent is not confirmed concerning pregnancy, use in children and the elderly, interactions, and so on (3). Although controversial, self-medication is still a worldwide phenomenon, and the prevalence varies in different countries around the world. For example, it was 22% in Spain (4) and 35.9% in Ethiopia (5).

In the twenty-first century, population aging has become a global trend due to the development of medical science. The elderly population is growing faster than other age groups (6). In general, people who live longer tend to suffer from multiple chronic diseases and, consequently pay higher costs for health care treatments (7). Moreover, financial distress and limited mobility can make it difficult for the elderly to seek medical care. Therefore, the elderly sometimes resort to self-medication to ameliorate disease symptoms.

Among the elderly, the prevalence of self-medication was reported from 4 to 87%, and the mean prevalence was 38% (8). For instance, 14.3% of Brazilians aged ≥60 years had reported using drugs without prescription during the 15 days before the interview (9). Likewise, a study conducted in Mexico showed that the reported prevalence of self-medication was 53.5% among the elderly aged >65 years during the last 30 days (10). Moreover, socio-demographic variables associated with elderly self-medication were gender (11, 12), marital status (12), an education level (3, 11), and income (3).

In addition to the studies mentioned above, many papers have studied inappropriate self-medication in the elderly (13). For instance, among the Brazilian elderly who practiced self-medication, 55.5% used inappropriate drugs (14). Inappropriate self-medication includes the following ways: (a) Taking the drugs included on the list of potentially inappropriate medications for the elderly (14); (b) Wrong way of taking drugs (e.g., using excessive dosages) (13); (c) Polypharmacy, Non-essential medication (e.g., irrational use of antimicrobials) (13). Inappropriate self-medication may result in the worsening of the disease, drug interaction, drug toxicity, drug dependence, adverse events, microbial resistance, and so on (15). These inappropriate medication ways are often derived from past medication experiences. So, do the elderly have no communication with doctors before or after self-medication? For instance, before self-medication, the elderly may get information from the doctors that they can self-purchase certain medications; or after inappropriate self-medication, the elderly may have to seek medical service due to the worsening condition. However, previously published self-medication studies focused on its prevalence, reasons, and associated factors. Few studies have explored the doctor-patient communication status before or after self-medication.

Therefore, we conducted a cross-sectional study on self-medication among the Chinese elderly. First, we aimed to evaluate the prevalence of self-medication and its associated factors among the Chinese elderly. Second, we tried to explore the doctor-patient communication status before or after self-medication. Then according to whether the elderly communicate with doctors (not matter before or after self-medication), we aimed to categorize self-medication and explore the associated factors.

Methods

Design of the study

This was a cross-sectional study. Its study population was the Chinese elderly aged ≥45 years. First, it described the prevalence of self-medication among the Chinese elderly. Then, Andersen's behavioral model-related variables, lifestyle variables, satisfaction variables, and province-level socioeconomic welfare variables were regarded as the independent variables. The status of self-medication was regarded as the dependent variable. After that, a binary logistic regression was used to identify which elderly were more likely to self-medicate. Second, according to whether the elderly communicate with doctors (not matter before or after self-medication), self-medication was reclassified as "didn't self-medicate," "self-medicate and NOT communicating with a doctor," and "self-medicate and communicate with a doctor." Likewise, a multinomial logistic regression was applied to explore the associated influencing factors of the three classifications.

Data

Data in this study were derived from the 2018 wave of the China Health and Retirement Longitudinal Study (CHARLS). Detailed information on CHARLS can be found on the website http://charls.pku.edu.cn/en/.

Briefly, the CHARLS was a national survey aimed to collect a representative sample of Chinese residents aged ≥45 years to serve the needs of scientific research on the elderly. Its baseline survey was conducted in 2011 and 17,708 individuals aged ≥45 years were nationally recruited from 28 provinces, 150 countries/districts, and 450 villages/urban communities. Then it performed wave 2 in 2013, wave 3 in 2015, and wave 4 in 2018. In

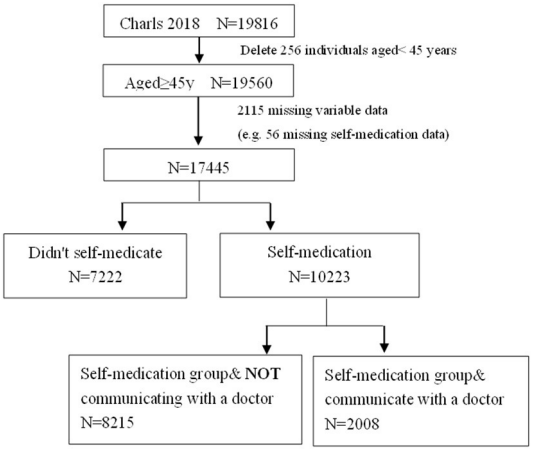

FIGURE 1
Flow chart of participants through the study.

each wave, a face-to-face computer-assisted personal interview was conducted and a detailed questionnaire was finished on each individual. The questionnaire includes the following modules: demographics, family structure, health status, and functioning, health care and insurance, work, retirement and pension, income and consumption, assets (individual and household), biomarkers, and community-level information. More details on the sampling method, the questionnaire, and the database introduction were available from Zhao et al. (16, 17).

As shown in Figure 1, there were a total of 19,816 individuals in the 2018 wave of CHARLS, of which 256 were under 45 years. After deleting the individuals aged <45 years, there were 19,560 individuals aged ≥45 years, of which 2,115 were missing some variable data (e.g., 56 were missing self-medication data and 61 were missing income data). Finally, 17,445 individuals were included in our study.

Measures

Self-medication (Dependent variable)

First, self-medication was the dependent variable of the binary logistic regression. It was measured by the question in the CHARLS questionnaire: (1). Did you take any purchased medicine during the past month? (Not including prescription medications, but any medicine delivered by others or stored by oneself is also counted). Those who answered "Yes" were recognized as self-medication cases.

Second, the self-medication classification was the dependent variable of the multinomial logistic regression. In the questionnaire, there was a question about doctor visits: (2) In the last month have you visited a public hospital, private hospital, public health center, clinic, or health worker's or doctor's practice, or been visited by a health worker or doctor for outpatient care (Not including physical examination)? Combined with the above self-medication question, those who answered "No" to question 1 were recognized as "didn't self-medicate." Those who answered "Yes" to question 1 and "No" to question 2 simultaneously were recognized as "self-medicate and NOT communicating with a doctor." Finally, those who answered "Yes" to question 1 and "Yes" to question 2 simultaneously were recognized as "self-medicate and communicate with a doctor." In this study, "communication with a doctor" means "visiting or consulting a doctor for a medical condition."

Andersen's behavioral model-related variables (independent variables)

Andersen's behavioral model has been widely applied in numerous studies for understanding access to and utilization of health services (18, 19). This model suggests that the use of health services in an individual is determined by three key factors: predisposing, enabling, and need factors.

Predisposing factors usually are socio-demographic variables. In this study, the predisposing factors include age, sex, marital status, Hukou (household registration), and education level. The Hukou system in China was created to modernize and manage rural to urban migration. In this system, individuals could only have one place of regular residence. Then according to the registered place of residence, Hukou is divided into two categories: rural Hukou and urban Hukou (20).

Enabling factors refer to resources that can impede or facilitate the utilization of health services. In this study, the enabling factors include individual income, health insurance, and pension. The individual income was calculated as the sum of the individual's wage, retirement pay, and all sources of subsidies or benefits (e.g., elderly family planning subsidies, unemployment compensation, and so on). Then according to the tertiles of income, subjects were divided into three groups: low, medium, and high-income groups.

Need factors represent the need for health care services and are generally related to health status. In this study, the need factors include self-reported general health status and chronic illness.

Lifestyle and satisfaction variables (independent variables)

Previous studies have shown that smoking and drinking alcohol might affect one's use of health services (21). These two lifestyles are also reported as influencing factors of self-medication behavior (22). Therefore, smoking and alcohol drinking were included in our study. Each included individual was classified as a current smoker or a non-smoker. Those who had quit smoking were regarded as non-smokers. In the

questionnaire, there was a question about alcohol consumption: Did you drink any alcoholic beverages, such as beer, wine, or liquor in the past year? Those who answered "Yes" were identified as current drinkers, otherwise were non-drinkers.

Moreover, several studies had published that dissatisfaction with publicly funded health services was significantly associated with self-medication (23, 24). Therefore, satisfaction with local medical services was added to our independent variables. In the CHARLS questionnaire, individuals were asked about their satisfaction with the quality, cost, and convenience of local medical services. Those who answered "Very satisfied" or "Somewhat satisfied" were regarded as "Satisfied" in our study. Those who answered "Somewhat dissatisfied" or "Very dissatisfied" were regarded as "Dissatisfied." Those who answered "Neutral" remained in the same group.

Province-level socioeconomic welfare variables (independent variables)

Individuals are social actors, residing in social environments that contain different levels of support and resources. Many studies have indicated a key role of social environments in affecting the use of health services (25, 26). Therefore, we planned to add social environment-related variables to this study.

Fortunately, we found an excellent article describing the association between province-level socioeconomic welfare and depression among the Chinese elderly (27). This study also used the 2018 CHARLS data. The research steps of this article are briefly described as follows: (a) Fourteen province-level socioeconomic welfare variables were extracted from the China Civil Affairs Statistical Yearbook for 28 provinces (the same provinces as the CHARLS study). (b) Principal component analysis (PCA) was used to extract three socioeconomic welfare factors constructed from the above 14 province-level variables. (c) These three socioeconomic welfare factors were named economic welfare, social welfare, and medical welfare. (d) A Bayesian mixed-effects logistic model was used to explore the associations between the three socioeconomic welfare factors and depression while controlling for socio-demographic variables. More details of the study can be found in its original text.

In this reference article, the three socioeconomic welfare factor scores for 28 provinces were publicly published and were used as independent variables in our study.

Statistical analysis

The self-medication and its classification were described, and the Chi-square test was used to examine the statistical difference in self-medication status between socio-demographic variables. The multicollinearity between variables was tested. All values of variance inflation factor (VIF) were <10 which indicated no multicollinearity existed. Then, a binary logistic regression was used to identify which elderly were more likely to self-medicate. Also, a multinomial logistic regression was applied to explore the associated influencing factors of the three classifications. The Odds Ratio (OR) and its 95% confidence interval (95%CI) were calculated.

All statistical tests were 2-sided, and P <0.05 were considered statistically significant. Data were statistically analyzed using STATA version 14.0 (STATA Corp, College Station, Texas).

Results

A total of 17,445 individuals aged ≥45 years were enrolled in this study, including 10,223 (58.60%) who reported self-medication during the past month.

Self-medication and its associated factors

As shown in Table 1, the results of the Chi-square test indicated that the distribution of self-medication prevalence was different according to various independent variables. For the predisposing factors, a higher proportion of female, older individuals had reported self-medication (both $P < 0.001$). Concerning the enabling factors, those with middle income ($P < 0.001$), having pension ($P = 0.002$) or health insurance ($P = 0.042$) seemed to have a higher prevalence of self-medication. As for the need factors, individuals with poor health status and more chronic diseases tend to self-medicate more frequently. Moreover, individuals without habits of smoking and alcohol drinking reported a higher rate of self-medication (both $P < 0.001$). Also, a higher prevalence was observed among individuals who were dissatisfied with the local medical services ($P < 0.001$).

Using the binary logistic regression, the associations between factors and self-medication were also analyzed in Table 1. First, the female elderly were more likely to self-medicate than the male elderly (OR = 1.15, 95% confidence interval = 1.06–1.25). Second, compared with the illiterate individuals, those with middle school education levels were markedly associated with higher odds of reporting self-medication [OR (95%CI) = 1.13 (1.01–1.26)]. Third, individuals with a pension or more chronic diseases would report a notably higher rate of self-medication. Fourth, lower odds of self-medication were observed among individuals with better self-reported health status and more satisfaction with local medical services. Fifth, as for the province-level socioeconomic welfare variables, we found increasing economic welfare and social welfare were significantly associated with a lower probability of self-medication [OR (95%CI) = 0.78 (0.74–0.83); OR (95%CI) = 0.82(0.78–0.85)], while medical

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TABLE 1 Associations between factors and self-medication among elder Chinese, 2018 (*N*, %).

Factors	All sample ($N = 17,445$)	Didn't self-medicate	Self-medication group	OR (95%CI)[a]
Sex				
Male	8,273	3,600 (43.52)	4,673 (56.48)	Reference
Female	9,172	3,622 (39.49)	5,550 (60.51)	1.15 (1.06–1.25)**
Age group				
45–59	7,727	3,442 (44.55)	4,285 (55.45)	Reference
60–74	7,793	3,063 (39.30)	4,730 (60.70)	0.99 (0.91–1.07)
75+	1,925	717 (37.25)	1,208 (62.75)	1.08 (0.95–1.22)
Marital status				
Married	15,029	6,261 (41.66)	8,768 (58.34)	Reference
Others[b]	2,416	961 (39.78)	1,455 (60.22)	0.93 (0.84–1.02)
Hukou				
Rural resident	13,710	5,725 (41.76)	7,985 (58.24)	Reference
Urban resident	3,735	1,497 (40.08)	2,238 (59.92)	1.05 (0.96–1.15)
Education				
Illiterate	3,753	1,523 (40.58)	2,230 (59.42)	Reference
Elementary school	7,599	3,083 (40.57)	4,516 (59.43)	1.08 (0.99–1.18)
Middle school	3,887	1,629 (41.91)	2,258 (58.09)	1.13 (1.01–1.26)*
High school	1,844	825 (44.74)	1,019 (55.26)	1.01 (0.88–1.16)
College graduate and above	362	162 (44.75)	200 (55.25)	1.12 (0.87–1.44)
Income				
Low	5,937	2,475 (41.69)	3,462 (58.31)	Reference
Middle	5,715	2,152 (37.66)	3,563 (62.34)	1.07 (0.98–1.17)
High	5,793	2,595 (44.80)	3,198 (55.20)	0.99 (0.90–1.08)
Pension				
No	1,866	835 (44.75)	1,031 (55.25)	Reference
Yes	15,579	6,387 (41.00)	9,192 (59.00)	1.11 (1.00–1.24)*
Health insurance				
No	493	226 (45.84)	267 (54.16)	Reference
Yes	16,952	6,996 (41.27)	9,956 (58.73)	1.13 (0.93–1.37)
Self-reported general health status				
Bad	4,585	1,240 (27.04)	3,345 (72.96)	Reference
Fair	8,551	3,475 (40.64)	5,076 (59.36)	0.69 (0.63–0.75)***
Very good/good	4,309	2,507 (58.18)	1,802 (41.82)	0.43 (0.39–0.48)***
Chronic illness				
None	3,511	2,204 (62.77)	1,307 (37.23)	Reference
1	4,153	2,015 (48.52)	2,138 (51.48)	1.61 (1.46–1.77)***
≥2	9,781	3,003 (30.70)	6,778 (69.30)	2.82 (2.58–3.08)***
Smoke				
No	12,735	5,148 (40.42)	7,587 (59.58)	Reference
Yes	4,710	2,074 (44.03)	2,636 (55.97)	0.99 (0.91–1.08)
Alcohol drinking				
No	11,469	4,588 (40.00)	6,881 (60.00)	Reference
Yes	5,976	2,634 (44.08)	3,342 (55.92)	1.03 (0.95–1.11)
Satisfaction with local medical services				
Dissatisfied	2,861	941 (32.89)	1,920 (67.11)	Reference
Neutral	7,969	3,319 (41.65)	4,650 (58.35)	0.81 (0.73–0.89)***
Satisfied	6,615	2,962 (44.78)	3,653 (55.22)	0.74 (0.67–0.81)***

(Continued)

TABLE 1 (Continued)

Factors	All sample ($N = 17,445$)	Didn't self-medicate	Self-medication group	OR (95%CI)[a]
Economic welfare[c]	17,445	7,222 (41.40)	10,223 (58.60)	0.78 (0.74–0.83)***
Medical welfare[c]	17,445	7,222 (41.40)	10,223 (58.60)	1.08 (1.03–1.13)**
Social welfare[c]	17,445	7,222 (41.40)	10,223 (58.60)	0.82 (0.78–0.85)***

[a]P for logistic regression. *P < 0.05, **P < 0.01, ***P < 0.001.
[b]Include divorced, separated, widowed and single.
[c]Source from the article of Li et al. (27).

facilities were associated with a higher probability of self-medication [OR (95%CI) = 1.08 (1.03–1.13)].

Typology of self-medication and its associated factors

The distribution of self-medication classification was shown in Table 2. According to whether the elderly communicate with doctors during the last month (not matter before or after self-medication), the self-medication was reclassified as "didn't self-medicate," "self-medicate and NOT communicating with a doctor," and "self-medicate and communicate with a doctor." The total number of each group was 7,222 (41.40%), 8215 (47.09), and 2008 (11.51%), respectively. In other words, about 19.64% of self-medication populations had visited a doctor during the same period before the investigation.

We also conducted a multivariate multinomial logistic regression to explore the associated factors. In the regression model, those who didn't self-medicate were regarded as the reference category. Similar results of associated factors were found in both the "self-medicate and NOT communicating with a doctor" group and the "self-medicate and communicate with a doctor" group. For example, female individuals and those with more chronic diseases reported a higher rate of self-medication. Likewise, in both groups, we found those with better self-reported health status and more satisfaction with local medical services were less likely to self-medicate. Economic welfare and social welfare were also significantly associated with a lower probability of self-medication.

However, there were still differences in associated factors between these two self-medication groups. For instance, the regression results revealed that younger age and higher educational level were associated with a higher probability of "self-medication and communication with a doctor." But in the "self-medication and NOT communicating with a doctor" group, a higher odds ratio was found among individuals aged >75 years, and no significant associations were observed with education levels. In addition, middle income and medical welfare were significantly associated with a higher probability of "self-medication and NOT communicating with a doctor." While in the "self-medication and communication with a doctor" group, we couldn't observe similar results.

Discussion

In this study, we found the prevalence of self-medication was 58.60% among the Chinese elderly in 2018. However, using the data derived from CHARLS 2011 and 2013, a published study has reported that the prevalence of self-medication is 32.69% for over-the-counter medicines (OTCs) and 15.02% for prescription-only medicines (POMs) among the Chinese elderly (22). The definition of self-medication in the above-published study is the same as ours. But it divides the self-medicating drugs into OTCs and POMs, and the total prevalence of all drugs' self-medication is not reported. Although the prevalence in our study couldn't be directly compared with that in the published study, we still find the prevalence of 58.60% in 2018 is greater than the sum of prevalence in 2011 and 2013. Therefore, the prevalence of self-medication is increasing among Chinese elderly aged ≥45 years. Under the same definition of self-medication, the prevalence (58.60%) among Chinese elderly is lower than that of Brazilian elderly (68%) (28). However, the prevalence of self-medication between China and other countries is still hard compared due to the different definitions of self-medication.

In our study, we found that self-medication was strongly associated with several factors such as sex, education level, pension, self-reported general health status, chronic illness, satisfaction with local medical services, and three province-level socioeconomic welfare variables. First, sex and education level are predisposing factors of Andersen's behavioral model. Consistent with previous research (11, 12, 29), the results showed females and those with higher education levels resorted to self-medication more frequently than others. Second, income, pension, and health insurance are enabling factors of Andersen's behavioral model. Several studies have described that people with higher income (3, 30) or without health insurance (11, 31) are more likely to self-medicate. However, no significant associations between income, health insurance, and self-medication were indicated in our study. Third, self-reported general health status and chronic illness are need factors of Andersen's behavioral model. In our study, people with

TABLE 2 Multinomial logistic regression model for influencing factors of self-medication and doctor communication among elder Chinese, 2018 (reference category is the group who didn't self-medicate).

Factors	Didn't self-medicate	Self-medicate & NOT communicating with a doctor		Self-medicate & communicate with a doctor	
	N (%)	*N* (%)	OR (95%CI)[a]	*N* (%)	OR (95%CI)[a]
Sex					
Male	3,600 (43.52)	3,856 (46.61)	Reference	817 (9.87)	Reference
Female	3,622 (39.49)	4,359 (47.53)	1.14 (1.04–1.24)**	1,191 (12.98)	1.21 (1.06–1.39)**
Age group					
45–59	3,442 (44.55)	3,368 (43.59)	Reference	917 (11.86)	Reference
60–74	3,063 (39.30)	3,852 (49.43)	1.03 (0.95–1.12)	878 (11.27)	0.78 (0.69–0.89)***
75+	717 (37.25)	995 (51.69)	1.15 (1.01–1.31)*	213 (11.06)	0.77 (0.63–0.94)*
Marital status					
Married	6,261 (41.66)	7,051 (46.92)	Reference	1,717 (11.42)	Reference
Others[b]	961 (39.78)	1,164 (48.18)	0.92 (0.83–1.02)	291 (12.04)	0.95 (0.81–1.11)
Hukou					
Rural resident	5,725 (41.76)	6,429 (46.89)	Reference	1,556 (11.35)	Reference
Urban resident	1,497 (40.08)	1,786 (47.82)	1.04 (0.94–1.14)	452 (12.10)	1.12 (0.96–1.30)
Education					
Illiterate	1,523 (40.58)	1,803 (48.04)	Reference	427 (11.38)	Reference
Elementary school	3,083 (40.57)	3,625 (47.70)	1.06 (0.97–1.16)	891 (11.73)	1.19 (1.03–1.37)*
Middle school	1,629 (41.91)	1,822 (46.87)	1.10 (0.98–1.23)	436 (11.22)	1.29 (1.08–1.54)**
High School	825 (44.74)	810 (43.93)	0.96 (0.83–1.11)	209 (11.33)	1.27 (1.02–1.59)*
College graduate and above	162 (44.75)	155 (42.82)	1.03 (0.79–1.34)	45 (12.43)	1.71 (1.15–2.55)**
Income					
Low	2,475 (41.69)	2,695 (45.39)	Reference	767 (12.92)	Reference
Middle	2,152 (37.66)	2,908 (50.88)	1.10 (1.00–1.21)*	655 (11.46)	0.97 (0.84–1.12)
High	2,595 (44.80)	2,612 (45.09)	1.01 (0.92–1.11)	586 (10.11)	0.90 (0.77–1.04)
Pension					
No	835 (44.75)	834 (44.69)	Reference	197 (10.56)	Reference
Yes	6,387 (41.00)	7,381 (47.38)	1.11 (0.99–1.24)	1,811 (11.62)	1.13 (0.95–1.35)
Health insurance	226 (45.84)	220 (44.62)	Reference	47 (9.53)	Reference
No					
Yes	6,996 (41.27)	7,995 (47.16)	1.11 (0.91–1.36)	1,961 (11.57)	1.21 (0.86–1.70)

(Continued)

TABLE 2 (Continued)

Factors	Didn't self-medicate	Self-medicate & NOT communicating with a doctor		Self-medicate & communicate with a doctor	
	N (%)	*N* (%)	OR (95%CI)[a]	*N* (%)	OR (95%CI)[a]
Self-reported general health status					
Bad	1,240 (27.04)	2,423 (52.85)	Reference	922 (20.11)	Reference
Fair	3,475 (40.64)	4,173 (48.80)	0.77 (0.70–0.84)***	903 (10.56)	0.47 (0.42–0.53)***
Very good/good	2,507 (58.18)	1,619 (37.57)	0.52 (0.47–0.58)***	183 (4.25)	0.18 (0.15–0.22)***
Chronic illness					
No chronic disease	2,204 (62.77)	1,170 (33.33)	Reference	137 (3.90)	Reference
One chronic disease	2,015 (48.52)	1,828 (44.02)	1.56 (1.41–1.72)***	310 (7.46)	2.07 (1.67–2.56)***
Two chronic diseases and more	3,003 (30.70)	5,217 (53.34)	2.54 (2.32–2.78)***	1,561 (15.96)	5.07 (4.18–6.16)***
Smoke					
No	5,148 (40.42)	5,984 (46.99)	Reference	1,603 (12.59)	Reference
Yes	2,074 (44.03)	2,231 (47.37)	1.03 (0.95–1.13)	405 (8.60)	0.79 (0.68–0.91)**
Alcohol drinking					
No	4,588 (40.00)	5,427 (47.32)	Reference	1,454 (12.68)	Reference
Yes	2,634 (44.08)	2,788 (46.65)	1.05 (0.97–1.13)	554 (9.27)	0.93 (0.82–1.06)
Satisfaction with local medical services					
Dissatisfied	941 (32.89)	1,488 (52.01)	Reference	432 (15.10)	Reference
Neutral	3,319 (41.65)	3,756 (47.13)	0.83 (0.75–0.91)***	894 (11.22)	0.73 (0.64–0.85)***
Satisfied	2,962 (44.78)	2,971 (44.91)	0.75 (0.68–0.83)***	682 (10.31)	0.68 (0.59–0.79)***
Economic welfare[c]	7,222 (41.40)	8,215 (47.09)	0.78 (0.73–0.83)***	2,008 (11.51)	0.78 (0.71–0.87)***
Medical welfare[c]	7,222 (41.40)	8,215 (47.09)	1.08 (1.03–1.14)**	2,008 (11.51)	1.07 (0.99–1.15)
Social welfare[c]	7,222 (41.40)	8,215 (47.09)	0.81 (0.78–0.84)***	2,008 (11.51)	0.85 (0.79–0.91)***

[a]P for logistic regression.*P < 0.05, **P < 0.01, ***P < 0.001.
[b]Include divorced, separated, widowed and single.
[c]Source from the article of Li et al. (27).

worse self-reported health status or more chronic diseases were reported to be more likely to self-medicate, and this finding was consistent with other studies (32). There might be two explanations: One is that people with poor health status may have limited mobility, making it difficult to see a doctor. They have to self-medicate to ameliorate disease symptoms. The other is that the people with more diseases may have more experience in treatment, and try to self-medicate for old weaknesses. They see no need for visiting a doctor. Fourth, people who are more satisfied with local medical services are more likely to use medical treatment rather than self-medication. Fifth, negative associations were detected between economic welfare, social welfare, and self-medication in our study. Generally speaking, the better the economic welfare and social welfare in an area, the more convenient the transportation and the more developed the informatization. Therefore, it is convenient to seek medical treatment rather than self-medicating. While better medical welfare means more hospitals are available, there

are also more pharmacies and more ways to buy medicines. In addition, high-quality medical resources will attract more seriously ill patients from other areas. For common minor problems, local people may be more willing to go to the pharmacy to buy medicine, rather than crowding the hospital to see a doctor.

Most of the influencing factors of the two self-medication classifications were basically the same. Two obvious differences were: (a) education was significantly associated with "self-medication and communication with a doctor," not with "self-medication and NOT communicating with a doctor." (b) Older people were more likely to "self-medicate and NOT communicate with a doctor," while younger people were more likely to "self-medicate and communicate with a doctor." In other words, individuals with younger ages and higher education levels were more frequently communicating with a doctor no matter before or after self-medication. There are two possible explanations for these differences: (a) Individuals with younger age and higher education levels generally have better communication skills than those with older or lower education levels. They are better able to explain themselves to their doctors if they had problems before and after self-medication. (b) Individuals with younger age and higher education levels are more capable of deciding about their own health-related needs (4, 33). Once they have problems derived from self-medication, they can decide more quickly whether to seek a doctor's help than those who are older or less educated.

The strength of our study is the large national sample used, which ensures the representativeness of the sample and sufficient statistical power. We have included many reasonable factors to find out which are the best predictors for self-medication. Most important of all, we have explored the relationship between self-medication and doctor communication, and also reclassified self-medication according to whether the elderly communicate with doctors (not matter before or after self-medication). This is the first study on self-medication and doctor communication among the Chinese elderly. Nevertheless, the study has several limitations. First, it is a cross-sectional study and the observed associations may not be causal. Second, due to the limited information provided by the questionnaire, we cannot know why and when the patients communicated with their doctors. In other words, we cannot know whether self-medication occurred before or after doctor communication. Third, information about drugs and their sources for self-medication, and reasons for self-medication are not collected in our study.

Conclusion

In summary, the prevalence of self-medication was 58.60% among the Chinese elderly and was increasing over the years. Self-medication was strongly associated with several factors such as sex, education level, pension, self-reported general health status, chronic illness, satisfaction with local medical services, and three province-level socioeconomic welfare variables. Moreover, about 19.64% of self-medication populations had communicated with a doctor. Higher education level and younger age were significantly associated with a higher probability of "self-medication and communication with a doctor."

These findings can provide theoretical bases for self-medication studies. Previously published self-medication studies focused on its prevalence, reasons, and associated factors. Few studies have explored the doctor-patient communication status before or after self-medication. In this study, self-medication was classified according to whether communicate with a doctor or not. Education and age were also found associated with "self-medication and communication with a doctor." These discoveries are novel, and we believe the typology of self-medication and its factors are new research entry points and could be meaningful for future self-medication studies, as well as doctor-patient communication studies.

Moreover, our findings have important health policy implications for China. Health education on appropriate medication use targeting elder adults with low education levels is highly recommended. Local economic welfare, social welfare, and people's satisfaction with local medical services should be improved, which will help reduce the prevalence of self-medication. In pharmacies, stricter implementation of prescription-only regulations should be enforced to reduce the source of self-medication. The prevalence of "self-medication and communication with a doctor" was not low in our study, suggesting that self-medication-related problems (e.g., adverse events, inappropriate drug use) should be paid attention to.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: The datasets 2018 Charls for this study in a public database, and can be found on the website http://charls.pku.edu.cn/en/.

Ethics statement

Ethical approval for human participation in the CHARLS project was granted from the Institutional Review Board at Peking University. The participants provided their written informed consent to participate in the CHARLS survey.

Author contributions

SQ conceived the idea and design of this study. JZ, MZ, and YC further improved the quality of manuscript writing. YD

dealt with data analysis and wrote the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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The effect and mechanism of Internet use on the physical health of the older people—Empirical analysis based on CFPS

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The use of the Internet has a promoting effect on the physical health of the older people. However, previous studies are mostly focused on the perspective of the overall population, or limited to the direct effects, ignoring the exploration of the mechanism of action and the perspective of the older people. Based on the data of the China Family Panel Survey (CFPS) in 2014, 2016, 2018, and 2020, this study found that the use of the Internet has a significant effect on the physical health of the older people, especially among the population groups of females, rural residents, and those living in central and western regions of China. In addition, this study also found that the use of the Internet by the older people can increase their exercise frequency, thereby improving their physical health. Therefore, to promote active aging, this study proposes to further increase the popularity of the Internet among the older people, encourage the introduction of age-appropriate Internet systems and sports facilities, create an online fitness platform for the older people, and promote scientific fitness programs for them.

KEYWORDS

Internet use, the older people, physical health, physical exercise, mediation effect

Introduction

Since the 21st century, the growth of the aging population has become an increasingly prominent challenge in countries around the world, and it is expected that the population aged 60 and above will reach 25% by the middle of this century (1). The WHO pointed out that the global population aged 60 and over was 1 billion in 2019, and will grow to 2.1 billion by 2050, where a more significant increase would be found in developing countries (2). Taking China as an example, as of November 2021, its population aged 60 and above reached 264 million, accounting for 18.70% of the total volume, an increase of 5.44% over 2010. Among them, the number of people aged 65 and above reached 191 million, an increase of 4.63% over 2010 (3). With the increase of age, the immune function of the human body weakens, and the prevalence of chronic diseases, comorbidities,

and other basic diseases gradually increases. During the COVID-19 epidemic, most critically ill patients are older people, and their susceptibility to diseases may often lead to increasingly severe health conditions. In less-developed areas, a shortage of advanced medical service facilities, national fitness venues, and social security measures jeopardizes the effort to improve the physical health of the older people. Therefore, the Chinese government has continuously increased its emphasis on the health of the older people and has issued relevant policies to promote the health care consumption of the older people (4).

Simultaneous with the aging process of the population is the rapid development of the Internet industry. So far, the popularity of the Internet in countries around the world is on the rise. Many studies have found that the number of "silver surfers" is increasing in countries and regions such as the United States and Europe due to the enormous benefits of the Internet for aging populations (5). For example, the Internet can help the older people strengthen their social connections while increasing their offline leisure and recreational activities at the same time (6). Therefore, many countries advocated the construction of age-appropriate venues, facilities, and equipment using sports intelligence and Internet technology to facilitate the older people's participation in sports, hence helping them to be healthy and achieve active aging (7). It can be seen that the Internet is closely related to the daily life of the older people. It is not only a guarantee to meet their basic living needs in the information age, but also an important way to promote their physical health and improve their quality of life.

Therefore, this study focuses on the older people and uses the micro-panel data of China Family Panel Studies (CFPS) in 2014, 2016, 2018, and 2020 to analyze the impact of Internet use on the physical health of the older people. This study aims to: (1) explore whether there is a relationship between Internet use and the physical health of the older people; (2) if so, determine the direction of the relationship; (3) verify the relationship between exercise behavior and the physical health of the older people.

Literature review

The continuous advancement of the "Internet +" action has brought a huge impact on the lives of residents. In an aging society, the increased use of the Internet has provided technical and informative sources for the older people to maintain a healthy physical state. The WHO classifies people aged 60 and above as the older people (8). Most studies show that the most frequent use of the Internet in the older people group is among those between the ages of 60 and 70 (9, 10). In addition, factors such as occupation, education, and family economic status before retirement will also affect the frequency of using the Internet (11). In the existing research, few scholars directly correlate Internet use with the physical health of the older people in China. Usually, the physical health of the older people is used as a mediator or moderator to study the impact of Internet use on mental health (11), social participation (12), and subjective wellbeing of the older people (13). In related research, domestic and foreign scholars mostly study the impact of Internet use on the health of the older people from the perspectives of sociology and psychology. Consequently, two major views have been formed, namely the "network gain effect theory", which believes that Internet use has a positive impact on the health of the older people; and the "presence substitution effect theory", which believes that Internet use has no significant relationship with the health of the older people, and may even have a negative impact (14).

First, in the "network gain effect theory", some scholars found that older people may acquire knowledge of disease prevention and health care through online publications *via* channels such as WeChat, which is helpful to improve their health level (15, 16). Jiang and Chen (17) used the physical and mental health of the older people as a mediating variable and proved its positive mediating utility in the impact of Internet use on the subjective wellbeing of the older people. Moreover, it has also been confirmed that the health level of the older people who use the Internet to obtain health information is significantly higher than those who do not use the Internet (17). Lv et al. (18) found that the use of the Internet can also improve the physical health of the older people, thereby promoting their employment and social participation (18). Thus, the Internet is a conducive tool to fully leverage the human capital of the older people, relieving the social pension pressure.

Second, in the "presence substitution effect theory", some scholars pointed out that Internet technology will occupy the social and outdoor sports duration of the older people, narrow the social network of the older people, and form bad living habits, which is not conducive to the physical health of the older people (19). He and Yan used the Probit model to analyze the data of the China Longitudinal Aging Social Survey (CLASS) and found that the Internet has isolated the older people from the community, replacing the offline participation of the older people in community sports and entertainment activities (20). Taken together, the two effect theories correspond to the two development paths of an aging society in the Internet era. Based on this, this study proposes a set of competing hypotheses:

H1a: The physical health level of the older people who use the Internet is significantly higher than those who do not use the Internet.

H1b: The physical health level of the older people who use the Internet is significantly lower than those who do not use the Internet.

In fact, there are still prominent problems such as urban-rural differences and unbalanced regional development in

China, which may lead to a certain degree of heterogeneity in the use of the Internet by the older people. In addition, the social characteristics of the older people themselves also have a certain degree of heterogeneity. For example, because women are more accustomed to using the Internet for shopping or socializing, the Internet has a significantly higher inhibitory effect on rural women's sports participation behavior than men, and has a more significant inhibitory effect on women's physical health (21). Differences in areas such as urban-rural gap, physical conditions, incomes, and social status also cause the divergence in data gathered among the older people (22). Therefore, this study proposes the second research hypothesis:

H2: The use of the Internet has different effects on the physical health of the older people living in different regions, with different household registrations and genders.

Existing research shows that whether it is through social networking, media publicity, popular science APPs, or traditional websites, the information acquired will have an impact on the old people's participation in physical exercise (15). The main mechanism is that the older people can obtain medical, health care, and other related knowledge from different channels through the use of the Internet. Therefore, when they are not sick or suffering from chronic diseases, they may participate more in physical activities in the community, squares, and so on for their physical health. Wang et al. used the data from the Chinese General Social Survey (CGSS) in 2017 and used a logistic model to find that Internet use significantly promoted both the frequency and intensity of exercise among the older people (23). Relevant foreign studies also pointed out that the older people who use the Internet demonstrate a higher frequency of active exercise. In poverty-stricken areas, this conclusion is even more obvious, and the inequality between the two group is even more severe as the older people who do not use the Internet have a stronger sense of loneliness and a higher degree of social isolation (24). Therefore, based on Hypothesis 1, to further explore the impact mechanism of Internet use on the physical health of the older people, this study introduces the mediating variable of physical exercise to study its mediating mechanism, and proposes the third research hypothesis:

H3: The use of the Internet can promote physical activity in the older people, which in turn affects their physical health.

Although this study suggests that physical activity may be a mediator of the effects of Internet use on the physical health of the older people, we believe that such a factor may not be sufficient to explain all the differences in the effects. That is, in addition to physical exercise, there may be other mediating variables at the same time. Therefore, this study only attempts to explore the role of physical exercise as an intermediary variable from an exploratory perspective.

Materials and methods

Data sources

The research data in this paper comes from the China Family Panel Studies (CFPS) database (Data access online: http://www.isss.pku.edu.cn/cfps/). CFPS collects data from three dimensions: individual, family, and community, and adopts various forms of questionnaires such as long, short, pick-up, and telephone interviews, aiming to reflect the development and changes in China's society, economy, population, health and education. To maintain the period of the data and the consistency of variables, this study used the survey data of 2014, 2016, 2018, and 2020 with high similarity in the questionnaires. In this study, the samples aged 60 and above were screened, and after excluding the samples with severe missing variables, the total number of samples included in this analysis was 32,947, where the numbers of valid samples in 2014, 2016, 2018 and 2020 are 8,414, 9,113, 9,251, and 6,169, respectively. All results in this study were calculated by Stata software.

Variable selection

Dependent variable

This study leveraged the method of Du and Wang by using self-rated health status to measure health level (14), and the selected dependent variable is the self-rated health status of the older people. The question in the questionnaire is "How do you think your health is?", the answer to the question ranges from "very healthy" to "very unhealthy", at the rate of 1–5. As shown in Table 1, the average self-assessed physical health of the older people is 3.587, indicating that more older people are in a "relatively healthy" state. In 2014, 2016, 2018, and 2020, the self-assessed physical health status of the older people was 3.60, 3.65, 3.59, and 3.49, respectively, showing that the physical health status of the older people is getting better.

Independent variable

The core independent variable of this study is whether to use the Internet, including mobile Internet access and computer Internet access. The descriptive statistics in Table 1 show that the proportion of the older people who use the Internet is relatively low, only 10.1%. Figure 1 shows that the Internet usage rate of the older people has increased significantly in recent years, an increase of 19%, and the increase in males is even greater, from 0.05 to 0.25, an increase of 20%. In the robustness test, this study selects four variables: spare time online, the importance of the Internet, the importance of using the Internet to learn, and the importance of using the Internet to socialize as independent variables to verify the robustness of the model in this study.

TABLE 1 Descriptive statistical results of key variables.

Categories	Variables	Coding values	Mean	SD
Dependent variable	Self-rated health status	Measured on a scale of 1 (very healthy) to 5 (very unhealthy)	3.587	1.216
Independent variable	Internet use	Use = 1, not use = 0	0.101	0.301
Mediating variable	Exercise frequency		3.728	3.689
Controlled variables				
Social characteristics	Gender	Male = 1, female = 0	0.488	0.500
	Age	Measured in years	69.341	7.395
	Marital status	Married = 1, unmarried = 0	0.987	0.112
	Education	Measured in years	4.566	4.510
	Family count	The number of family members living together	2.842	3.971
	Political status	Communists = 1, non- Communists = 0	0.004	0.345
	Subjective social status	Measured on a scale of 1 (low) to 5 (high)	3.231	1.134
Economic characteristics	Family medical expenditure	Take logarithm	7.869	1.452
	Subjective economic income status	Measured on a scale of 1 (low) to 5 (high)	2.551	1.428
	Subjective wellbeing	Measured on a scale of 0 (low) to 10 (high)	3.194	7.315
Regional characteristics	Urban	Urban = 1, rural = 0	0.472	0.499
	Economic area	Eastern region = 1, Central region = 2, North-eastern region = 3, Western region = 4	2.340	1.205

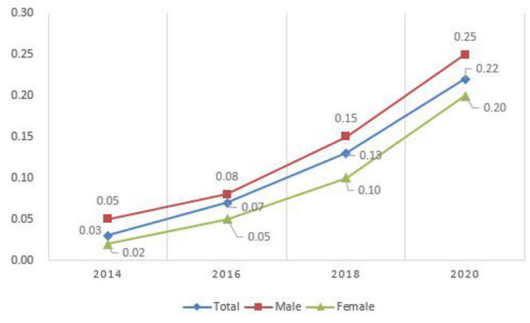

FIGURE 1
Changing trend of Internet usage frequency among the elderly.

Controlled variables

This study refers to the existing literature and selects control variables from three aspects: social, economic, and regional. Among them, the personal social characteristics include gender, age, marital status, education, political status, and subjective social status, a total of seven variables. Of all the samples enrolled, female older people account for 48.77%, which is slightly lower than that of male older people; the average age of the older people is about 69 years old, and the majority of the relatively younger ones in the group are between 60 and 70 years old; the average number of years of education for the older people is about 5 years; The number of Communist Party members is significantly lower than that of non-party members. The economic characteristics mainly include family medical expenditure, individual subjective economic income status and subjective wellbeing. The data shows that most of the older people enrolled believe that their economic income is among average level, and the proportion of those who scored 3 is 37.66%, which is much higher than other scores. The regional characteristics mainly include two variables: urban-rural residence and economic regions. In the 2014–2020 survey, the ratios of older people living in urban areas were 46.58, 47.12, 47.28, and 48.16%, respectively, showing that the number of older people in rural areas is still relatively large, while the number of their peers in urban areas is under significant growth. Meanwhile, according to the division of China's economic zones by the National Bureau of Statistics of China, this study divides the regions into four regions: eastern, central, north-eastern, and western (25). Among them, the eastern region has the largest sample size of older people, accounting for 34.47%, while the northeast region accounts for the least, only 14.60%.

In terms of mediating variables, a large number of studies have pointed out that residents can access and master sports-related knowledge and publicity content through the Internet, thereby stimulating their motivation to participate in sports, that is, the use of the Internet has a significant impact on residents' participation in physical exercise. Therefore, this study refers to the method of Wang et al. (23), and uses the exercise frequency of residents to measure their enthusiasm for physical exercise, and uses it as a mediating variable to explore the impact mechanism of Internet use on the physical health of the older people.

Model construction

In order to examine the impact of Internet use on the health of the older people and its heterogeneity, according to the characteristics of the dependent variable, that is, ordered categorical variables, the ordered logistic regression model (ordered logit) was used to construct the benchmark regression model of this study:

$$\mathbf{Y_i}=\beta_0+\beta_1\mathbf{X_i}+\sum\beta_k\mathbf{Z_{k,i}}+\varepsilon_i \quad (1)$$

Where, Y_i is the explained variable, which represents the subjective health status of the i-th older person. X is an explanatory variable, indicating whether the i-th older person uses the Internet. Z_k ($k = 1 \ldots 11$) is a control variable, including gender, age, marital status, years of education, number of family members, political status, subjective social status, family medical expenditure, subjective economic income status, etc. ε is a random disturbance term, which obeys the Logistic distribution. β_0 is the intercept term, and β_1 and β_k are parameters to be estimated.

Results

Basic regression

Table 2 is based on the 4-year survey data from 2014 to 2020, showing the regression results of whether the use of the Internet affects the physical health of the older people. Column (1) mainly examines the influence of each controlled variable on the dependent variable (self-rated health status). Column (2) introduces the independent variable (Internet use) on the basis of the previous step. Column (3) is the overall regression result after including the mediator variable (exercise frequency). From (1) to (3), there is a slight increase in Pseudo R^2, indicating a certain improvement in the overall fit of the model.

The results in column (1) show that the estimates of the controlled variables are as expected. In terms of personal social characteristics, the physical health level of male older people is higher than that of female older people. In terms of age, there is a significant negative correlation between the age of the older people and their physical health, that is, with the increase of age, their physical health decrease significantly. Older adults with more years of education are healthier than those with less education. Older people with more family members have higher levels of physical fitness than those with relatively few family members. In addition, economic characteristics also showed that at the 1% level, the subjective social and economic status of the older people also had a significant positive correlation with their physical health. In terms of regional characteristics, the physical health of the urban older people are better than that of the rural older people.

TABLE 2 Baseline regression results.

Variables	(1)	(2)	(3)
Internet use		−0.123*** (0.040)	−0.118*** (0.040)
Exercise frequency			−0.027*** (0.004)
Gender	−0.341*** (0.026)	−0.342*** (0.026)	−0.341*** (0.026)
Age	0.013*** (0.002)	0.012*** (0.002)	0.013*** (0.002)
Marital status	−0.229* (0.117)	−0.231** (0.117)	−0.232** (0.117)
Education	−0.023*** (0.003)	−0.021*** (0.003)	−0.018*** (0.003)
Family count	−0.040*** (0.006)	−0.041*** (0.006)	−0.043*** (0.006)
Political status	−0.073** (0.032)	−0.077** (0.032)	−0.064** (0.032)
Subjective social status	−0.035*** (0.013)	−0.036*** (0.013)	−0.034*** (0.013)
Family medical expenditure	0.275*** (0.009)	0.276*** (0.009)	0.277*** (0.009)
Subjective economic income status	−0.130*** (0.010)	−0.130*** (0.010)	−0.128*** (0.010)
Subjective wellbeing	−0.153*** (0.007)	−0.152*** (0.007)	−0.149*** (0.007)
Urban	−0.168*** (0.026)	−0.159*** (0.026)	−0.138*** (0.026)
Year	Controlled	Controlled	Controlled
Economic area	Controlled	Controlled	Controlled
Pseudo R^2	0.037	0.037	0.038
N	22,591	22,591	22,591

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.
Robust standard error for t-statistics in parentheses.

According to the characteristic that the dependent variable is ordinal, this study uses the logit model for estimation. In column (2) of Table 2, it is found that Internet use is significantly positively correlated with the physical health of the older people, and it is significant at the 1% level when the controlled variables are controlled, which validates H1a and rejects H1b. Column (3) shows that after the introduction of exercise frequency, there is also a significant positive correlation between physical exercise and the level of physical fitness of the older people. That is, the higher the frequency of exercise, the higher the level of physical fitness of the older people.

Robustness test

Although the variable "Internet use" is an intuitive indicator to measure the Internet access of the older people through mobile or computer, it cannot reflect the degree of Internet use by the older people due to the nature of the dichotomous variable. For example, it is difficult to measure whether the Internet is used singularly or frequently, or the main purpose of using the Internet. To this end, this study uses questions related to "how important is obtaining information when using the Internet", "how important is learning when using the

TABLE 3 Robustness test results.

Variables	(1)	(2)	(3)
Importance of internet	−0.061*** (0.012)		
Importance of internet to learn		−0.014*** (0.004)	
Importance of internet to socialize			−0.013*** (0.004)
Controlled variables	Controlled	Controlled	Controlled
Year/economic area	Controlled	Controlled	Controlled
Pseudo R^2	0.037	0.037	0.037
N	22,591	22,591	22,591

***$p < 0.01$.
Robust standard error for t-statistics in parentheses.

TABLE 4 Test results of Heckman model.

Variables	First stage (Probit)	Second stage (OLS)
Internet use		−0.496*** (0.060)
Λ		0.230*** (0.035)
_cons	0.282 (0.218)	3.644*** (0.010)
Controlled variables	Controlled	Controlled
Pseudo R^2/rho	0.250	0.191
N	22,593	22,593

***$p < 0.01$.
Robust standard error for t-statistics in parentheses.

Internet", and "how important is social interaction when using the Internet" to replace independent variables. The results in Table 3 show that after replacing the independent variables, the regression results are basically consistent with the benchmark regression. That is to say, the higher the older people emphasize the importance of the Internet and its use in learning or socializing, the more likely they are to have better physical conditions. In conclusion, the above analysis results further show that the model estimation structure of this study has good robustness.

Endogenous test

To eliminate the selection bias of the research sample, this study used the Heckman model for endogeneity treatment. The endogeneity test results are shown in Table 4. The λ in the second-stage OLS model is 0.230, which is significant at the 1% level. It shows the rationality of the Heckman model and that there is indeed a selection bias in the sample of this study. After eliminating the selection bias and addressing the endogeneity problem caused by missing variables, the use of the Internet by the older people still has a significant positive effect on their physical health, which is consistent with the previous verification results. H1a is hence verified again.

Heterogeneity analysis

It can be seen from the foregoing that the influence of Internet use on the physical health of the older people is heterogeneous in terms of gender, urban, and economic area. Therefore, this study conducts heterogeneity analysis from these three aspects. As shown in Table 5, the impact of Internet use on female older people, rural older people, and the older people in the central and western regions is more significant, and all of them are significant at the 5% level. Thus, H2 is partially verified.

The mechanism of internet use on the physical health of the older people

Currently, the mechanism of action between Internet use and the physical health of older adults is unclear. However, physical activity is often considered an important foundation for improving physical health. Therefore, to further explore the issue, this study selected exercise frequency as a mediating variable to verify its mediating mechanism. On the basis of previous research, this study refers to the research ideas of Wang et al. (23), and uses structural equation modeling to verify the mediating effect. Table 6 presents the results of the mediating effect of the frequency of physical exercise among the older people on the impact of Internet use on physical health. The results show that Hypothesis 3 holds.

Figure 2 more clearly shows the positive mediating role of exercise frequency in the process of Internet use affecting the physical health of the older people. The results showed a significant positive correlation between Internet use and exercise frequency. Internet use and exercise frequency were also significantly positively correlated with the physical health status of the older people. The indirect effect of exercise frequency on the physical fitness of the older people was significant at the 1% level, and the effect was about 25%. These results suggest that exercise frequency has a significant mediating effect between Internet use and physical health in the older people, with a mediating effect of 0.048 (a*b), which is significant at the 1% level.

Discussion

Summary

In this study, we used 4 years of CFPS data to examine the impact of Internet use on physical health in older adults

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TABLE 5 Heterogeneity test results.

Variables	Gender		Urban		Economic area			
	(1) Male	(2) Female	(3) Urban	(4) Rural	(5) Eastern	(6) Central	(7) South-eastern	(8) Western
Internet use	−0.054 (0.053)	−0.222*** (0.062)	−0.084* (0.050)	−0.250*** (0.081)	−0.040 (0.063)	−0.272*** (0.081)	−0.053 (0.097)	−0.234** (0.097)
Controlled variables	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Year	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Pseudo R^2	0.036	0.031	0.034	0.039	0.038	0.037	0.046	0.034
N	11,297	11,294	10,628	11,963	7,925	5,569	3,326	5,779

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.
Robust standard error for t-statistics in parentheses.

TABLE 6 Results of the mediating effect of exercise frequency on the influence of Internet use on the physical health of the elderly.

	β	SE	95% CI	*P*-value
Total effect	−0.219	0.024	(−0.262, −0.175)	0.000
Direct effect	−0.171	0.025	(−0.218, −0.128)	0.000
Indirect effect	−0.048	0.004	(−0.058, −0.040)	0.000

Bootstrap sampling times is 500 times.

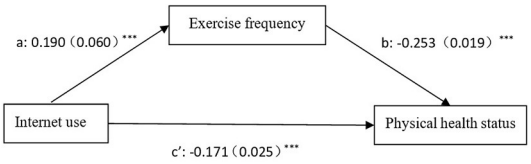

FIGURE 2
Path diagram of the influence of Internet use and exercise frequency on the physical health of the elderly.

by assessing possible heterogeneity and mediating mechanisms. The results show that, under the premise of including control variables, Internet use has a significant effect on the physical health of the older people, which is consistent with some existing research results (11, 22, 23, 26). In terms of controlled variables, the physical health of the older people decreased significantly. This is consistent with the law of human growth (27), because aging is often accompanied by the degradation of bodily functions, such as calcium loss, hearing and visual decline, decreased response ability, and decreased immune resistance of the body. The longer the years of education, the better the health of the older people, and the "happiness effect" of education is gradually highlighted. This may result from the role education plays in boosting people's awareness of scientific exercise and regular lifestyle, and providing theoretical know-how for the improvement of physical health (28). In addition, empty nesters tend to have worse health than those with children and grandchildren around their knees. With the increase in the number of relatives around, the social time and frequency of the older people have increased significantly, and the rich daily life allows the older people to experience the warmth and need of the family, which in turn helps to improve physical and mental health (29). Moreover, social status and economic income are also important factors affecting the health of the older people. The older people with higher economic income and social status have sufficient material security to support their healthy life in their leisure time, such as regular participation in outdoor sports activities and community events (30).

The results of heterogeneity analysis show that the impact of Internet use on the health of the older people varies between genders, urban-rural areas, and economic zones. The health promotion effect of using the Internet on female older people is significantly higher than their male counterparts. The possible reason is that the older people enrolled in this study are a generation who grew up when the whole society had a prevailing "preference for sons", giving the female group a stronger craving for social resources (31). In the new era, this craving has evolved into the acceptance of new things, that is, female older people are more willing to try new things to prove that they have an equal position in social resources. Therefore, in the Internet age, female older people are more willing to obtain information through the Internet, such as health information, shopping information, social information, etc. Under the influence of the national strategy of "Healthy China", the older women's awareness of their health has increased significantly, and their physical health conditions have been effectively improved by actively collecting health-related information. In terms of urban-rural differences, the use of the Internet has a more significant effect on physical health promotion of the rural older people. This may largely result from the dual structure in China where a significant gap can be found in many facets between urban and rural areas for a long time, such as government financial expenditure, Internet penetration level, and infrastructure construction. Boosting the rural older people's access to the benefits of scientific achievements is an

important task in China's poverty alleviation campaign (32). The sample group in this study comes from 2014 to 2020, which coincides with the year in which poverty alleviation was carried out. It shows that with the effort of the government to bring technology into the countryside, the health level of the older people in rural areas has been fully improved due to the influence of the Internet. As for economic zones, the effect of Internet use on the physical health of the older people in the central and western regions is more significant. This may be due to differences in the level of economic development, environmental quality, and urban infrastructure in different regions. As a result, older people living in areas where technologies such as the Internet have developed late have a higher interest in technology and higher expectations (33). Generally speaking, the healthy aging of the older people in the eastern region is better, while the sub-health status of the older people in the central and western regions is more common (34). Therefore, with the spread of the Internet, although the physical health level of the older people in the eastern and north-eastern regions has improved, the improvement rate is relatively low due to their higher overall health level. On the contrary, under the influence of the Internet, the overall health of the older people in central and western regions has been greatly improved through scientific information and methods.

The results of mediation analysis showed that Internet use was positively correlated with physical exercise behavior in the older people, which was consistent with previous research results (21, 35). The Internet helps to broaden the channels for the older people to acquire health knowledge and protect their fitness rights and interests (36). Therefore, the older people can use the Internet to grasp relevant information such as national fitness and scientific fitness. With the continuous participation of the older people in physical activities to strengthen their bodies, whether it is square dance, Tai Chi, jogging, or other forms of aerobic exercise, the physical function of the older people has been improved and physical discomfort has been alleviated (37). This helps to cultivate the fitness awareness of the older people, promote them to become a sports population, and then improve the physical health of the older people.

The difference in the frequency of the older people's participation in outdoor sports will inevitably affect their health. For example, the health benefits of regular outdoor sports for a month are significantly higher than that of a single day, and residents who seldom or never participate in outdoor sports within a year generally have worse physical health (38). This may be because long-term regular exercise is beneficial for the older people to recover after appropriate exercise, and this knowledge can usually be found on the Internet. In general, the physical recovery level of the older people is significantly lower than that of the young. Therefore, the older people who do outdoor exercise every day may not be able to recover the physical function level, which greatly reduces the exercise effect and even has an adverse effect on their health. However, older people who are less active and do not participate in outdoor sports are unable to enjoy the benefits of exercise. This may be because they have not yet learned the benefits of exercise from the Internet, so they lack motivation to help them change their existing habits.

Policy Implication

The conclusions drawn from this study have several important policy implications. First, speed up the popularization of the Internet among the older people in China. According to relevant data, although there are nearly 1 billion Internet users in China, the number of older people using the Internet is still relatively small (21). Therefore, in the context of "Internet +", the infrastructure of the Internet should be strengthened, and the accessibility of the Internet for the older people should be enhanced through publicity lectures, community volunteer services, and family counseling. This measure will help the older people to master the use methods and operating procedures of the Internet, computers, smartphones, etc., and prevent the older people from being isolated by the information society.

Second, encourage the introduction of age-appropriate Internet systems and sports facilities. With the development of an aging society, it is urgent to meet the older people's need for the Internet and sports & fitness from the supply side. On the one hand, on the basis of meeting the needs of the older people to obtain information, socialize, and study, it will simplify the Internet usage process, and launch a special model for the older people in a timely manner to optimize the Internet experience of the older people. On the other hand, a special area for sports for the older people is divided. According to the sports needs of the older people in the region, introduce older people-friendly fitness facilities and fitness equipment, and increase the participation of the older people in physical exercise through simple, convenient and high-safety sports facilities.

Third, through platforms such as TikTok, create an online fitness platform for the older people and promote scientific fitness programs for them. Encourage communities and gyms to work with professional nutritionists to formulate targeted scientific fitness and nutrition programs for the older people with different regions, genders, ages and other characteristics. And build an online fitness platform for the older people through the Internet to provide the older people with convenient, professional and comprehensive exercise guidance, thereby improving the physical health of the older people.

Strengths

This study has several advantages. First, it examines the mediating role of exercise frequency in the relationship

between Internet use and physical fitness in older adults. This not only complements previous research, but provides new evidence for understanding the health status of older adults and the benefits of physical activity. Second, this study uses CFPS data across years to construct panel data to estimate the impact of Internet use on the physical health of older adults. This helps to reflect more comprehensively the physical health of the older people and the changing attitudes toward the Internet. Third, this study uses the Heckman two-stage model, which eliminates the endogeneity problem caused by sample selection bias and ensures the robustness of model estimation.

Limitations

There are still some shortcomings in this study. First, this study only measures the physical health level of the older people from the subjective level, and lacks a description of the objective health level. In the future, we will continue to collect empirical data to further explore the impact of Internet use on the objective physical fitness of the older people. Second, this study only measured the exercise behavior of the older people from in terms of exercise frequency, and lacked the investigation of exercise duration and exercise motivation. In the future, we will continue to expand the research indicators related to exercise behavior for further exploration and interpretation.

Conclusion

With the further development of informatization and aging, the Internet has gradually become an important channel for the older people to obtain information. This study found that Internet use has a promotion effect on the physical health of the older people. Moreover, exercise frequency is an important channel linking Internet use and physical health of the older people, and has a partial mediating effect between the two. Therefore, to support people to age well, we should speed up the popularization of the Internet among the older people, and introduce fitness facilities suitable for aging, so as to provide guarantees for the improvement of the health of the older people.

Data availability statement

The datasets presented in this study are publicly available via the China Family Panel Studies (CFPS) database. Access data online *via* http://www.isss.pku.edu.cn/cfps/. Further queries can be directed to the authors.

Ethics statement

The studies involving human participants were reviewed and approved by Peking University Biomedical Ethics Committee. The patients/participants provided their written informed consent to participate in this study.

Author contributions

EG and ZW: theme. EG: methodology. EG and LL: software. YG: resources. EG and JL: original draft. JL, LL, and ZW: review and editing. ZW: supervision and funding acquisition. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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A qualitative study of health care access among African American older adults in a socio-demographically under-resourced region during the COVID-19 pandemic

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Background: In the U.S., health inequities experienced by the African American community, specifically among those ages 65 and older, have been well-documented in research literature. Alongside the findings regarding disparities in disease prevalence and management, researchers have also highlighted disparities in health care access. Despite recent evidence of health inequities experienced by African Americans during the COVID pandemic, there is little research on the lived experience of this group in this critical time, health care access challenges that may be exacerbated by the pandemic, and the community's outlook for the future in addressing health disparities.

Methods: We conducted a qualitative study of African Americans to gather their perspectives about access to health care, particularly during the COVID-19 pandemic. Study participants consisted of African Americans, ages 50–85 years, who spoke English as their primary language, who resided in one of 17 counties in South Carolina that represent a region of the State known as the corridor of economic disadvantage.

Results: Forty-seven telephone interviews were conducted. While research has shown that certain populations experienced health care access disparities during the early COVID pandemic, these disparities did not appear to be exacerbated in our sample. However, participants noted an increase in the use of telehealth, and identified challenges to using this technology. Participants made recommendations about how to address disparities in health care access in their communities.

Conclusion: Our qualitative approach was useful in obtaining perspectives about access to health care during the COVID-19 pandemic from African American older adults. Continued research with older African Americans, particularly those in under-resourced communities are warranted to further elucidate these findings.

KEYWORDS

health care access, African American, COVID-19, older adult, health disparities

Introduction

In the U.S., health inequities among African Americans, specifically among those ages 65 and older, have been well documented in research literature. For instance, African Americans have higher rates of chronic disease such as high LDL cholesterol, heart disease, and diabetes (1–3) compared to others of different racial and ethnic backgrounds. These preexisting conditions are more saturated among, and less likely to be effectively managed by, African Americans (2, 4) compared to other racial and ethnic groups. This has resulted in higher death tolls, lower quality of life, and lower life expectancies for older African Americans (5). The most enduring primary contributing factor to the avoidable differences in health outcomes experienced by this community is socioeconomic status.

Alongside the findings regarding disparities in disease prevalence and management, research has also revealed disparities in health care access (2, 6). The causes of health care access disparities are multifaceted and include social and economically driven factors such as intersectionality, health insurance coverage and affordability, geography, educational level, housing conditions, and lack of adequate guidance about how to navigate the health care system (7). According to the growing body of literature that has emerged since the start of the COVID-19 pandemic, many health care disparities have been reinforced, and others have become even more substantial (8–10). The sections that follow briefly review the literature on intersectionality and health insurance coverage to delineate some of the challenges in health care access among African Americans.

Intersectionality

Intersectionality helps in understanding how "multiple social identities…intersect to reflect interlocking systems of privilege and oppression at the macro social-structural level" (11). In this instance, identifying as both an older adult and an African American are the relevant social identities. These characteristics have been two of the most salient risk factors for contracting COVID-19 in the U.S. According to the CDC, persons aged 65 and older have a greater chance of both contracting and dying from the virus compared to other age groups. Over 81% of COVID-19 deaths are associated with persons ages 65 and older with preexisting conditions (12). Furthermore, African Americans not only contract the virus at more alarming rates, but also suffer more negative health outcomes from the pandemic compared to their White counterparts (3). African Americans suffer hospitalization and death at almost double the rates of persons of other racial groups (13).

Three factors have been found to contribute to adverse health outcomes in the older African American population during the COVID-19 pandemic: risk of exposure, the weathering processes, and health care access and quality. This population has a higher risk of exposure due to living in multigenerational households and their employment conditions (e.g., jobs that frequently interface with the public). Over 41% of African Americans work front-line jobs in low-income and under-resourced neighborhoods. This population also has high instances of older family members living within the home, increasing exposure risks (14). Weathering processes refer to the phenomenon of premature biological aging due to exposure to social adversity such as racism (15). Racism-related stressors are correlated with increased activity in the sympathetic nervous symptom, a finding which is correlated with higher instances of increased blood pressure in African Americans (15). Lastly, research has shown that inequality in health care access and quality further exacerbate African American health and wellbeing (2, 6, 16–18). Addressing these inequities will help to mitigate the impact of COVID-19 on marginalized groups.

Health insurance coverage

According to 2019 South Carolina Behavioral Risk Factor Surveillance Survey (SCBRFSS) data collected from those aged 50 years and above, non-Hispanic White persons were more likely to report health care coverage (94 vs. 90%) and that they had one person they thought of as their personal health care provider (92 vs. 89%) compared to non-Hispanic Black persons. White persons were less likely to report that they needed to see a doctor in the past 12 months but could not because of cost (8.8 vs. 14%) compared to Black persons. However, non-Hispanic Black persons were more likely to report they had received a checkup from a doctor in the past 12 months (93.8%) compared to non-Hispanic White persons (89.2%) (19). When considering the additional impact of COVID-19, economic hardship, co-morbidities, and challenges with visiting health care providers (e.g., shuttered doors, fear of contracting COVID, telehealth inconsistencies, etc…) worsened access to care for older adults, particularly African Americans, and persons with geographic barriers that made getting to the doctor difficult (15, 20, 21).

Despite recent evidence of health inequities experienced by African Americans during the COVID pandemic, there is little research on the lived experience of this group in this critical time, any health care access challenges that may be exacerbated by the pandemic, and the community's outlook for the future in addressing health disparities. Research on the extent of testing and vaccine disparity has been rich; however, research regarding the community's perspective about fundamental causes of disparities has been limited (18). To address this gap, we conducted a qualitative study of older African American

adults to gather their perspectives about access to health care, particularly during the COVID-19 pandemic.

Method

Study Participants

The rigor of qualitative methods such as those used in our study has been well established (22, 23). The key principles of qualitative analysis promote the use of systematic methods to ensure rigor and quality of the approach and thus validity and meaningfulness of study findings. As described below, we adhered to these principles in our study. We conducted interviews with African American older adults about factors that contribute to health disparities, their perceptions of selected health disparities, and potential strategies to address the disparities. A particular focus of these interviews was given to participants' perspectives about access to health care during the COVID pandemic which is the focus of this paper. Study participants consisted of African Americans, ages 50–uth Carolina that represent a region of the State known as the corridor of economic disadvantage. This rural and underserved region of the State has historically been poorly resourced, is economically distressed (i.e., low income, high unemployment, and high poverty), and has under-resourced schools resulting in low educational attainment. This toxic combination of factors yields significant health disparities among this population.

Recruitment strategy

A local marketing research group managed participant recruitment. In order to access the population, an e-mail blast was distributed to over 180 African Americans in the firm's databases whose profiles suggested they lived in one of the target counties and met the age criteria. Social media ads and posts were also used. For example, Facebook ads were posted seeking South Carolina African Americans who resided in specific counties, and were ages 50–85 years, for a paid telephone research project. One of these posts had a paid boost that was concentrated in Hampton, Jasper, and Allendale counties (specifically targeting social media users in these areas). Requests for participants were also posted in targeted Facebook affinity groups (i.e., Hampton County SC Buy Sell Trade Wanted, Marion County Habitat for Humanity, Lowcountry Government Facebook, and For Sale, Wanted, or Free in Darlington SC). Additionally, the recruiters reached out to several different agencies and organizations in specific counties to solicit assistance in identifying potentially eligible respondents, particularly those who did not complete high school or a GED. Flyers were posted in key areas in these locations, and local staff was offered an incentive for referring older African Americans who qualified and ultimately completed the telephone interview.

Instrumentation

As part of the screening process, participants were asked demographic questions about their age, sex, income level and education level, and county of residence to determine their eligibility. Also, an interview guide was developed to standardize the conduct of interviews. Open-ended questions were developed by the research team led by the first author based on the research aims of the study. The questions were guided by a review of extant literature that had been led by the second author regarding common health disparities experienced by African American older adults including chronic disease, obesity, and dental health. Additional questions focused on COVID experience and impact, namely telehealth, social isolation, and vaccine hesitancy. Additionally, questions were adapted from existing validated instruments such as the Centers for Disease Control and Prevention (CDC) Behavioral Risk Factor Surveillance System (BRFSS), the CDC Household Pulse Survey, and the National Social Life, Health, and Aging Project (NSHAP). The interview questions were pre-tested with members of the intended population to ensure content validity. Based on the feedback received during the pre-test, the interview questions were refined and finalized. Such refinements included re-wording questions to ensure face validity and removing questions that did not fit within the scope of the research. The data presented here will focus on participant responses to questions about COVID-19 and its impact on health care access.

Procedure

Prospective participants were invited to participate in a telephone interview about racial differences in health among the 50 and older African American population in South Carolina. Staff trained in proper conduct of interviews and protection of human subjects research served as interviewers. Interviews were scheduled for days and times that were convenient to study participants. All participants received a $100 incentive for their participation. The telephone interviews were conducted over a nine-week period, from May through July 2021. Interviews lasted on average about 45 min each.

Data Analysis

Interviews were digitally audio-recorded, and audio recordings were transcribed for review and analysis. The analysis team consisted of a primary and secondary coder, with collective research expertise in the following areas: racial

health disparities, African American health, health promotion, chronic disease self-management, disease prevention, and older adult health. Both coders were responsible for reviewing and coding transcripts independently, that is, each transcript was independently reviewed by each coder. Further, the primary coder was responsible for developing the initial codebook and establishing a sound basis for the themes that were included. The coding process began with pre-constructed codes with additional codes added as part of an iterative process. The establishment of a priori themes was guided by a comprehensive review of the literature that focused on the leading health disparities experienced by African Americans, with particular interest in the health disparities experienced by African Americans during the height of COVID-19. For example, one a priori theme was *telehealth convenience during COVID*. An emergent theme was the *impersonality of telehealth*. Another example of an a priori theme was the concern about *complications of the COVID-19 vaccine*. An emergent theme was about the *ease of access in obtaining the vaccine* (an unexpected theme given the media attention at the time of data collection regarding challenges to vaccine access). Codes were added during the transcript review process until the coders agreed that the review had yielded saturation. Any disagreements were discussed until the team reached consensus about the final codes to be included in the process of establishing the codebook. This approach is a method that has been used widely in other qualitative analyses (22).

Results

Characteristics of the sample

Forty-seven telephone interviews were conducted with African Americans ages 50 and older in South Carolina. The majority (57.7%) were female, 51.0% reported having an annual income <200% of the poverty level, and nearly 60% had greater than a high school diploma or GED. Participants resided in one of 17 counties in South Carolina that represent areas of socio-economic disadvantage within the State. See Table 1 for the demographic characteristics of the sample.

TABLE 1 Demographic characteristics of the sample ($N = 47$).

Characteristic	*N* (%)
Age	
50–59	17 (37.7)
60–69	15 (33.3)
70–79	13 (28.8)
80–85	2 (4.4)
Sex	
Male	20 (42.5)
Female	25 (57.5)
Income	
Income < 200% poverty	24 (51.0)
Income > 200% poverty	23 (49.0)
Highest level of education	
Less than high school graduate/GED	16 (34.0)
High school/GED	3 (6.4)
Greater than high school/GED	28 (59.6)
County of residence	
Allendale	2 (4.3)
Bamberg	1 (2.1)
Beaufort	4 (8.5)
Clarendon	1 (2.1)
Colleton	4 (8.5)
Darlington	3 (6.4)
Dillon	1 (2.1)
Dorchester	4 (8.5)
Florence	5 (10.6)
Hampton	1 (2.1)
Jasper	1 (2.1)
Lee	3 (6.3)
Marion	2 (4.3)
Marlboro	1 (2.1)
Orangeburg	5 (10.6)
Sumter	5 (10.6)
Williamsburg	4 (8.5)

Qualitative findings

Below is a summary of themes from the participant interviews highlighting responses to questions related to COVID-19 and its impact on health care access. Representative quotes are included to help elucidate findings, and each quote is referenced by a pseudonym (fictitious name used to protect participants' anonymity). The themes presented represent the most frequently noted phenomena by the participants.

COVID-19 impact on health care access

Participants were asked about the impact of COVID-19 on their access to health care. Participants noted that the primary impact of the pandemic on their ability to access health care was in the form of re-scheduled appointments by their providers. One participant stated that, *"a lot of my appointments [were] canceled by the physician."* [Steven] Another participant noted, *"I avoid going to the doctor because for one thing, the doctors, they wasn't letting you come to their office anyway. So, I just took my medicine like I was supposed to take it."* [Teresa].

Conversely, many participants offered that they felt no impact by the pandemic on their ability to access health services. As noted by Sandra: *"I kept all my doctor's appointments. I took*

my shots. I did whatever needed to be done to keep myself safe." As stated by another: *"Well actually, I would try to keep up with my medical care. If I had needed to go, just say if I was out of a prescription and I was just going to the doctor, going like I should, I wouldn't have to go in because they could call in a prescription. . . But at first, I didn't want to be out around in places like that around a lot of people. And I didn't."* [Cynthia].

Telehealth experience

Given some of the accommodations that were made to address the need to social distance to mitigate the spread of COVID-19, many health centers shifted to offering telehealth services to still meet the demands of some of their patient population. Participants were asked about their experience with telehealth and any suggestions they may have to enhance telehealth services. Themes that emerged regarding telehealth experience were: impersonality of the services and increased convenience. Themes regarding solutions to enhance telehealth included: providing instructions to older adults and addressing Internet barriers.

Regarding an impersonal telehealth experience, participants noted missing the human connection that a face-to-face office visit provides. For example, one participant noted: *"She was really nice, but personally, I do not like this over-the-phone conference or whatever you want to call it with doctors, I do not. If I've got pain in my chest, how can you diagnose my pain in my chest or know the rhythm of my heart, I'm having a heart attack or whatever, just looking at me over the phone?"* [Teresa]. As stated by another participant: *"It's the only reason I had the virtual, but I just didn't like the idea because it's not hands-on and it's not my doctor that I normally see. If I had any questions I could ask him there at the facility, something I might be going through. And then I couldn't get my urine test and my blood test like I normally do."* [Robert].

Alternatively, some participants remarked about the convenience of the telehealth services, primarily *"because you didn't have to leave home for number one."* [Larry]. According to Karen: *"It worked out well. It was great because I didn't have to wait for an appointment, I could get what I needed right away. I think it's great. It's great. Yes."*

Participants also suggested solutions to enhance telehealth services. The first theme that emerged was to provide instruction and opportunities to practice for older adults. As noted by Sandra: *"For me, it will be hard because I never did and I don't know how to. I know somewhat how to get on the Internet, but I never did it."* Further, Denise remarked: *"You're going to have to really get some sort of an outreach program, to go in or have them come and so they can be taught. I mean, it's just the same thing like a smartphone, getting my mom to understand how that works. You need someone to sit down and explain that to them."*

Lastly, another theme that emerged regarding potential solutions was to address Internet challenges. One participant stated about accessing telehealth: *"It would be hard because my parents don't have Internet."* [Donald]. According to another: *"A lot of people still don't have Internet. A lot of Black folks still don't have Internet or still don't have access to computers. So, that would be one."* [Bruce].

Perspectives on the COVID-19 vaccine

There are a variety of perspectives about the COVID-19 vaccine, some of which yield what has been termed "vaccine hesitancy," particularly among people of color. Given this, this particular group of questions was of great importance. Themes that emerged regarding participants' perspectives on the vaccine included: ease of obtaining the vaccine, skepticism about the vaccine, and concerns about potential complications from the vaccine.

Several participants described from either first-hand experience or from others that obtained the COVID-19 vaccine, that it was an easy process. As noted by Charles: *"Everybody around here says it was easy to get when it was time for them."* Denise offered a similar sentiment stating: *"It was easy. I signed her up and I went and took her to the first one, and I took her to the second one. We stayed in the car and they came and did it there, and that was it."* Steven stated: *"It wasn't no big deal. They said it was here and they went, my father-in-law, he went straight and got his. Everybody I knew that was older than me, they didn't have no... They didn't have no bunch of red tape to go through."*

While there was much discussion about the ease of accessing the vaccine, there were several comments about skepticism regarding the vaccine. Some of the basis for the skepticism was steeped in historical events, others with personal experience, and others based on current events. For example, Gary stated: *". . . they find a vaccine that would slow it up. Wasn't no guarantee that it would stop it. But it slows it up. But Black people would kind of hesitate because what happened many years ago, long years ago. We heard that they used to use Black people as the guinea pigs as far as. . . any kind of experiment."* Richard offered his own personal experience with shifts in skepticism. He states:

> *We've had the Moderna. In the beginning, during the Trump era, I was a little nervous and it had nothing to do with the President. My question was, if we can't get a vaccine for AIDS, which is something that's been out a long time, how were they able to get this so fast? So, I was a little nervous, then when I started seeing it on TV. I started seeing a lot of African-Americans on TV saying they've got it. So, I've said, "Okay. Well then, some of them got it." Then some people I know had told me, "Listen, we went and got it. It was okay. I think you should get it." So, by the time for me to get it, I was a little more at ease.*

Gary also discussed how the debate about which vaccine to take as well as reports of issues fueled his skepticism:

> *After you keep hearing different things about it, they had a call back and something happened about one or two times with Johnson. That scared me right then. So, I went to Moderna. I take the other one. I already had an appointment and everything with Johnson. But I changed my mind because of the things that we heard about Johnson.*

Another source of concern was about the potential complications and side effects from the vaccine. For instance, Denise was concerned that *"maybe it won't act right with the medications that I'm taking."* Similarly, Cynthia states this concern: *"I guess sometimes I think about what about the side effects, which some people don't have no side effects but some do. And then I read that some have had the vaccine and shortly after they had it, a couple days, they died."* Another comment was in regard to blood clotting: *"I want to wait and see the results from other people first. I want to see, because I hear people getting blood clots and different things. So, I basically want to wait, just for about six months."* [Karen].

Participants were asked for their suggestions about how to improve vaccination rates among African Americans ages 50 and older. Themes that emerged included: providing more information about the vaccine, engaging community organizations to provide information, and using familiar faces/trusted person as sources of information about the vaccine.

Related to providing more information, participants suggested that African Americans, in particular, need more information in order to make informed decisions about getting the vaccine. Denise remarked about the need to accommodate the lack of trust among some African Americans. She stated: *"I think that it should be more information given because of us here, especially, not being trusting. We're not too trusting because there's been so much that happened here in South Carolina, with us being given stuff because of us being African-Americans, bad stuff."* Patricia suggested the type of information that should be provided. She stated: *"I think everything's being done, but I think there needs to be more education about it because what I'm hearing is the whole premise is, get the vaccination, get the vaccination, get the vaccination, but really educating and telling them why and the importance of getting it."* Likewise, Kenneth stated: "*I think if they stress it more and telling more and more, and that it won't be that bad on you if you get a shot done. Because I kept saying I wasn't, then I talked about it and I had it. Even though it made me feel bad, I went through a rough day afterwards, but I'm glad I took it."*

Others suggested that community organizations would be ideal sources to disseminate information about the vaccine and help address concerns. As noted by Robert: *"And I think now I believe the community leaders and the church pastors are now getting involved with it so I think little by little, I think the process of the African American getting that shot, is going to pick up tremendously."* Similarly, Charles stated: *"More information at the churches and senior citizen groups. If you can provide information to them, like the little senior citizen clubs, where they are just sitting around talking, if there is some kind of way you can have pamphlets or someone to have discussion."* One participant specifically noted that this approach is critical in rural communities. Cheryl stated: *"In the rural African American communities, you have to get stuff to the church. You have to get it to the church and you have to get it to the members or somebody within the community that interacts with the people within the community."*

Lastly, an important strategy that was noted was to use familiar faces and trusted persons as persons to deliver information about the vaccine. For example, Teresa stated: *"I read for myself, read up on different stuff. That helps me. And, maybe for other people, maybe if they had someone that they trust talk to them about it. Maybe their children might can convince [them] or someone that already had it. That might help…"* Similarly, Steven noted: *"Get somebody or you identify somebody out of that area that they trust. That they know personally. Oh, I know him. He's straight up. I'll do it. But if they send a bunch of strangers, no, that ain't going to work."*

The final set of questions was about organizational partnerships and their effectiveness in promoting health and access to health care among persons in their community. Emergent themes included: having more attentive physicians, promoting fair medical treatment, and increased advocacy and family support.

Participants noted that an important factor for promoting health and health care access by community partners is to have more attentive physicians. Some of that, begins with trust. Robert stated: *"You almost have to start early where we could trust doctors."* Charles recounts his own experience with an attentive physician: *"She's more attentive to your health. She would go over your chart and if it was time for you to have a blood test for this or a blood test for that, or an EKG or a scan…she was more attentive to you. Like you were the only patient that she had. We need more doctors like that."* Cynthia also describes the qualities of an attentive physician. She noted:

> *"Well, explain to them what's what. Don't rush them whenever you go to an appointment. Are you asking questions, but then you rush and you know that you're being rushed. Sometimes some doctors act like they don't have time to explain something to them, but then they want to write you a prescription for this. But then, they don't have all their questions answered. So, that brings up a flag as well, too."*

Partnering with organizations that promote fair medical treatment was also a suggested strategy for promoting health care. For instance, Bruce and Denise remarked about fair treatment respective of insurance coverage. Bruce stated: *"Just because your insurance is a better insurance than mine, that shouldn't make a difference. I should get the same treatment that*

you get." As noted by Denise: *"They need to do more. They need to look at each particular State in detail and see what's happening here. It's ridiculous to work all your life and then get sick, and you don't have any extra help because they just don't allow you."* Trust was also a factor that contributed to fair treatment. As explained by Cheryl:

> *"In order for African Americans to have that trust, it has to be doctors within a facility that they have access to, that they know that there are doctors that they can trust, they know that they can go to those doctors and not be judged that, I know they're not going to do right because as soon as they see the color of your skin they don't treat you right or they don't do right."*

Lastly, having supportive family or other advocates who can intercede when needed was noted as an important factor to promote health. Charles stated: *"I was trying to think of a group, but I was thinking more family. Younger family should keep an eye out for older family and stress upon them that they do need to go to the doctor."* Cynthia describes non-familial advocate support in this way:

> *Well, with some insurance, they do have things like where the nurse or someone will come out, ask them about their medications and this and that. It is some things out there like that, but some don't take it up…And some, when they go to the doctor, they don't really know about a lot of things going on with them. Like I say, they could have a family member or their health care provider to go with them.*

Gary suggests that there is much support available, but some are unaware. According to him: *"I think they should find out more about what's available because a lot of time people don't keep up with the news or the best way of going about getting help. Because it's a lot of help out there, but you got to know who to talk to and where to go."*

Discussion

While research has shown that certain populations experienced health care access disparities during the early COVID pandemic (8–10), these disparities did not appear to be exacerbated in our sample. Based on our findings, participants identified few disruptions in routine health care access due to COVID-19. Many reported either re-scheduled health care visits or no impact of the pandemic on their access. Of note is that, in communities where access may already be problematic, as long as the situation doesn't worsen, community members may remain satisfied with the status quo. An opportunity to capture a true baseline measure of health care access prior to the pandemic would further elucidate this finding.

Participants did report disparagingly about their telehealth experiences, noting primarily that the experiences felt impersonal, and that common challenges included lack of instruction about how to use the technology and barriers to Internet access. Recent research from some scholars has documented African Americans using telehealth increasingly over the course of the pandemic; however, they do not report input from the community about the barriers to telehealth access that were experienced at the height of the pandemic (24). The effects of public compared to private insurance on telehealth use were also recently documented by Schenker (25). Individuals with public health insurance, such as that found in the Affordable Care Act (ACA) expansion and widely held by the older African American community, used telehealth at much lower rates than those with private health insurance. In order for telehealth to work effectively, a patient must have reliable access to both technology and broadband service (26). These resources are not widely available in older, racial and ethnic minority populations, creating a disparity in telehealth experience for older African Americans (27). Older populations are also at a specific disadvantage of lower rates of technology knowledge and slower technology adaptation (28). By increasing access to affordable technology and Internet providers, older African Americans can have positive telehealth experiences, particularly those in rural communities (26, 29).

Regarding the COVID-19 vaccine, we found a range of perspectives from ease of access, to skepticism and concern about complications from the vaccine. Vaccine hesitancy is defined as uncertainty and ambivalence about vaccination (30). Nationwide studies have shown that Whites are receiving the COVID vaccine at two times higher rates than African Americans (13% of Whites vs. 7% of African Americans) (31, 32). The National Association for the Advancement of Colored People (NAACP) and its partners also conducted a survey that reported that only 14% of African Americans trusted the vaccines' safety and only 18% said they would like to be vaccinated (33). Contrary to national statistics, African Americans in South Carolina currently account for 58.51% of completed vaccine distributions, while Whites account for 22.94% (34). The noted differences in vaccination rates across the State can be explained by geographic challenges to accessing health care in rural areas. Rural counties in South Carolina are experiencing up to 20% lower vaccination rates than the State's overall average of 55% (34).

Further, our participants attributed vaccine hesitancy among African Americans to both historical references to maltreatment of African Americans in the U.S. and distrust of the medical community. One of the foremost examples of unethical medical treatment of African Americans is the U.S. Public Health Service Syphilis Study at Tuskegee. This study provides important context for understanding African Americans' loss of confidence in the U.S. health care system (35, 36). As a result of the medical experimentation on 600 poor African American males in rural

Alabama that occurred 1932–1972, the health of the men in the research study was compromised, men's lives were lost, and their families suffered the fate of these men as well as their own residual physical and mental health challenges. Some researchers suggest that African Americans possess a communal medical distrust (37), a position that should not be surprising given the harrowing history of African Americans' engagement with the U.S. health care system. During the pandemic, this distrust has taken the form of what the general public calls "conspiracy beliefs" about the virus. Bogart et al. (38) found that 34% of African Americans believed that COVID-19 was a government-fabricated virus, created in a lab, to encourage vaccinations. This is in comparison to 26% of their White counterparts. The Tuskegee Study is but one example that represents countless other instances of experimentation and exploitation on African Americans and is a meaningful indicator of the work that needs to be done to build and sustain trusting relationships between African Americans, particularly those in the American South, and the health care system.

An important corollary to the discussion of vaccine hesitancy is recognition of the systems and structures that perpetuate this sentiment. Dr. Vanessa Northington Gamble, internationally renowned expert on the history of American medicine and its intersection with racial and ethnic disparities and bioethics, states: "I think the problem is, with this focus on the distrust of African Americans, it becomes like this inherent trait of African Americans, that these distrustful Black people, as opposed to focusing on a health care system that does not have trustworthiness" (37). This perspective was echoed by our study participants and is a significant indicator of the work to be done to make substantial improvements to the U.S. health care system.

Based on participant responses, we offer three recommendations about how to improve health status and health care quality and access for older African Americans. While these data were obtained during the height of the COVID-19 pandemic, we find them useful and transferable to contexts beyond COVID to mitigate health care access disparities. First, we recommend that community advisory committees be formed to provide opportunities for feedback from community members and from organizations that were cited as being effective in promoting health among older African Americans. For example, churches were frequently cited as community organizations effective in reaching older African Americans and several participants recommended that churches become more involved in disseminating health information, providing health education programming and facilitating access to health care. Second, we recommend bringing access to community members. For instance, participants suggested providing mobile dental health clinics staffed by dental students to improve dental health status and mobile farmers' markets as a way to provide more fresh produce in rural communities without grocery stores. Third, we recommend examining the quality of broadband and Internet access use for older African Americans in rural communities. Even with the best of platforms, if persons either do not have quality Internet access or have experience with using technology, innovations such as telehealth will not reach communities that could greatly benefit from their use. These recommendations can assist in making needed policy enhancements to address barriers experienced by certain racial groups or socioeconomically challenged and under-resourced areas.

We acknowledge the robust data that we obtained from our sample regarding their perspectives on health disparities, access to health care, and solutions for addressing disparities. However, there are some limitations of this study that should be noted. First, the size of the sample could be perceived as a limitation. However, we used a key tenet of qualitative research, data saturation, to determine that our sample size was adequate and that collecting additional data would produce little to no new information to address our study aims. Secondly, we limited our catchment area to a specific geographic region of the State of South Carolina. While our rationale for aiming our efforts to an underserved and socioeconomically depressed part of the State were sound, this further limits our ability to generalize findings beyond comparable communities.

Several study strengths should also be noted. First, we employed an effective recruitment strategy to obtain the sample. Partnering with a local agency to focus exclusively on recruitment and data collection yielded a relatively short recruitment period (9 weeks), which allowed more time to clean, review, and analyze the data. Secondly, this study represents a growing body of work designed to understand the context of life and health during the COVID 19 pandemic. In particular, our approach to obtaining community members' perspectives about disparities in health care access during the pandemic from African American elders is one that illuminates their lived experiences. Oftentimes, researchers use quantitative data to draw conclusions about the impact of disparities on communities, without engaging community members about this topic. Other studies have observed disparities in accessing care during the COVID-19 pandemic, but few have done so by highlighting the community's voice (8–10). Lastly, this study focuses on an understudied population. Health disparities are widespread among the aging African American community, thus future research should aim to examine not only health outcomes among this group, but the key drivers of theses disparities so that culturally relevant solutions can be devised and implemented.

Conclusion

Our qualitative approach was valuable in obtaining perspectives about access to health care during the COVID-19 pandemic from African American older adults. Our findings

suggest that while traditional access to health care was not disrupted very much, telehealth efforts designed to enhance or extend health care access were challenging. Continued research with African American elders, particularly those in under-resourced communities are warranted to further elucidate these findings. Extensions of this work might include examining the underlying causes of health care access challenges, asking community members to help inform viable solutions to further improve health care access, and working alongside community members and partnering with organizations who can communicate with the population to help devise effective solutions to address and eliminate health care access issues. The wisdom and lived experience of these community members can help ensure that programs are tailored to the needs and desires of the intended audience.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

LI conceptualized the study, conducted data analysis, and wrote the initial draft of the manuscript. CD conceptualized the study, conducted data analysis, edited, and contributed to the final draft of the manuscript. HB helped conceptualize the study, edited, and contributed to the final draft of the manuscript. YL edited, and contributed to the final draft of the manuscript. TH conducted the literature review and helped write the initial draft of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Factors related to self-rated health of older adults in rural China: A study based on decision tree and logistic regression model

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Objective: This study aimed to explore the related factors of self-rated health (SRH) by using decision tree and logistic regression models among older adults in rural China.

Methods: Convenience sampling was employed with 1,223 enrolled respondents who met the inclusion criteria from 10 randomly selected villages in M County in China. The content of the questionnaire covered demographic characteristics, physical and mental health, sleep status, and risk of falling. The Pittsburgh Sleep Quality Index (PSQI) and the Morse Falls Risk Scale (MFS) were used to evaluate sleep status and risk of falling, respectively. The decision tree and logistic regression models were employed to analyze the related factors of SRH.

Results: Notably, 817 (68.7%) subjects had good SRH. The logistic regression model showed that living standard, alcohol consumption, sleep quality, labor, hospitalization, discomfort, the number of chronic diseases, and mental health were associated with SRH (P-value < 0.05), while the decision tree model showed that the number of chronic diseases, sleep quality, mental health, hospitalization, gender, and drinking were associated with SRH. The sensitivity and specificity of the logistic regression model were 67.7 and 75.5%, respectively, and the area under the ROC curve was 0.789 (0.763, 0.816); the sensitivity and specificity of the decision tree model were 71.5, and 61.4% respectively, and the area under the ROC curve was 0.733 (0.703, 0.763).

Conclusion: Decision tree and logistic regression models complement each other and can describe the factors related to the SRH of the elderly in rural China from different aspects. Our findings indicated that mental health, hospitalization, drinking, and sleep quality were the important associated factors.

KEYWORDS

SRH, rural elderly, logistic, decision tree, influencing factors

Introduction

China has increasingly developed into an aging society, with 264 million people aged 60 and over, accounting for 18.70% of the total population (1). At the same time, there is an inversion of population aging in urban and rural areas. The proportion of the population aged over 60 and 65 years in rural China is 23.81 and 17.72%, respectively, with 7.99 and 6.61 percentage points higher than those in urban areas (2). With the change in physiological and social roles, the prevalence of noncommunicable chronic diseases, disability, and social role function loss has increased significantly in the elderly (3). Compared with the elderly in urban locations, the elderly in rural areas have poorer medical and health conditions, material living standards, and self-care awareness (4, 5). Therefore, how to improve the health of the elderly in rural areas is one of the major challenges facing Chinese society.

Self-rated health (SRH) is an individual's subjective assessment of his or her health status and expectations (6, 7) and is also a recommended health testing indicator by the World Health Organization (8). Based on an overview of an individual's current health status and relevance to future health outcomes, SRH has been shown to predict mortality, morbidity, etc. in various countries/settings (9–11). SRH is a composite concept that reflects not only aspects of an individual's physical, psychological, and social adaptations but also health behaviors and cultural beliefs (12, 13).

Self-rated health is affected by many factors, such as socio-demographics, including gender, age, income level, and education level (14, 15). Health indicators cover factors such as disease, drug abuse, and mental health (16, 17). Studies have shown that suffering from one or more chronic diseases could be an important factor in poor SRH status (18). In addition, studies have shown that smoking, alcohol consumption, physical activity, and other daily behaviors and lifestyles were related to SRH (19). Sleep quality was significantly related to SRH, as shown by Min-Fang Hsu's study (20). Furthermore, the risk of poor SRH increases with the number of chronic diseases (NCDs), mental health symptoms, and decreased social support (18). From the perspective of etiology, the influencing factors of diseases can be divided into proximal factors that directly play a role and distal factors that indirectly play a role; thus, many of the above factors are not independent but synergistic [e.g., low physical activity + age + smoking can all lead to cardiovascular disease and therefore to low SRH (21)].

Logistic regression and decision tree models can be used to construct predictive models for influencing factors (22, 23). Although logistic regression highlights the main effects of influencing factors, it does not deal well with interactions or provide good decision recommendations. In contrast, the decision tree model breaks the traditional linear processing method by eliminating the collinearity among variables and including a series of logical decisions. Each path from the root nodes to the leaf nodes corresponds to a rule. The importance of the indicators is ranked to determine the main influencing factors. However, the classification effect varies with the number of nodes, thus it could be less stable and forbid main effect analysis. As a result, the interpretation of the results is limited. The joint use of the decision tree and logistic regression models can complement each other and improve the analysis performance.

A combination of decision tree model and logistic regression is still lacking at home and abroad to analyze the factors related to the SRH status of rural elderly. In this study, focusing on a population sample of older adults in a rural area of Anhui Province, we proposed two models to analyze the factors related to SRH in older adults to gain an in-depth understanding of the health status of older adults and provide a reference basis for improving the health and quality of life of rural older adults.

Methods

Study design and data collection

A cross-sectional study was carried out from July to August 2021 in Anhui, China. Anhui Province is located in the central region of China and is one of the major agricultural provinces. The population aged 60 years and above is 11.469 million, accounting for 18.79%; of which, 9.159 million are aged over 65 years, accounting for 15.01%.

Using a convenience sampling method, a total of 10 villages in two townships in M County were selected as the study sites, taking into account the different economies and populations, and the rural elderly who met the inclusion criteria were selected as the subjects. Inclusion criteria were as follows: (1) age $\geq$ 60 years, (2) normal hearing, clear consciousness, and basic communication skills, and (3) voluntary participation in this study. With the assistance of local village committees and village doctors, five postgraduates from Anhui Medical University who had been uniformly trained conducted a face-to-face survey with each subject. Prior to the survey, the purpose and procedures of the study were verbally presented to all respondents, and verbal consent was obtained from them. The question-and-answer technique was adopted, and the investigator filled in the questionnaire according to the answers. A total of 1,223 questionnaires were distributed in this study, and 1,189 valid questionnaires were recovered, with an effective recovery rate of 97.2% (1,189/1,223).

Measurement of sleep quality

The Pittsburgh Sleep Quality Index (PSQI) was used to evaluate the sleep quality of the survey object in the past month. The scale contains 18 items measuring the following seven

factors: sleep quality, sleep onset time, sleep duration, sleep efficiency, sleep disturbance, hypnotic medication, and daytime dysfunction. The score range for each factor is 0 to 3, and the cumulative score for each factor is the total PSQI score, with a total score range of 0 to 2l. A total score of ≤ 7 indicates good sleep quality, and >7 indicates poor sleep quality. This study verified that the Chinese version of the PSQI has good reliability and validity, with an overall reliability coefficient of 0.82 to 0.84 (24).

Measurement of mental health

Mental health was assessed using the 12-item General Health Questionnaire (GHQ-12), which is widely used in epidemiological surveys and screening for mental disorders in community groups. The scale consists of 12 items, and each item contains the following four options: (1) not at all, (2) the same as usual, (3) more than usual, and (4) much more than usual. The GHQ-12 is scored as 0 for those who choose to answer the first two items and 1 for those who answer the last two. A total score of 3 on the GHQ-12 is used as the threshold, i.e., a score of ≥ 3 indicates poor mental health. The GHQ-12 of the Chinese version has good reliability and validity, with Cronbach's alpha coefficients ranging from 0.75 to 0.82, and retest correlation coefficients ranging from 0.82 to 0.85 (25).

Measurement of risk of falling

The risk of falling was assessed using the Morse Falls Risk Scale (MFS). The scale assessment was not time-comsuming, was simple, operational, and had good reliability and validity with Cronbach's alpha coefficient of 0.891. Items and scoring criteria were as follows: history of falls (none = 0, yes = 25); 1 or more disease diagnoses (none = 0, yes = 15); use of mobility aids (none need, bed rest or nurse assistance = 0, crutches, walker, cane = 15, walking with furniture = 30); receiving medication (none = 0, yes = 20); gait (normal/immobility = 0, weakness = 10, severely frail = 20); and cognitive status (voluntary behavior = 0, no control = 15). A total score of <25 was considered low risk, 25–45 for moderate risk, and ≥ 45 for high risk of falling.

Measurement of other variables

Other variables included basic demographics and health-related information. Specifically, the following were included: gender (female and male), age (60–69, 70–79, and ≥ 80 years), marital status (stable, unstable consisting of divorce, widowed, and unmarried), residence status (living alone living with others: living with children, relatives, caregivers, etc.), the education level (illiterate and junior high school), source of income (employment income, child support, and government subsidy), smoking (yes or no), drinking: drinking alcohol twice or more a week for 1 year (yes or no), taste for food (moderate, light, and salty), living standard (good and poor; good: self-assessed living standard is very good, good, and average; poor: self-reported poor or very poor), labor: the daily physical work of the respondents (heavy and easy), BMI (healthy, overweight, and obese; healthy: 18.5–23.9, overweight: ≥ 24, obese: ≥ 28). Information was also collected on noncommunicable diseases, physical discomfort (within 2 weeks), and hospitalization (within 1 year).

The dependent variable in this study is SRH, which was measured and analyzed in responding to the questionnaire item "How do you feel about your current health status?" The answers to this question were set to five options: "very good," "good," "fair," "bad," and "very bad." The first three options were categorized as "good," while the last two were categorized as "poor."

Statistical analysis

First, we used chi-square tests to examine differences between the different SRH groups (good and poor) and used ratios and percentages to describe the demographic characteristics of the participants.

Second, we tested correlations among the variables (Figure 1). The variables that were statistically significant in the chi-square test included logistic regression and decision tree models. To obtain the optimal model, we chose the exhaustive CHAID growth method, with a maximum growth depth of 3. The CHAID growth method uses the chi-square test or variance analysis principle to optimally segment data according to variable type and automatically judges and groups multivariate contingency tables according to P-value to generate a multi-tree, which can efficiently mine the main influencing factors. According to the variance expansion factor (VIF) results, there was no evidence of multicollinearity in the logistic regression model, and no factor exceeded the critical value (Supplementary Table S1).

Finally, the prediction effects of logistic regression and decision tree models were compared by constructing a subject operating characteristic curve (ROC curve), Z-value was calculated based on the area under the curve and standard deviation, and the corresponding P-value was matched to determine the difference between the two statistical models. The check level was set at $\alpha = 0.05$.

All statistical analyses were performed using SPSS statistical software version 26. Two-tailed P-value of < 0.05 was considered statistically significant.

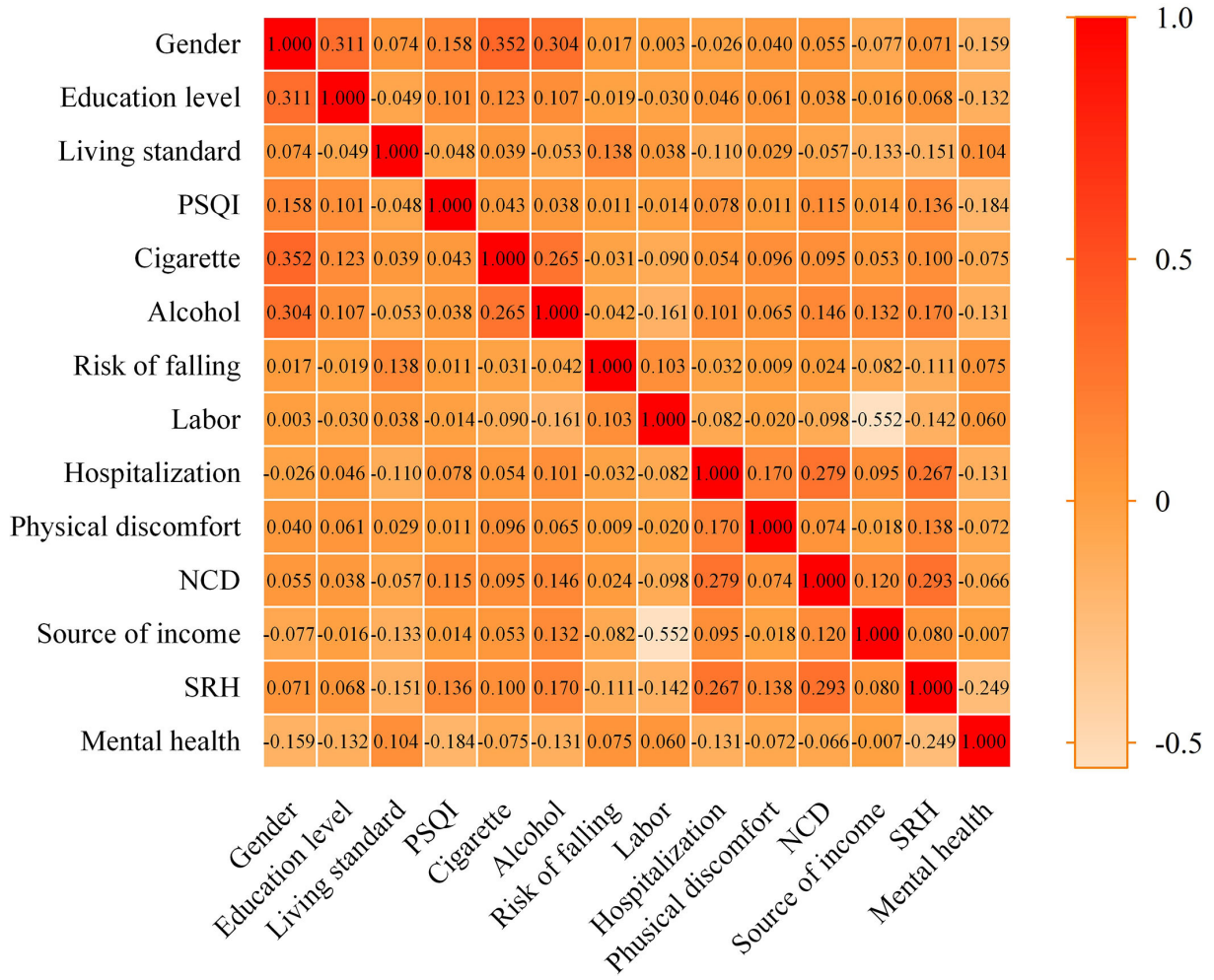

FIGURE 1
Correlation between variables.

Results

Characteristics of participants

The general demographic characteristics of the respondents are shown in Table 1. A total of 1,189 subjects were included in this study, of which 817 subjects self-assessed good health. Significant statistical differences were found between the two groups on the dimensions of gender, education level, smoking, drinking, taste for food, physical labor, source of income, mental health, risk of falling, sleep quality, and NCD (P-value < 0.05). Among the 817 subjects, 51.8% (423/817) were female, 77.7% (635/817) did not smoke, 70.5% (576/817) did not drink, 66.6% (544/817) had not been hospitalized in the past year, and 55.3% (452/817) had economic income from their own work. At the same time, 86.3% (705/817) of the survey respondents who rated themselves as the ones having good health had a higher living standard.

Results of logistic regression analysis

Table 2 shows the variable assignments. The results of multivariate logistic regression analysis (Figure 2) showed that living standard, drinking, PSQI, labor, hospitalization (within a year), discomfort (within 2 weeks), NCD, and mental health were influencing factors for SRH of the elderly (P-value < 0.05). In addition, the model did not show any statistically significant association between the risk of falling and SRH. Compared with the control group, the higher standard of living (OR = 0.476, 95% CI: 0.327–0.692), heavier physical labor (OR = 0.687, 95% CI: 0.486–0.971), and better mental health status (OR = 0.410, 95% CI: 0.302–0.558) were associated with better SRH. No drinking (OR = 1.701, 95% CI: 1.149–2.518), poor PSQI (OR = 1.397, 95% CI: 1.045–1.867), hospitalization (within a year; OR = 2.163, 95% CI: 1.619–2.890), discomfort (within 2 weeks; OR = 1.739, 95%CI: 1.209–2.500), NCD = 1 (OR = 1.647, 95%CI:

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TABLE 1 General characteristics of the respondents ($N = 1,189$).

	Total ($N = 1,189$)	SRH		χ^2	*P*-Value
		Good ($N = 817$)	Poor ($N = 372$)		
Gender					
Female	602 (50.6)	394 (48.2)	208 (55.9)	6.045	0.014
Age (years)					
60–69	414 (34.8)	293 (35.9)	121 (32.5)	1.502	0.472
70–79	578 (48.6)	388 (47.5)	190 (51.1)		
≥80	197 (16.6)	136 (16.6)	61 (16.4)		
Marital status					
Stable	829 (69.7)	574 (70.3)	255 (68.5)	0.354	0.552
Unstable	360 (30.3)	243 (29.7)	117 (31.5)		
Residence status					
Living alone	250 (21.3)	167 (20.4)	83 (22.3)	0.539	0.463
Living with others	939 (78.7)	650 (79.6)	289 (77.7)		
Education level					
Illiterate	963 (81.0)	647 (79.2)	316 (84.9)	5.497	0.019
Junior high school and above	226 (19.0)	170 (20.8)	56 (15.1)		
Living standard					
Good	980 (82.4)	705 (86.3)	275 (73.9)	26.982	<0.001
Poor	209 (17.6)	112 (13.7)	97 (26.1)		
Smoking					
Yes	233 (19.6)	182 (22.3)	51 (13.7)	11.907	0.001
No	956 (80.4)	635 (77.7)	321 (86.3)		
Alcohol					
Yes	292 (24.6)	241 (29.5)	51 (13.7)	34.392	<0.001
No	897 (75.4)	576 (70.5)	321 (86.3)		
Taste for food					
Medium	523 (44.0)	370 (45.3)	153 (41.1)	4.751	0.093
Light	423 (35.6)	274 (33.5)	149 (40.1)		
Salty	243 (20.4)	173 (21.2)	70 (18.8)		
Risk of falling					
Low	11 (0.9)	6 (0.7)	5 (1.3)	14.986	0.001
Medium	63 (5.3)	30 (3.7)	33 (8.9)		
High	1,115 (93.8)	781 (95.6)	334 (89.8)		
Labor					
Heavy	652 (54.8)	487 (59.6)	165 (44.4)	24.014	<0.001
Easy	537 (45.2)	330 (40.4)	207 (55.6)		
BMI					
Healthy	538 (45.2)	366 (44.8)	172 (46.2)	3.122	0.210
Overweight	472 (39.7)	336 (41.1)	136 (36.6)		
Obese	179 (15.1)	115 (14.1)	64 (17.2)		
NCD					
0	273 (23.0)	237 (29.0)	36 (9.7)	102.672	<0.001
1	391 (32.9)	296 (36.2)	95 (25.5)		
≥2	525 (44.2)	284 (34.8)	241 (64.8)		

(Continued)

TABLE 1 (Continued)

	Total ($N = 1,189$)	SRH		χ^2	*P*-Value
		Good ($N = 817$)	Poor ($N = 372$)		
Physical discomfort (within 2 weeks)					
No	997 (83.9)	713 (87.3)	284 (76.3)	22.538	<0.001
Yes	192 (16.1)	104 (12.7)	88 (23.7)		
Hospitalization (within a year)					
No	686 (57.7)	544 (66.6)	142 (38.2)	84.545	<0.001
Yes	503 (42.3)	273 (33.4)	230 (61.8)		
PSQI					
Good	715 (60.1)	528 (64.6)	187 (50.3)	21.981	<0.001
Poor	474 (39.9)	289 (35.4)	185 (49.7)		
Source of income					
Labor	614 (51.6)	452 (55.3)	162 (43.5)	21.481	<0.001
Child support	360 (30.3)	214 (26.2)	146 (39.2)		
Government	215 (18.1)	151 (18.5)	64 (17.2)		
Mental health					
Good	859 (72.7)	652 (80.2)	207 (56.3)	73.254	<0.001
Poor	322 (27.3)	161 (19.8)	161 (43.8)		

1.035–2.619), and NCD $\geq$ 2 (OR = 03.967, 95%CI: 2.558–6.153) were risk factors for SRH.

Results of classification and regression tree model

The results of the decision tree model are shown in Figure 3. SRH was mainly related to NCD, PSQI, mental health, hospitalization, gender, and drinking. NCD was the primary influencing factor for SRH. Taking NCD as the root node, the probability of having good SRH without chronic diseases in older adults is 86.85%. SRH was higher in women without chronic disease and with better sleep quality. Conversely, those with two or more chronic diseases, hospitalization within 1 year, and poor mental health have poor SRH.

Comparison of model prediction results

According to the predicted probabilities obtained by the two models as test variables, ROC curves were drawn, respectively, as shown in Figure 4. The ROC curves of both models are far away from the diagonal line, indicating that the model has a certain predictive effect. The ROC curves of both models are almost coincident, indicating that the classification effects of the two models are similar. However, it should also be noted that there are differences between the two models. The influencing factors in the logistic regression model, living standard, discomfort, and labor are eliminated in the classification decision tree model, while gender in the decision tree model is not statistically significant in the regression model.

TABLE 2 Variable assignment table.

Variables	Assignment
Self rated health	0 = good, 1 = poor
Mental health	0 = poor, 1 = good
Gender	0 = Male, 1 = Female
Education level	0 = Junior high school and above, 1 = Illiterate
Living standard	0 = poor, 1 = good
PSQI	0 = good, 1 = poor
Smoking	0 = yes 1 = no
Alcohol	0 = yes 1 = no
Risk of falling	0 = low, 1 = medium, 2 = high
Labor	0 = easy 1 = heavy
Hospitalization (within a year)	0 = no, 1 = yes
Physical discomfort (within 2 weeks)	0 = no, 1 = yes
Chronic disease	0 = 0, 1 = 1, 2 = $d \geq 2$
Source of income	0 = labor, 1 = child support, 2 = government subside

SRH, self-rated health; NCD, noncommunicable chronic disease; PSQI: Pittsburgh sleep quality index; GHQ-12, the 12-Item General Health Questionnaire; MFS, the Morse fall risk scale.

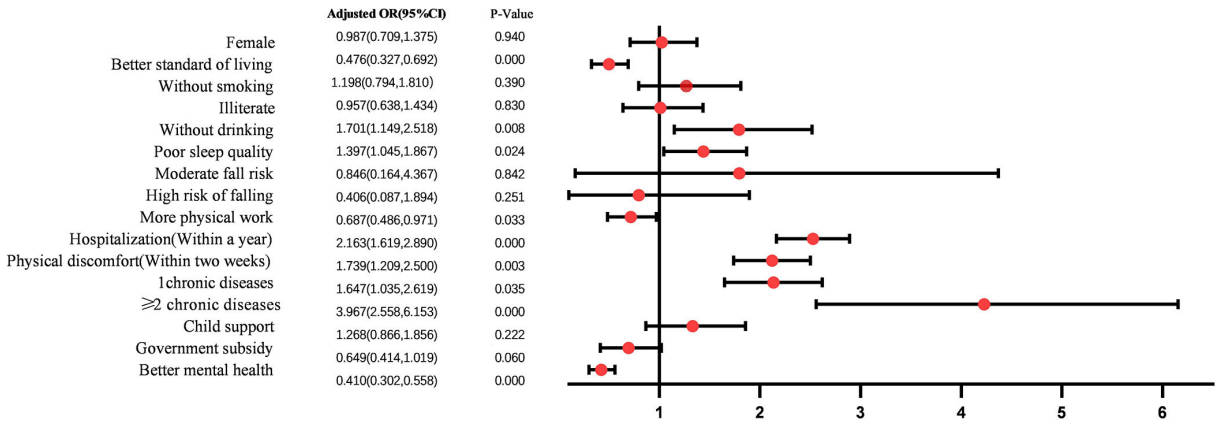

FIGURE 2
Logistic regression analysis results.

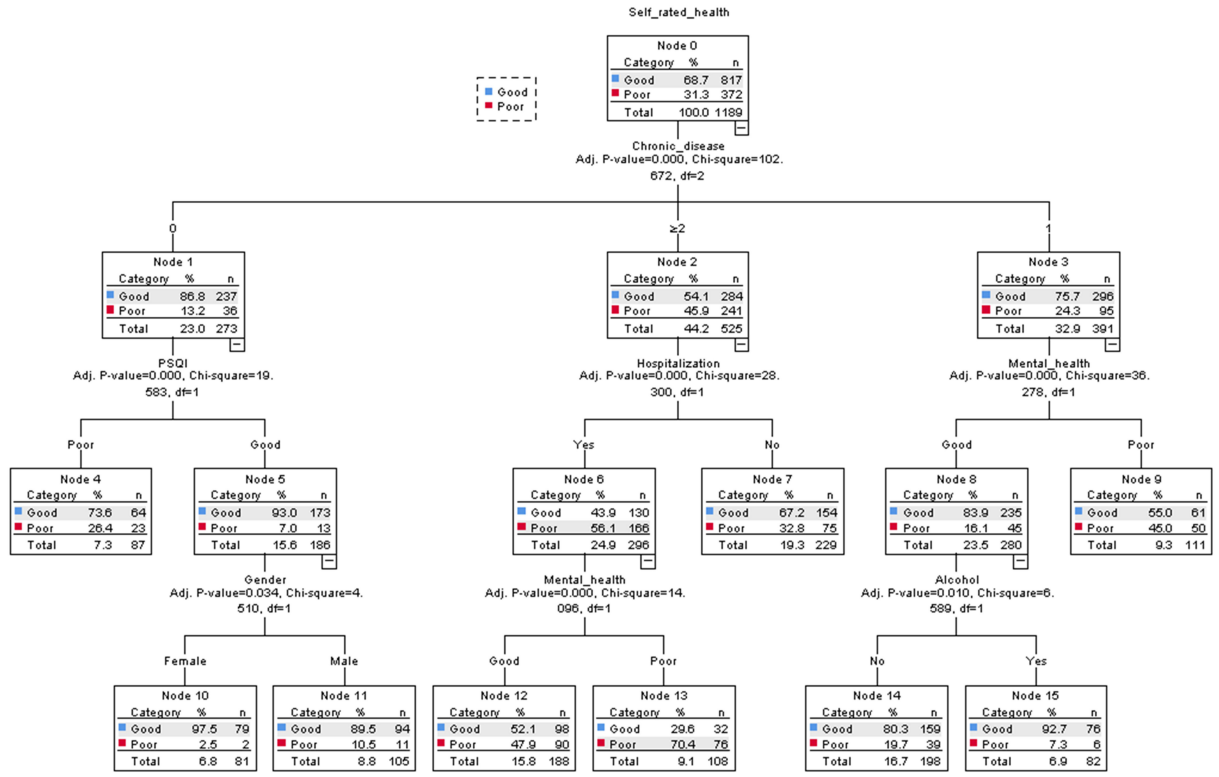

FIGURE 3
Classification and regression tree model (N = 1,189).

The common influencing factors screened by the logistic regression model and decision tree model were NCD, mental health, hospitalization, drinking, and PSQI. The logistic regression model had a sensitivity of 67.7%, a specificity of 75.5%, and an area under the ROC curve of 0.789 (0.763–0.816); the decision tree model had a sensitivity of 71.5%, a specificity of 61.4%, and the area under the ROC curve was 0.733 (0.703–0.763). The difference between the two models is statistically significant ($Z = -2.729$, $P = 0.003$), and the prediction effect of the two models was moderate (0.7–0.9).

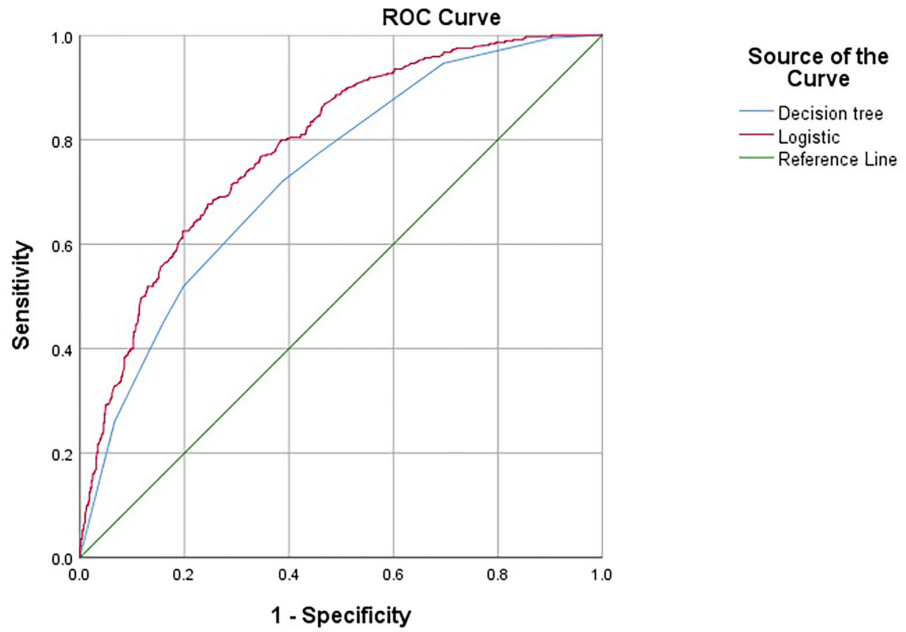

FIGURE 4
ROC curve predicted by decision tree and logistic regression model.

Discussion

In this study, the prevalence of poor SRH was 31.3%. The prevalence of reported poor SRH in older adults varies in different studies. Ana M Pereira-de-Sousa found that 52.9% of Spaniards rated their health as "good" or "very good," compared to 19% of Portuguese ($P < 0.01$) (26). A Chinese study showed that 38.33% of the study subjects reported good/excellent SRH (27). The percentage of subjects reporting good SRH in this study is somewhat higher than in the other studies discussed, possibly due to differences in national culture and historical background, as well as differences in assessment scales and samples. In general, due to age, physical function degradation, and other reasons, the elderly tend to choose a reference object in their self-assessment of health, such as relatives and friends, neighbors, and other elderly people of the same age group. Even when they are ill, they tend to adjust the reference object to maintain a more positive health self-assessment. The level of an individual's SRH depends on the selected reference group. This theory is often used to explain why people have a more positive evaluation of their own health (28).

Significant variables in the logistic regression model were different from the nodal variables that entered the decision tree model. The decision tree analysis did not reflect the effects of three factors: living standards, discomfort (within 2 weeks), and labor. The reason might be that the logistic regression model expresses the correlation of variables while the decision tree takes into account the interactions and relationships among variables and shows the function form of variables in each subcategory in detail, providing a wealth of information.

Influence of personal characteristics on SRH

In this study, gender, age, and marital status were not significantly associated with SRH, but the proportion of women was 11.8% higher than that of men in the 372 unhealthy samples, stable marital status was higher by 37% than those with an unstable marital status, and people aged 70–79 accounted for half of the unhealthy population. Elderly people with a high standard of living, heavy physical labor, and no medical treatment within 2 weeks tend to have higher levels of SRH, which is consistent with previous studies (29, 30).

The higher SRH rates are among older adults with better living standards than those with poorer living standards, suggesting that the living standards of the elderly have a significant positive effect on their health and that improved living conditions can improve the level of SRH. An adequate source of income is an important material basis for health. On the one hand, living standards directly affect health; on the other hand, they affect health through intermediary mechanisms

such as lifestyle, psychological factors, and access to health resources. As a form of social activity, physical labor can increase social opportunities for the elderly, achieve group-coordinated development, and improve SRH levels (7). Elderly people who have not seen a doctor within 2 weeks may have higher physical fitness and therefore are more likely to have higher SRH.

NCD and SRH

Specifically, older adults who suffer from multiple chronic diseases may have lower SRH. This further confirms the consistency between the SRH and the objective state of the body. Henrike Galenkamp's study evaluated the impact of heart disease, peripheral atherosclerosis, stroke, diabetes, and other diseases on SRH and found an association between comorbidities and SRH (31). The association was nonlinear, with the effect of the individual disease being greater than the additive effect of concurrent diseases. However, starting with the second disease, the incidence of comorbid multi-morbidities was cumulatively negatively associated with SRH. At the same time, studies have shown that the elderly with multiple chronic diseases have deteriorating mental and physical health and can negatively affect SRH (32). One possible explanation for this result is that SRH in the elderly is affected by objective health, and chronic diseases bring problems such as pain, insufficient self-care ability, limitation in daily activities, and dependence on or incompatibility with drug therapy. At the same time, rural older adults with chronic diseases often require medication and hospitalization, which makes them more likely to be impoverished by their illness, thereby reducing the level of SRH. It is necessary to further improve the community supervision of chronic diseases, refine the management of chronic diseases, regularly carry out a physical examination of middle-aged and elderly people, and do a good job in community supervision of chronic diseases to further improve the health level of the population (33).

Mental health and SRH

In short, people with goodmental health have higher SRH when compared to those with poor mental health. This is consistent with Mikyong Byun's finding that depression appeared to be the strongest predictor of negative SRH (34). Death of a spouse, chronic diseases, and reduced interpersonal communication can all lead to mental health problems. Long-term experienceof negative emotions is consistent with SRH deterioration (35). People who have been experiencing negative emotions for a long time are more likely to subjectively believe that they are in poor health due to the hypochondria effect, thus exaggerating physical health problems. People with poor mental health may suffer from dull, irritable, and even depressed moods, are tired of social communication, and lack physical activity, resulting in poorer health status.

Hospitalization and SRH

Self-rated health tended to be more negative in older adults hospitalized within 1 year, which is consistent with the findings of Wang (36), further confirming that SRH is consistent with objective physical status (37). In this study, the elderly in rural areas were characterized by a high prevalence of chronic diseases and a low level of education. They lack knowledge about chronic diseases and their prevention and control, as well as the awareness of timely medical treatment and active use of health services (38). By the time medical care is consciously sought, the disease may have developed to a complex and severe level, therefore, SRH is lower in older adults with a history of hospitalization within 1 year. Tertiary prevention of chronic diseases to reduce their prevalence of chronic diseases and control their further development is an effective way to improve the SRH.

Drinking and SRH

An interesting phenomenon was found in this study that drinking is a protective factor for SRH. This is consistent with the findings of Li Tongyao and Riediger (7, 39). This may be due to "Optimistic bias," that is, drinkers believe that drinking is less harmful to them than other drinkers. In addition, it may be because drinkers are in better physical condition to tolerate a certain amount of drinking and that there are social benefits to drinking (40). At the same time, those in poor health are more inclined to avoid alcohol consumption. Moderate drinking can produce positive emotional effects and protect against cardiovascular disease, but it is not recommended to drink to improve health. In view of this, relevant departments must implement health education, gradually deepen health promotion work, effectively advocate for the elderly to develop healthy habits, quit smoking and limit alcohol, eat well, and improve levels of daily exercise.

PSQI and SRH

Among the rural elderly population, those with better PSQI had higher SRH. This result is similar to a Japanese study of adequate sleep (COR $=$ 5.22, $P < 0.001$), which was associated with high SRH (41). Anna Andreasson's study (42) showed that people with good sleep quality reported significantly higher SRH than those with moderate sleep quality (95% CI $=$ 0.48, 0.89, $P < 0.001$). Insufficient sleep duration can affect circadian rhythms, impair insulin sensitivity, increase

insulin resistance, decrease glucose tolerance, and lead to elevated levels of catecholamines, cortisol, and sympathetic activity, which are associated with various diseases (43). Also, poor sleep quality may increase daytime fatigue, leading to negative events and negative emotions, which can affect SRH levels. Attention should be paid to the role of sleep quality in promoting the health of the elderly. Through psychological counseling, knowledge explanation, and other means, the elderly can be helped to develop good sleep habits. Attention should always be paid to helping a pleasant mental state be maintained in order to improve physical and mental health.

Strengths and limitations

Our study has the following advantages. First, the effective response rate in this study was 97.2% (1,189/1,223), and it is known that the results of studies with a highly effective response rates are more reliable. Second, the combined use of decision tree and logistic regression models is beneficial, where each model can be learned from and where the strengths of each one can complement the other. The combined use of both can allow analysis of the factors affecting the SRH of the elderly at different levels and help to quickly find the most influential combination of factors. Taking advantage of the intuitive effect of the decision tree, ease of interpretation, and generation of partial classification rules, combined with the logistic regression model giving parameter estimates and hypothesis testing results for each variable, the main effect variables were filtered out through the logistic regression model, and then using the decision tree, the model further investigated the interactions between the variables.

However, the limitation of this study is that the selected samples were only from the rural elderly population in 10 villages of M county. In addition, this is a cross-sectional study with a limited inference of causality, which needs to be verified by a high-quality cohort study. At the same time, our study did not include all the potential factors of SRH, which will be considered in future studies.

Conclusion

The SRH of the rural elderly is affected by many factors such as personal characteristics, health level, behavior, and lifestyle. This study combined logistic regression and decision tree models to screen key influencing factors affecting SRH in older adults, including NCD, mental health, hospitalization, alcohol consumption, and PSQI. This study may be helpful to plan and take measures to improve SRH in older adults and promote active aging. Grass-roots medical and health institutions in rural areas should make full use of existing health resources to improve the community health care network and strengthen the rehabilitation and treatment of patients with chronic diseases, which is conducive to the improvement of the health status of the elderly in rural areas. With an increase in age, the elderly pay more attention to social environment and the degree of psychological and emotional pleasure; thus society and families should provide more care to the elderly to help them achieve healthy aging.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

All participants in this study were fully informed about the purpose and methods of this study. The purpose and procedures of the survey were explained to all respondents prior to conducting the survey, and informed consent for the survey was secured from all respondents. For illiterate respondents, informed consent was also obtained from the guardians.

Author contributions

MZ conceptualized the study and wrote the manuscript. JR, SL, and BZ contributed to the study design, data collection, data processing, and statistical analysis. JR contributed to the literature review. MZ, JR, YZ, and HW revised the manuscript. All authors reviewed the manuscript and approved the final manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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Impact of main residential locations on depressive symptoms among older adults in China: A Blinder–Oaxaca decomposition analysis

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Background: With the development of urbanization in China, the scale of internal migration and the number of immigrants among older adults are increasing. This requires paying attention to the living conditions and environment of immigrants. Many studies note a gap in the prevalence of depressive symptoms among older adults living in different main residential locations. However, few studies have examined the extent to which main residential locations influence depressive symptoms among older adults. This study aims to quantify the effect of main residential locations on depressive symptoms.

Methods: For this study, we used data from the 2018 Chinese Longitudinal Health and Longevity Survey and randomly selected 8,210 individuals aged 65 years and older were from the community to determine the effect of main residential locations on depressive symptoms among older adults. We further used the Blinder–Oaxaca decomposition method to quantify the explanatory factors of depressive symptom gaps among older adults and to estimate the relative effect of individual characteristics on depressive symptoms.

Results: In this study, we noted significant differences in depressive symptoms among older adults in different main residential locations. Rural–urban migrants had higher depressive symptom scores (7.164). According to the Blinder–Oaxaca decomposition analysis, the high proportion of the depressive symptom gap can be explained by years of education, income, and exercise among different main residential locations groups. In addition, in the main parts of the explained differences, the proportions of the limitation of activities of daily living (2.28, 0.46, and −52.11%) showed opposite effects, while their share in different main residential locations groups varied widely.

Conclusion: Urbanization has resulted in more rural people moving to urban areas in China; Rural–urban migrants have the highest prevalence of depressive symptoms, which needs attention. Thus, there is an urgent need to integrate the health insurance and pension policy for

urban and rural residents. This study provides a basis for formulating health policies and promoting the mental health of older adults in China as well as in low- and middle-income countries.

KEYWORDS

depressive symptoms, older adults, Blinder-Oaxaca decomposition, rural-urban migrants, urbanization

Introduction

Urbanization and population aging have become the main trends worldwide, especially in China. Following the acceleration of urbanization, a large number of rural people work or have settled in urban areas. Compared with the data collected during the sixth population census of China in 2010, the internal migration population increased by 69.73% during the seventh population census conducted by the National Bureau of Statistics in 2020 (1). The mental health status of older adults in the internal migration population requires more attention as they are a vulnerable group. The decline in the health status, stress-coping ability, and social networks of older adults may affect their mental health.

Depressive symptoms are common among people with chronic diseases, cognitive impairment, or disabilities, especially older adults. According to the World Health Organization (WHO), ∼280 million people worldwide suffer from depressive symptoms, 5.7% of whom are adults older than 60 years (2). Although there are effective treatments for mental disorders, more than 75% of the patients in low- and middle-income countries do not have access to treatment (3). The WHO estimated that three-quarters of this burden occurred in low- and middle-income countries (4). A meta-analysis study has shown that the overall prevalence of depressive symptoms has reached 23.6% among older adults in China (5); this is significantly higher than that reported more than 20 years ago (6). Simultaneously, the development of urbanization has caused a disparity in mental health between people in urban and rural areas. Studies in China have consistently reported that the prevalence of depressive symptoms among older adults in rural areas is higher than among those in urban older adults (7–11).

To the best of our knowledge, when studying the location of residence, urbanization is, in general, used as the basis for grouping. The previous literature has documented the relationship between urbanization and depressive symptoms in China (12), the potential influencing factors of urbanization on depressive symptoms, and the role of mediating variables on depressive symptoms among rural–urban migrants, such as neighborhood social capital (13). In addition, although individual and urban–rural differences have been examined in the literature (11), it does not accurately quantify urban–rural differences and the extent to which the characteristics of each individual can explain the gap resulting in depressive symptoms. Therefore, there is a need for appropriate statistical methods to evaluate the degree to which relevant individual characteristics explain the difference between depressive symptoms among people in urban and rural areas. The Blinder–Oaxaca decomposition method has been used to examine the wage gap between men and women in the United States to further assess the average of various factors in the variables as well as the effect of wage differences caused by non-explanatory variables (14). Since then, it has been applied to health research many times (15, 16). Therefore, we use the Blinder–Oaxaca decomposition to quantify the average differences between groups by decomposing variables into explainable differences and unexplained differences caused by unobserved differences between groups (17).

The study aims to assess whether there is a gap in the prevalence of depressive symptoms among older adults in main residential locations and, in the case of a gap, quantitatively estimate the influence of main residential location on depressive symptoms among older adults. We expected that by focusing on the prevalence of depressive symptoms among older domestic immigrants, we could explore the effect of the main residential location on effectively narrowing the mental health gap between urban and rural older adults. This is conducive to reducing the prevalence of depressive symptoms and promoting the mental health of older adults.

Conceptual framework and hypotheses

The acculturation theory can be used to explain the relationship between main residential locations and depressive symptoms among older adults. The acculturation theory states that immigrants may experience the pressure of cultural adaptation on interacting with local residents, which can result in physical and psychological problems (18). Previous studies have shown that when people stay longer in a place, they tend to adapt to the culture of the place. As a result, their health

Abbreviations: CLHLS, Chinese Longitudinal Healthy Longevity Survey; CES-D, Center for Epidemiologic Studies Short Depression Scale; SES, socioeconomic status; ADL limitation, activities of daily living limitation; SD, standard deviation.

improves (19–21). In general, the duration of residence in a settlement relatively affects the health status of immigrants by changing their education, income, and health awareness. Based on this, we propose a hypothesis regarding the relationship between the main residential location and depressive symptoms.

Hypothesis: Rural–urban migrants have higher depressive symptom scores than permanent urban and rural residents.

Methods

Study population

We obtained data from the 2018 Chinese Longitudinal Healthy Longevity Survey (CLHLS), which was organized by the Health Aging and Development Research Center of Peking University/National Institute of Development. The project launched a baseline survey in 1998, which has been conducted eight times so far, covering the family structure, living arrangements, social participation, and quality of life of adults aged 65 and older. The survey involved face-to-face interviews with interviewees in the form of household visits to the community to collect information in Chinese. Investigators were selected by recruiting volunteers who required people with a bachelor's degree or higher to apply. Through the unified pre-job training, familiarization with the items of the questionnaire, question and answer skills, and the instructor led them to conduct interviews. The interviews were free of questions and answers. The cumulative number of visitors exceeded 110,000, of whom 67.4% were ≥80 years old. The sampling design of the survey adopted the multi-stage and unequal-proportion target random sampling method. First, ∼50% of the counties, county-level cities, or districts in 23 provinces, municipalities, or autonomous regions were randomly selected. In these areas, all centenarians who were alive and voluntarily participated in the survey were interviewed at home. Age and sex were randomly selected according to the number of centenarians in order to ensure that the number of respondents in other age groups is roughly similar to that of centenarians, and that the sex ratio of the sample is roughly similar. In 2018, we focused on all the older adults. The 2018 CLHLS data included 15,874 observers aged ≥65 years. Those who were younger than 65 years ($n = 84$), had missed data ($n = 6{,}705$), were not applicable ($n = 191$), and refused to participate ($n = 684$) were excluded. The remaining 8,210 older adults were included in the study (Figure 1). To maintain a nationally representative sample, the weight of age, sex, and residence in the 2018 CLHLS sample was based on categories of respondents with similar sociodemographic characteristics (22, 23); there were 7,042 weighted samples.

Measures of depressive symptom score

The depressive symptom score, which was a continuous variable, was selected as the dependent variable. The 2018 CLHLS questionnaire evaluated depressive symptom scores among older adults using the Center for Epidemiologic Studies Short Depression Scale (CES-D). The CES-D scale was developed by Radloff at the National Institute of Mental Health in 1977 and is widely used in epidemiological surveys to screen for depressive symptoms. The scale included three positive questions and seven reverse questions. The answers are "always" = "3," "often" = "2," "sometimes" = "1," and "rarely" or "never" = "0." After reversing the three positive impact items, a total score of 10 items was summed, with "depressive symptoms" assigned a value of "1" for those with a total score of ≥10; otherwise, it was normal, which was assigned a value of "0" (24, 25). The higher the depressive symptom score, the more severe the depressive symptoms. The purpose of determining whether there are depressive symptoms or not is to describe the prevalence rate of depressive symptoms among older adults in different groups and to further intuitively analyse the gap in depressive symptoms in different main residential locations. Related studies have proven that the CES-D scale can be used in Chinese and reported good reliability and validity (26). In this study, Cronbach's alpha coefficient of the CES-D scale was 0.774.

Classification of main residential locations

The existing literature proposes many methods for classifying main residential locations. For example, residents were previously classified according to the criteria of living in the local area for 6 months within a year or 5 or more years (27, 28). However, China's hukou system has affected the distribution of basic public services. This system divides hukou into urban hukou and rural hukou according to blood inheritance and geographical location. Under this system, people's employment and social welfare are related to household registration. In general, people with urban hukou enjoy far more benefits than rural hukou, such as education, healthcare, and social security (29, 30). Currently, in China, compared with older adults with rural hukou who can only enjoy basic pension benefits, those with urban hukou are much better off after retirement. However, the vast majority of people who migrate from rural to urban areas are unable to obtain urban hukou due to some reasons, such as a low level of education, so they are still associated with their place of birth and cannot enjoy the treatment guarantee of the urban population. With the rapid development of urbanization in China, more and more people are migrating from rural areas to urban areas, forming a subgroup. We take account of the place of residence, and hukou and residence time have a greater impact on older adults, especially mental health. Therefore, this study used a measure that combines the interviewees' residence and hukou identity information and the number of years of residence. Based on these, three types of main residential locations were determined: (a) urban residents, meaning that

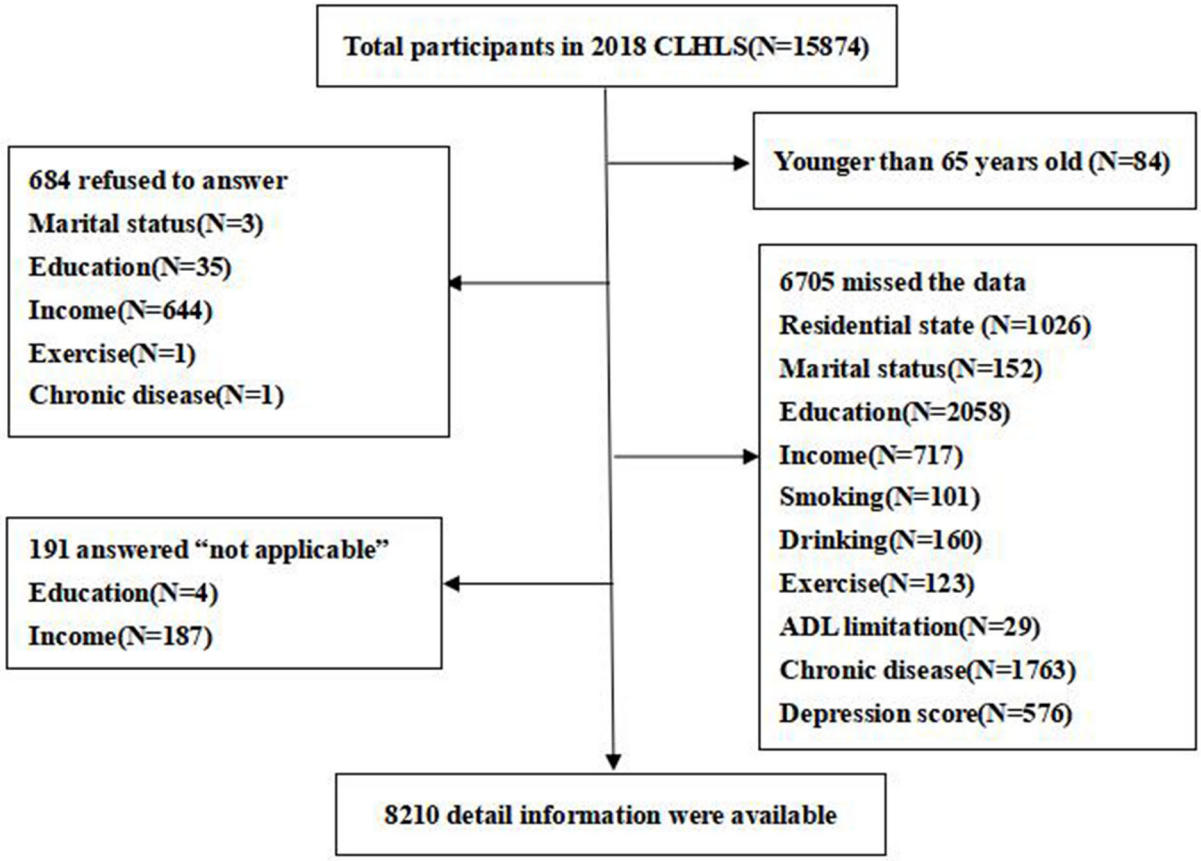

FIGURE 1
Study flowchart of participants selection (aged 65 years or older) from the Chinese Longitudinal Healthy Longevity Survey 2018 survey data.

the respondents had an urban hukou and had lived in the city for 10 years or more; (b) rural–urban migrants, indicating that interviewees had a rural hukou, but live in urban areas; and (c) rural residents, implying that respondents have a rural hukou and have lived in rural areas for 10 years or more (31, 32).

Covariates

Population baseline characteristics included (a) sociodemographic factors: age (continuous variable), sex (male or female), and marital status (married/cohabiting or single); (b) socioeconomic status (SES): years of education (continuous variable) and income (continuous variable); (c) lifestyle: smoking (yes or no), drinking (yes or no), and exercise (yes or no); and (d) health status: activities of daily living limitation (ADL limitation; yes or no) and chronic diseases (yes or no). Among them, the assignment of chronic diseases was based on whether the patient had been diagnosed with a certain disease, which we defined as suffering from chronic disease if interviewers had one or more types of chronic disease. We collected data on chronic diseases in the form of self-reports by interviewees. Table 1 shows covariate collection and assignment.

Statistical analysis

We used STATA/MP 15.0 (Stata Corp, College Station, TX, USA) for all the analyses. The analysis process in this study was divided into three steps. First, descriptive statistics were expressed as mean and standard deviations (SD) or numbers and percentages. Second, ordinary least squares regression was used to estimate whether there was a significant correlation between the main residential location and depressive symptoms. In the regression analysis, we divided the participants into three models according to the sociodemographic characteristics and behavioral health: model 1 (only considering main residential location and depressive symptom score), model

TABLE 1 Covariates and assignment.

Variable	Question	Assignment
Sociodemographic characteristics		
Age	Validated age	
Gender	Sex	1. Male (1)
		2. Female (0)
Married/cohabiting	Current marital status	1. Married and living with spouse (1 = married)
		2. Married but not living with spouse (1 = married)
		3. Divorced (0 = single)
		4. Widowed (0 = single)
		5. Never married (0 = single)
SES		
Education (years)	How many years did you attend school?	Continuous variables
Income	What was the income per capita of your household last year?	Continuous variables
Life styles		
Smoking	Do you smoke at the present time?	1. Yes (1)
		2. No (0)
Drinking	Do you drink alcohol at the present time?	1. Yes (1)
		2. No (0)
Exercise	Do you do exercises regularly at present?	1. Yes (1)
		2. No (0)
Health status		
ADL limitation	For at least the last 6 months have you been limited in	1. Yes, strongly limited (1 = yes)
	activities people usually do, because of a health problem?	2. Yes, limited (1 = yes)
		3. Not limited (0 = no)
Chronic disease	Are you suffering from any of the following chronic disease?	1. Yes (1)
	(Diagnosed by hospital?)	2. No (0)

ADL limitation, activities of daily living limitation. Chronic diseases include hypertension, diabetes, heart disease, stroke, cerebrovascular disease, bronchitis, emphysema, asthma, pneumonia, pulmonary tuberculosis, cataracts, glaucoma, cancer, prostate tumor, gastric or duodenal ulcer, Parkinson's disease, bedsores, arthritis, dementia, epilepsy, cholecystitis, cholelithiasis disease, blood disease, rheumatism or rheumatoid disease, chronic nephritis, galactophore disease, uterine tumor, hyperplasia of prostate, hepatitis, and others.

2 (considering the sociodemographic characteristics and socioeconomic status), and model 3 (considering both the sociodemographic characteristics and lifestyle and health status). The Blinder–Oaxaca decomposition method was then used, which acts as the average difference of results between different groups. The depressive symptom gap between the two groups was divided into two parts, namely, the "explained" group difference and the difference of other factors that cannot be explained (14, 15, 33). The model is represented as follows:

$$\bar{y}_a - \bar{y}_b = \left(\bar{x}_a - \bar{x}_b\right)\beta_b + \bar{x}_b\left(\beta_a - \beta_b\right),$$

where a and b represent the groups of older adults with different main residential locations, $(\bar{x}_a\text{-}\bar{x}_b)\beta_b$ is referred to as the "explained component", and $\bar{x}_b(\beta_a\text{-}\beta_b)$ is the "unexplained component." By calculating the average difference in depressive symptom scores among groups, the explainable factors resulting in the depressive symptom gap between groups were estimated and quantified (34). According to the principle of Blinder–Oaxaca decomposition, we acquired three models and performed a comparative analysis of urban residents, rural–urban migrants, and rural residents.

Results

Participants' characteristics

Table 2 presents the descriptive characteristics of the study participants. A total of 7,042 (weighted) older adults participated in this study. Of these, 1,926 (27.35%) were urban residents, 1,886 (26.78%) were rural–urban migrants, and 3230 (45.87%) were rural residents. Of all the participants, 23.02% exhibited depressive symptoms. Rural–urban migrants had the highest depressive symptom score (7.164), followed by rural

TABLE 2 Descriptive characteristics of study participants from CLHLS 2018 (weighted).

	Total	Urban resident	Rural–urban migrant	Rural resident
Total	7,042	1,926	1,886	3,230
	(100.00%)	(27.35%)	(26.78%)	(45.87%)
Depressive symptoms	1,621	414	497	710
	(23.02%)	(21.50%)	(26.35%)	(21.98%)
CES-D score[a]	6.867	6.761	7.164	6.758
	(4.351)	(4.706)	(4.422)	(4.073)
Sociodemographic characteristics				
Age[a]	72.391	72.935	72.494	72.006
	(6.592)	(6.668)	(6.783)	(6.407)
Male	3,330	917	908	1,505
	(47.29%)	(47.61%)	(48.14%)	(46.59%)
Married/cohabiting	5,167	1,453	1,337	2,377
	(73.37%)	(75.44%)	(70.89%)	(73.59%)
SES				
Education (years)[a]	4.905	8.268	3.671	3.620
	(4.310)	(4.643)	(3.469)	(3.366)
Income (yuan)[a]	43,534.45	70,883.57	33,993.25	32,799.24
	(36,014.88)	(30,640.93)	(32,731.05)	(32,072.14)
Life styles				
Smoking	1,336	283	402	651
	(18.97%)	(14.69%)	(21.31%)	(20.15%)
Drinking	1,321	310	378	633
	(18.76%)	(16.10 %)	(20.04 %)	(19.60%)
Exercise	2,928	1,175	730	1,023
	(41.58 %)	(61.01%)	(38.71%)	(31.67%)
Health status				
ADL limitation	1,462	386	417	659
	(20.76%)	(20.04%)	(22.11%)	(20.40%)
Chronic disease	5,943	1,729	1,563	2,651
	(84.39%)	(89.77%)	(82.87%)	(82.07%)

[a]Continuous variables are reported as mean values and standard deviations; categorical variables are reported as numbers and percentages.
CES-D, Center for Epidemiologic Studies Short Depression Scale; ADL limitation, activities of daily living limitation.

residents; urban residents had the lowest depressive symptom scores. This finding was consistent with our hypothesis. In general, compared with other older adults, the majority of those who had depressive symptoms were woman, single persons, people who liked smoking and drinking alcohol, could not perform their daily activities, and were temporary city residents.

Ordinary least square regression analysis

Table 3 presents the results of the ordinary least square regression analysis. In the unadjusted model, rural–urban migrants were at higher risk of exhibiting depressive symptoms. Model 1 considered sociodemographic characteristics and socioeconomic status. With the urban residents as the reference group, the coefficient of rural–urban migrants was −0.320, and the coefficient of rural residents was −0.719; both passed the 5% statistical test, indicating that the main residential location negatively affected depression scores. Model 2 not only considered the sociodemographic characteristics and socioeconomic status but also adjusted for lifestyles and health status. The results showed that the relationship between rural–urban migrants and depressive symptoms was significantly stronger.

TABLE 3 Ordinary least squares regression for main residential location and total depressive symptom score (weighted).

Model specifications	All sample		
	Unadjusted model	Adjusted model 1	Adjusted model 2
Urban resident		(Ref.)	
Rural–urban migrant	0.403**	−0.320*	−0.447**
	(0.126,0.679)	(−0.638, −0.002)	(−0.759, −0.136)
Rural resident	−0.003	−0.719***	−0.924***
	(−0.249,0.242)	(−1.015, −0.424)	(−1.215, −0.633)
Sociodemographic characteristics			
Age		0.024**	0.001
		(0.008, 0.041)	(−0.015, 0.018)
Male		−0.543***	−0.399***
		(−0.760, −0.327)	(−0.635, −0.163)
Married/cohabiting		−0.836***	−0.876***
		(−1.085, −0.586)	(−1.119, −0.633)
SES			
Education		−0.031*	−0.004
		(−0.060, −0.001)	(−0.033, 0.024)
Income		−0.000015***	−0.000013***
		(−0.000018, −0.000012)	(−0.000016, −0.000010)
Life styles			
Smoking			0.186
			(−0.095, 0.467)
Drinking			−0.643***
			(−0.919, −0.368)
Exercise			−1.426***
			(−1.632, −1.220)
Health status			
ADL limitation			1.537***
			(1.291, 1.783)
Chronic disease			0.295*
			(0.023, 0.566)

95% confidence intervals (CI) in parentheses.
ADL limitation, activities of daily living limitation.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

Decomposition of the depressive symptom gap between urban residents and rural–urban migrants (weighted)

As shown in Table 4 (model 1), the depressive symptom score of urban residents was 0.403 lower than that of rural–urban migrants ($p < 0.05$). The gap in depressive symptoms is mainly explained by individual attribute differences (499.75%), indicating that the explained component "overexplains" the difference in the average score between the two groups. Assuming that this value is 100%, the difference in the explained component simply explains all the differences in depressive symptom scores. However, if it is >100%, it signifies that once the explained component is controlled, the score gap is reversed. The depressive symptom score of rural–urban migrants was not higher than that of urban residents but was lower than that of urban residents. This is mainly because of the difference in depressive symptoms according to income (49.90%). In addition, the difference in education years (38.53%) was also a significant reason for the difference in depressive symptom scores between the two groups. By contrast, the differences in scores caused by other explanatory factors were significantly less.

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TABLE 4 Blinder–Oaxaca decomposition of the gap in depressive symptoms between the urban resident and rural–urban migrant samples (weighted).

	1. Urban resident (1) and Rural-urban migrant (2)	
	Mean (95%CI)	N/%
Group_1 (urban resident)	6.761***	1,926
	(6.563, 6.959)	
Group_2 (rural–urban migrant)	7.164***	1,886
	(6.972, 7.355)	
Difference	−0.403**	100.00%
	(−0.678, −0.127)	
Explained difference	−2.014***	499.75%
	(−2.355, −1.673)	
Unexplained difference	1.611***	−399.75%
	(1.189, 2.033)	
Explanatory variables		
Sociodemographic factors		
Age	−0.010	0.50%
	(−0.026, 0.006)	
Male	0.005	−0.25%
	(−0.023, 0.033)	
Married/cohabiting	−0.015	0.74%
	(−0.036, 0.007)	
SES		
Education (years)	−0.776***	38.53%
	(−1.055, −0.496)	
Income	−01.005***	49.90%
	(−1.214, −0.797)	
Life styles		
Smoking	−0.004	0.20%
	(−0.037, 0.028)	
Drinking	−0.012	0.60%
	(−0.033, 0.008)	
Exercise	−0.174***	8.64%
	(−0.260, −0.088)	
Health status		
ADL limitation	−0.046	2.28%
	(−0.101, 0.010)	
Chronic disease	0.023	−1.14%
	(−0.010, 0.057)	

95% confidence intervals (CI) in parentheses.
N, number; ADL limitation, activities of daily living limitation.
**$p < 0.01$.
***$p < 0.001$.

TABLE 5 Blinder-Oaxaca decomposition of the gap in depressive symptoms between urban resident and rural resident samples (weighted).

	2. Urban resident (1) and Rural resident (2)	
	Mean (95%CI)	N/%
Group_1 (urban resident)	6.761***	1,926
	(6.563, 6.959)	
Group_2 (rural resident)	6.758***	3,230
	(6.607, 6.908)	
Difference	0.003	100.00%
	(−0.246, 0.252)	
Explained difference	−1.293***	−43,100.00%
	(−1.585, −1.002)	
Unexplained difference	1.297***	43,233.33%
	(0.924, 1.669)	
Explanatory variables		
Sociodemographic factors		
Age	0.019	−1.47%
	(−0.005, 0.043)	
Male	0.002	−0.15%
	(−0.004, 0.008)	
Married/cohabiting	−0.018	1.39%
	(−0.043, 0.007)	
SES		
Education (years)	−0.630***	48.72%
	(−0.854, −0.407)	
Income	−0.480***	37.12%
	(−0.652, −0.308)	
Life styles		
Smoking	−0.023	1.78%
	(−0.046, 0.001)	
Drinking	0.042**	−3.25%
	(0.013, 0.072)	
Exercise	−0.191***	14.77%
	(−0.283, −0.098)	
Health status		
ADL limitation	−0.006	0.46%
	(−0.042, 0.031)	
Chronic disease	−0.008	0.62%
	(−0.037, 0.021)	

95% confidence intervals (CI) in parentheses.
N, number; ADL limitation, activities of daily living limitation.
**$p < 0.01$.
***$p < 0.001$.

Combined with descriptive statistics, in addition to the unexplained differences that result in the gap in depressive symptoms, other attributes of urban residents, such as better marital status and more opportunities for exercise, make the depressive symptom scores lower than the rural–urban migrants. The negative explained difference was counteracted by a larger positive unexplained difference. Rural–urban migrants reported more severe depressive symptoms for a given set of characteristics.

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TABLE 6 Blinder–Oaxaca decomposition of the gap in depressive symptoms between the rural resident and rural–urban migrant samples (weighted).

	3. Rural resident (1) and Rural-urban migrant (2)	
	Mean (95%CI)	N/%
Group_1 (rural resident)	6.758***	3,230
	(6.607, 6.908)	
Group_2 (rural–urban migrant)	7.164***	1,886
	(6.972, 7.355)	
Difference	−0.406***	100.00%
	(−0.650, −0.162)	
Explained difference	0.071	−17.49%
	(−0.032, 0.175)	
Unexplained difference	−0.477***	117.49%
	(−0.709, −0.246)	
Explanatory variables		
Sociodemographic factors		
Age	0.011	15.49%
	(−0.005, 0.028)	
Male	0.014	19.72%
	(−0.013, 0.042)	
Married/cohabiting	−0.009	−12.68%
	(−0.023, 0.006)	
SES		
Education (years)	0.009	12.68%
	(−0.024, 0.042)	
Income	0.033	46.48%
	(−0.018, 0.083)	
Life styles		
Smoking	−0.001	−1.41%
	(−0.007, 0.005)	
Drinking	−0.001	−1.41%
	(−0.009, 0.006)	
Exercise	0.055***	77.46%
	(0.021, 0.089)	
Health status		
ADL limitation	−0.037	−52.11%
	(−0.090, 0.015)	
Chronic disease	−0.003	−4.23%
	(−0.011, 0.005)	

95% confidence intervals (CI) in parentheses.
N, number; ADL limitation, activities of daily living limitation.
***$p < 0.001$.

Decomposition of the depressive symptom gap between urban residents and rural residents (weighted)

In model 2 of Table 5, the depressive symptom score of rural residents was 6.758 points, which was 0.003 points lower than that of urban residents. It is worth noting that the proportion of the explained difference in the Blinder–Oaxaca decomposition of depressive symptom scores was −43,100%. This suggests that the explained difference plays an inverse role in driving a gap in the depressive symptom scores between the two groups. This means that after considering these covariates, the score gap between the two groups will not increase but will decrease further. Years of education (48.72%), income (32.8%), and exercise (14.77%) were the most important factors that affected depressive symptoms.

TABLE 7 Contribution of individual characteristics to the explained gap in depressive symptoms (weighted).

Model	1	2	3
Explained difference	499.75%	−43,100.00%	−17.49%
Explanatory variables			
Sociodemographic factors			
Age	0.50%	−1.47%	15.49%
Male	−0.25%	−0.15%	19.72%
Married/cohabiting	0.74%	1.39%	−12.68%
SES			
Education (years)	38.53%	48.72%	12.68%
Income	49.90%	37.12%	46.48%
Life styles			
Smoking	0.20%	1.78%	−1.41%
Drinking	0.60%	−3.25%	−1.41%
Exercise	8.64%	14.77%	77.46%
Health status			
ADL limitation	2.28%	0.46%	−52.11%
Chronic disease	−1.14%	0.62%	−4.23%

Columns 1–3 correspond to models 1–3 in Tables 4–6.
ADL limitation, activities of daily living limitation.

Decomposition of the depressive symptom gap between rural residents and rural–urban migrants (weighted)

In model 3 of Table 6, the depressive symptom score of rural residents was 6.758 points, which was 0.406 points lower than that of rural–urban migrants ($p < 0.001$). Among the explainable differences in depressive symptoms, exercise (77.46%) and income (46.48%) were more likely to be explained. Interestingly, the proportion of ADL limitation was positive in the previous inter-group comparison, whereas it was negative in the rural residential and rural–urban migrant groups. Moreover, the proportion was very high.

Table 7 shows the contribution of individual characteristics to all models explaining the gap in depressive symptoms. Columns 1–3 correspond to models 1–3 in Tables 4–6. Table 7

clearly shows that a large part of the gap in depressive symptoms in all the models is explained by years of education and income. The proportion of ADL limitation in the explanatory difference among older adults in different main residential locations was relatively extreme, accounting for only 2.28% of urban residents and rural–urban migrants. However, the proportion of ADL limitation between rural residents and rural–urban migrants was as high as −52.11%.

Discussion

Our research shows that the prevalence of depressive symptoms among older adults in different main residential locations differs significantly. The depressive symptom scores of the rural population living in cities were significantly higher than those of the urban and rural residents. This is consistent with previous studies on older adults (35, 36). The analysis between the different groups showed that education and income were the most significant explanatory factors. This finding is consistent with the results of previous studies (37, 38).

The results of previous studies are inconsistent with regard to the relationship between main residential locations and depressive symptoms. Regarding high-income countries, the prevalence of depressive symptoms in urban areas was higher in 2017 (39). Regarding low- and middle-income countries, however, especially China, the prevalence of depressive symptoms was higher in rural areas in 2011 (38–40). This phenomenon is attributable to the difference in the economic level between high-income countries and low- and middle-income countries, resulting in different environmental characteristics in urban and rural areas and differences in basic public services enjoyed by residents.

Some studies show that internal migration populations from rural-to-urban areas have a lower rate of depression in China (11, 41). However, our study shows that older adults who lived in rural and urban areas for a long time had lower depressive symptom scores than rural–urban migrants, which is inconsistent with the findings of previous studies. In the process of urbanization, the internal migration population must overcome the social, physical, and even psychological challenges driven by migration. After a long period of cultural adaptation, it is possible to successfully migrate. However, for immigrants who do not have sufficient time to adapt to the environment in which they move, their psychological status is worrying.

This study shows that older adults with low depressive symptom scores had longer years of education, better income, and more exercise. In urban and rural areas, with relatively basic leisure facilities, exercise is an effective way to relieve stress (42, 43). When rural–urban migrants move to a new environment, they have to work for a living and often ignore healthy behaviors, such as exercise. However, older adults who have lived in urban or rural areas for a long time are stable and have more time and experience to pay attention to their own health. The prevalence of depressive symptoms among urban residents was the lowest, and a large part of the explanation was related to the social environment in our study. A high-quality urban environment is conducive to the mental health of urban residents. The depressive symptom score of rural–urban migrants was the highest, which can be explained by the institutional inequality facing rural migrants in Chinese urban areas. Owing to the existence of the hukou system, rural–urban migrants entering urban areas and rural–urban migrants can only receive the most basic pensions, which are not enough to support urban life. In addition, the living pressure on children is relatively high, while older adults have to worry about pension issues. At this stage, the physical and mental health of rural–urban migrants is significantly challenged.

The ratios of ADL limitation were the opposite among older adults with different main residential locations. This phenomenon can be explained by the acculturation theory. Following the increase in the age of the rural–urban migrants, the loss of their physical health has become more serious, especially for rural–urban migrants with ADL limitation. They do not have access to urban hukou and cannot enjoy the preferential medical resources of the urban population, thereby increasing their psychological burden. Older adults with more years of education have struggled in the urban areas for decades. However, their urban identity cannot be recognized, resulting in excessive psychological pressure and an increasing in the possibility of suffering from depressive symptoms.

In summary, this study decomposes the gap in the depressive symptom score between different main residential locations, positing that a long-term and stable residential environment may reduce the risk of depression among older adults.

The study of reducing depressive symptom scores among older adults provides us with a lot of inspiration. First, due to the development of urbanization, a large number of rural people go to the city, resulting in an increase in urban pressure. It is a good measure to attract more people to the countryside through the revitalization of the countryside. Thus, providing more development opportunities to rural areas is key to narrowing the gap between urban and rural areas. By tilting more resources to rural areas, for example, to attract more young people to return to their hometowns for the benefit of developing industries in rural talents, more ambitious and capable people can go to rural areas and build beautiful villages. We can improve education, provide more job opportunities, help people establish a correct concept of health, develop healthy behavior, and obtain more social support (44). More importantly, it is crucial to set up psychological counseling stations in grassroots medical and health institutions and install sports building materials in communities and villagers' activity centers to further improve the mental health of rural people. As urbanization is

an inevitable process of human progress, the coverage of the medical security system for the rural–urban migrants should be more comprehensive and consider the physical and mental health of older adults. The pension treatment standard should be gradually unified to achieve consistency between urban and rural areas.

This study shows that education and income are the most important explanatory factors for the impact of main residential location on depressive symptoms, which is not only applicable to China but also to other low- and middle-income countries. Education and income, as symbols of socioeconomic status, not only affect the physical health of older adults but also have a non-negligible effect on the mental health of the population. Among older adults in low- and middle-income countries, those with a long education are more able to take on light jobs and increase their income. This means that they do not need to worry about food or clothing in their later lives. By contrast, those with a short education are relatively more likely to work hard. Therefore, improving people's education is a priority in low- and middle-income countries.

Strengths and limitations

The main advantages are as follows: First, we used the CLHLS, a representative sample of long-lived older adults in China, to examine the mental health of long-lived older adults and add some health-related variables, such as ADL limitation and chronic diseases. Second, we used the Blinder–Oaxaca decomposition method to quantify the explainable factors that cause the gap in the depressive symptoms among older adults in urban and rural areas and to clarify the share of each factor in the effect of depressive symptoms.

Our study has several limitations. First, it is a cross-sectional study, which does not support the causal inference between main residential locations and depressive symptoms among older adults. It may be difficult to infer why the gap in the depressive symptoms among older adults under different main residential locations cannot be explained. Second, we may not be able to explain some of the factors that influence the difference between the groups in the unexplained part of the depressive symptom gap (45). Third, using the CES-D scale to evaluate depressive symptoms can only provide the prevalence rate of depressive symptoms but cannot provide the prevalence rate of depression.

Conclusion

This study reports that the scores of depressive symptoms among older adults differed according to main residential locations. The depressive symptom score of older adults living permanently in urban or rural areas was lower than that of rural–urban migrants. Women living alone, with lower education, lower income, no drinking, no exercise, ADL restrictions, and chronic diseases were associated with higher depressive symptoms among older adults. The most important reasons for the urban–rural gap in depressive symptoms are education and income.

The results of this study have several practical implications. The results showed that healthcare policymakers and professionals need to consider a number of factors when considering higher depressive symptom scores. These factors include the demographic characteristics, socioeconomic status, and behavioral lifestyle of different countries. Health education and health promotion strategies should be used to improve the health literacy of older adults and prevent an increase in their depressive symptom scores. Particularly, primary health institutions should focus on the mental health of older adults and provide mental health education and psychological counseling. Corresponding policies should be formulated according to the characteristics of the country. In this study, there was a significant difference in the depressive symptom scores between rural–urban migrants and permanent residents. The development of industries in rural areas attracts more young people to return to their hometowns for benefits. It is necessary for national health insurance policies to pay more attention to temporary residents and to unify urban and rural pension standards. There is a need for further research to explore why different factors have different effects on depressive symptoms among older adults.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found at: http://opendata.pku.edu.cn/dataverse/CHADS.

Ethics statement

The studies involving human participants were reviewed and approved by the Ethical Review Committee of Peking University (IRB00001052-13074). The patients/participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

YC and QY designed the study and responsible for the collation and analysis of the data. YC analyzed the data and wrote the first draft of the manuscript. QY supported the interpretation of the data. WL contributed to formal analysis. GZ contributed to conceptualization, methodology,

and editing. All authors contributed to the research programme, contributed to the final manuscript, and approved the final manuscript version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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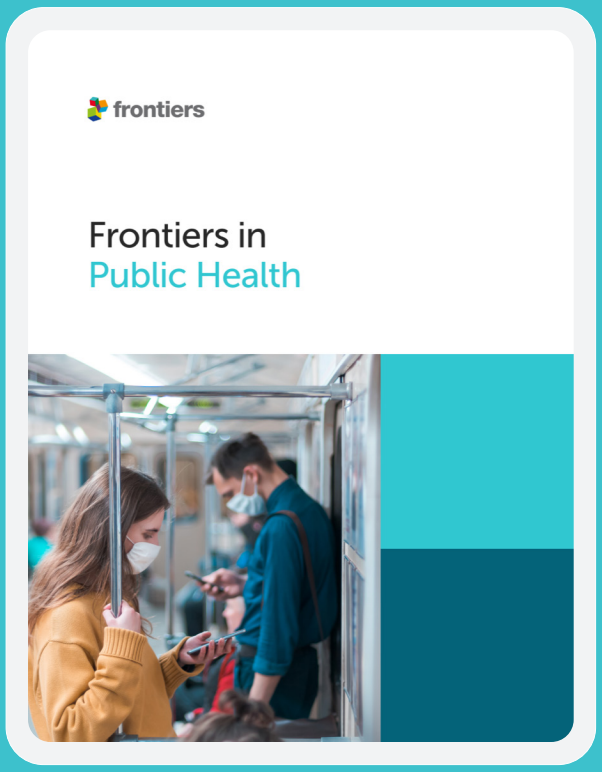

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