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Cognitive and mental health improvement under- and post-COVID-19

Edited by
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Cognitive and mental health improvement under- and post-COVID-19

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Editorial: Cognitive and mental health improvement under- and post-COVID-19

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Editorial on the Research Topic
Cognitive and mental health improvement under- and post-COVID-19

Introduction

An increasing body of research suggests that the COVID-19 pandemic has exacerbated mental health challenges worldwide (Santomauro et al., 2021; Penninx et al., 2022; Chen et al., 2023; Barlati et al., 2021; Harrison and Taquet, 2023), including higher levels of stress, depression, anxiety, and suicidal ideation, as well as a notable rise in cognitive impairments (Harrison and Taquet, 2023; Corbett et al., 2023; Galderisi et al., 2024; Nibbio et al., 2025). While the direct biological effects of the virus and the psychological toll of infection have contributed to these outcomes (Penninx et al., 2022; Harrison and Taquet, 2023), growing evidence underscores that key drivers also include a pervasive fear of contagion (Alimoradi et al., 2022; Chen et al., 2024a) and prolonged feelings of loneliness and social isolation (Hagiwara et al., 2024; Chen et al., 2024b). These psychosocial stressors have affected individuals across various age groups and socioeconomic backgrounds.

Although the World Health Organization officially declared an end to COVID-19 as a global public health emergency on May 5, 2023—after initially proclaiming it on January 30, 2020—new infections continue to be reported around the world. Moreover, the psychological toll remains evident: studies indicate that loneliness, which surged due to stringent quarantine and physical-distancing measures, has yet to return to pre-pandemic levels (Kullgren et al., 2023; Sugaya et al., 2024). Many individuals continue to experience a sense of isolation, reflecting the deep social and emotional impact of pandemic restrictions.

These developments emphasize the urgent need for initiatives to enhance cognitive and mental wellbeing during and beyond the pandemic era. By addressing persistent challenges, health professionals, policymakers, and communities can work together to foster resilience, reduce long-term psychological harm, and support cognitive recovery.

This Research Topic compiles 23 studies aimed at addressing these unresolved issues and advancing understanding of interventions that promote cognition and mental health. The participants represent diverse populations, including COVID-19 patients (Bonfim et al.; Li et al.), healthcare professionals (Cheng et al.; Jiang et al.; de Vroege and van den Broek; Zeng et al.; Zhu et al.), medical students (Wang, Zhang, et al.), the general population (Barbalat et al.; Hao et al.; Kulbin et al.; Sasaki et al.), college students (Qing et al.; Shi; Tang and He), and school teachers (Vega-Fernández et al.).

The topics of these studies are equally diverse. They explore mental health during and after the pandemic, identify risk and protective factors—such as emotion malleability beliefs (Sasaki et al.), self-control (He et al.), social support (Shi), and active leisure engagement (Kulbin et al.)—and evaluate the effects of various interventions. Interventions studied include exercise (Wang, Tian, et al.), exposure to urban green spaces (Patwary et al.), online mindfulness programs (Melvin et al.), multicomponent lifestyle medicine (Wong et al.), and light therapy (Chen et al.).

Cognitive and mental health status

Being infected by COVID-19 represents a major psychological stressor, with the virus itself exerting direct biological effects that may contribute to cognitive and mental health challenges. In a retrospective study conducted in Brazil, Bonfim et al. reported that 24% of 630 outpatients, confirmed COVID-19 positive between December 2020 and March 2022, exhibited cognitive symptoms. These symptoms ranged from difficulties with attention and memory to impaired thinking. Depression, fatigue, female gender were identified as risk factors for these cognitive symptoms. Similarly, Li et al. surveying 482 patients in China from December 2022 to June 2023, found that 13% experienced symptoms of depression, 27% anxiety, and 25% stress. The severity of long-term COVID symptoms correlated with poorer mental health outcomes, while resilience and social support emerged as protective factors.

While infection-control measures have been effective in limiting the spread of the virus, they have often come at a cost to mental health. For example, Barbalat et al. conducted a nationwide online survey during France's first lockdown (March–May 2020), involving approximately 19,000 participants. They observed a gradual decline in mental health over the course of the lockdown, with psychiatric conditions and concerns about access to protective equipment serving as risk factors. Conversely, optimism about the pandemic's trajectory, neighborhood support, and participation in collective actions were protective factors. Similarly, Qing et al. examined the impact of campus lockdowns on Chinese university students and found elevated levels of stress and depression compared to pre-lockdown periods. Using latent class mixed models, the authors identified distinct mental health trajectories and found that students with unfavorable peer relationships were more likely to experience poorer mental health trajectories.

Healthcare professionals, frequently exposed to patients and heavy workloads, have reported high levels of stress and mental health challenges during the pandemic (Hacimusalar et al., 2020). Zhu et al. surveyed 145 members of the medical security team at the 2022 Winter Olympic Games and Paralympics and found that longer work durations were associated with worse mental health outcomes, including higher levels of depression and anxiety. Females were particularly vulnerable. Such findings underscore the unique pressures faced by frontline workers during public health crises.

The pandemic's impact extends beyond mental health to physical wellbeing and motivation. Vega-Fernández et al., in a study of 161 Chilean school teachers conducted in late 2021, reported that 98% experienced musculoskeletal disorders in the past year. These disorders were associated with poorer physical and mental quality of life. In this study, females were also more likely to have musculoskeletal disorders. Tang and He found that college students with high depressive symptoms during the pandemic showed reduced academic engagement, highlighting the broader motivational consequences of mental health struggles.

As COVID-19 symptoms have become milder and restrictions relaxed, new mental health challenges have emerged. Hao et al. reported that after China eased its COVID-19 control measures in January 2023, about one in five individuals exhibited over-concern about the virus, characterized by obsessive thoughts and anxiety regarding infection. Poor self-rated health and worries about family members contracting the virus were associated with these over-concerns. Cheng et al., in a survey of over 2,000 healthcare professionals shortly after these relaxations, found that over half reported symptoms of depression and anxiety, with female gender, younger age, low professional rank, and longer working hours identified as risk factors. In another survey of healthcare professionals, Jiang et al. further suggested reciprocal relationships between mental health problems and job burnout during this period.

Despite the general decrease in infection risk and social isolation as the pandemic winds down, studies indicate that loneliness, heightened by stringent quarantine measures, has not fully returned to pre-pandemic levels (Kullgren et al., 2023; Sugaya et al., 2024). de Vroege and van den Broek surveyed 510 mental healthcare professionals and found improvements in work-life balance and reductions in mental health complaints post-pandemic compared to earlier stages. However, 36% reported increased stress and 21% experienced more depression. Wang, Zhang, et al. also noted that one in four medical students in March 2023 reported high stress levels. These findings emphasize the importance of ongoing mental health monitoring and tailored care, even as the pandemic subsides.

Not all outcomes of the pandemic have been negative. Some individuals have demonstrated resilience and even posttraumatic growth, characterized by deeper appreciation for life and more meaningful interpersonal relationships. For example, Zeng et al. reported that 39% of Chinese resident physicians surveyed in March 2023 exhibited posttraumatic growth. Satisfaction with income and sufficient workplace support were key factors associated with posttraumatic growth. These findings highlight the potential to foster resilience and posttraumatic growth and offer a pathway to improved mental health outcomes.

Risk and protective factors

Female gender

A consistent risk factor identified in the above mentioned studies is being female (Bonfim et al.; Zhu et al.; Vega-Fernández et al.; Cheng et al.). This gender difference is not a new finding; epidemiological studies have long observed that females are at higher risk of developing psychiatric disorders, particularly depressive (Salk et al., 2017) and anxiety disorders (McLean et al., 2011). Several mechanisms have been proposed to explain this vulnerability. For instance, females have been reported to experience more severe forms of adverse childhood experiences,

predisposing them to mental health challenges (Hirai et al., 2025). Moreover, females are more likely to engage in rumination (i.e., repetitive and passive focus on negative emotional experiences) (Johnson and Whisman, 2013) and exhibit risk-aversive behaviors in high stress situations (Lei et al., 2021). They are also less likely to engage in intense physical activity (Nakagawa et al., 2020), which has been associated with mental health benefits (Chen and Nakagawa, 2023a,b). Another explanation is highlighted by Sasaki et al., who investigated the role of emotion malleability beliefs. Their findings suggest that females are more likely to hold fixed beliefs that they cannot control or change their emotions. These beliefs were linked to higher levels of psychological distress and were particularly prevalent among women, in those under 45 years old, and those with psychiatric disorders.

Social support

Social support, consistent with extensive evidence (Taylor, 2011; Chen, 2017a), has been identified as a crucial protective factor. In addition to the findings by Li et al., Barbalat et al., Qing et al., and Zeng et al., Shi reported that college students with higher levels of social support experienced lower levels of depression and anxiety. The study suggested that social support may enhance perceived control, while a lack of support could lead to a sense of helplessness, a key factor contribute to the development of depressive states (Maier and Seligman, 2016). Perceived control promotes problem-focused coping strategies that help address stressors, while low perceived control is associated with maladaptive coping strategies, such as avoidance, rumination, and suppression, which increase the risk of psychopathology (Lincoln et al., 2022).

Self-control

Self-control also appeared as an important protective factor. He et al. found a negative correlation between self-control and symptoms of depression, anxiety, and irritability in college students. Using network analysis, they identified impulse control as a bridge between self-control and irritability or anxiety symptoms, while resistance to temptation acted as a bridge between self-control and depressive symptoms. Self-control, which enables individuals to manage their emotions, behaviors, and thoughts, is a crucial determinant of wellbeing (Tangney et al., 2018), including emotional development (Eisenberg et al., 2014).

Leisure engagement

In addition to social support and self-control, active leisure engagement has emerged as another key protective factor against stress and mental health challenges. Kulbin et al., using latent profile analysis, categorized 439 Estonia adults into four distinct trajectories based on changes in stress and coping. They found that participants in the healthiest trajectories reported higher levels of active leisure engagement, such as physical exercise, spending time in nature, and pursuing hobbies. These activities are known to promote mental health and resilience (see also the next section) (Taquet et al., 2016; Chen, 2017b; Koga et al., 2023).

Together, these findings highlight the importance of a multifaceted approach to mental wellbeing, combining psychological, behavioral, and social strategies to mitigate the risk of psychopathology.

Interventional strategies

The current Research Topic offers valuable insights into the benefits of various intervention strategies for mental health.

Physical exercise

Wang, Tian, et al. conducted a systematic review and meta-analysis to assess the effects of physical exercise interventions on mental health. Based on 12 identified studies, they estimated the effect size as follows: for depression, standardized mean difference (SMD) = −1.02 (95% CI: −1.42 to −0.62); for anxiety, SMD = −0.81 (95% CI: −1.10 to −0.52); for stress, SMD = −1.05 (95% CI: −1.33 to −0.78). The greatest benefits were observed with single exercise sessions lasting 30–40 min and a frequency of 3–5 times per week. These findings align with extensive evidence supporting the mental health benefits of regular physical activity (Nakagawa et al., 2020; Chen and Nakagawa, 2023a,b; Chen, 2017b; Koga et al., 2023; Sakai et al., 2021; Deste et al., 2023; Chen et al., 2017). The biological mechanisms behind these effects include the release of neurotrophic factors, endorphins, and endocannabinoids, along with activation of the dopamine and serotonin neurotransmitter systems (Chen and Nakagawa, 2023a,b; Chen et al., 2017, 2016; Hou et al., 2024).

Nature contact

Patwary et al. found that spending more time outdoors in green spaces after lockdowns significantly improved mental health, reducing symptoms of depression and anxiety. This finding is consistent with the growing interest in nature and horticultural therapy (Chen, 2018a; Chen and Nakagawa, 2018, 2019; Yamashita et al., 2021; Mizumoto et al., 2024). The benefits of nature contact are linked to the relaxation of the brain, as well as endocrine and immune effects (Chen, 2018a; Chen and Nakagawa, 2018, 2019; Yamashita et al., 2021; Mizumoto et al., 2024). Furthermore, engaging in physical activity while in nature promotes social interactions, reducing loneliness and enhancing perceived social support (Kabisch et al., 2017).

Mindfulness

Melvin et al. conducted a qualitative, interpretative phenomenological analysis of participants and facilitators in an online mindfulness program during the pandemic. Mindfulness practices, such as meditation and yoga, have been shown

to alleviate stress and promote mental health by enhancing body awareness, attention, and emotion regulation, as well as facilitating perspective shifts and clarifying values (Hölzel et al., 2011; Gu et al., 2015). This study identified both the benefits and challenges of delivering mindfulness programs online, providing valuable insights for the future development of more effective programs.

Multicomponent lifestyle medicine

Wong et al. evaluated an 8-week smartphone-delivered multicomponent lifestyle medicine intervention through a randomized controlled trial in a non-clinical sample. This intervention combined various lifestyle changes, including physical exercise, healthy eating, and mindfulness practices like yoga. While no studies in this Research Topic focused solely on nutrition, evidence supports the critical role of nutrition in proper brain function and mental health (Chen, 2018b; Chen and Nakagawa, 2020). The combination of healthy eating, exercise, and mindfulness is expected to have synergistic effects. Wong et al. reported improvements in overall mental health, including reductions in depressive symptoms, anxiety, stress, and insomnia, with effect sizes ranging from 0.13 to 0.56 (Cohen's d). Notably, the benefits persisted at a 1-month follow-up.

Light therapy

Chen et al. conducted a systematic review and meta-analysis on the effects of light therapy for depression in adolescents and young adults. The estimated effect sizes were: SMD = −2.1 (95% CI: −2.5 to −1.68) for individuals using concurrent medications, and SMD = −1.03 (95% CI: −1.27 to −0.78) for individuals without concurrent medications. Light therapy is thought to reset altered circadian and seasonal rhythms in depressive disorders (Pail et al., 2011). The authors also performed additional analyses to determine optimal dosing guidelines, providing insights for clinical applications.

Concluding remarks

We hope this Research Topic has offered valuable perspectives on the mental health challenges exacerbated by the COVID-19 pandemic and the strategies to address them. The findings highlight the intricate interplay of psychological, behavioral, and social factors in shaping mental health outcomes. This calls for a holistic approach that combines individual practices like mindfulness and exercise with broader systemic changes, including improved access to care and strengthened community support. By addressing these issues with a collaborative and interdisciplinary approach, we can transform the lessons of the pandemic into meaningful actions that improve mental health outcomes for future generations. We hope this Research Topic inspires ongoing research, innovation, and policy development to meet these ongoing challenges.

Author contributions

CC: Writing – original draft, Writing – review & editing. GN: Writing – review & editing. YK: Writing – review & editing.

Conflict of interest

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Post-pandemic self-reported mental health of mental healthcare professionals in the Netherlands compared to during the pandemic – an online longitudinal follow-up study

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The mental health of professionals was under pressure during- and post-pandemic. Initially, the focus was mainly on the health workers in the hospitals, but over time the pressure shifted to other sectors, including mental health care. An increase in workload and decrease in mental health of healthcare professionals in mental health care can lead to a decrease in the available care capacity. In an earlier online survey of mental health professionals, 1,300 professionals from a large number of mental healthcare institutions were involved. In this study, conducted in September 2021, about half of the respondents reported increased levels of stress. Feelings of anxiety, anger, and sadness were also increasingly experienced due to the COVID-19 pandemic. Furthermore, 4.2% replied that they were considering resigning their jobs. One of the recommendations of this previous study was to monitor these professionals repeatedly to be able to make an estimate of the stress and vision of work during the course of the pandemic and afterwards. Following this recommendation, the online survey was repeated. The aim of the current online longitudinal follow-up study was to re-evaluated mental status of healthcare workers. 510 healthcare workers participated in this follow-up survey. The reported mental health complaints were significantly higher during compared to post-pandemic. Respondents were less able to maintain work/life balance during the pandemic and even reported a shift to work. However, the majority of respondents indicated that they had restored this balance post-pandemic. Moreover, more sick leave was reported post-pandemic than during the pandemic and more frequent absences post-pandemic. This highlights the importance of focusing on resilience over training and career.

KEYWORDS

COVID-19, pandemic, mental health, HCW, mental healthcare workers, resilience, the Netherlands

1. Introduction

In December 2019 the outbreak of the Coronavirus started in Wuhan city, Hubei Province, China, with a few pneumonia cases. Initially, the virus was found in a few people in Europe and the United States. In March 2020, the World Health Organization (WHO) declared the COVID-19 outbreak a pandemic (1) and varying periods of lockdown and social distancing

followed with falling infection rates and new lockdown periods as well as an increase in social contradictions (2, 3). Many European countries struggled with overcrowded hospitals followed by a decrease of infections in the summer and an increase of infections in the autumn of 2020 which led to new periods of lockdown. After the first COVID-19 vaccination was carried out in the United Kingdom in December 2020, the start of a global immunization program began and brought hope and perspective for recovery (4, 5). Primarily all attention was paid to the healthcare workers (HCW) at the front in the hospitals given the high pressure they are working on. After a decrease in COVID-19 infections and the related number of hospital admissions, HCW were confronted with the 'delayed care' in hospital which caused renewed pressure. However this pressure shifted to other sectors. During the (post)-pandemic period the demand for mental health services continued to increase (6) while Mental Health Care Workers (MHCW) were struggling to provide needed care (7).

In the Netherlands, the DFY-study (Do not Forget Yourself-study) (8) which focusses on mental health of mental healthcare workers reported several results from the first measurement in January 2022 (9). Furthermore, 50% of the employees in mental health care institutions in the Netherlands reported elevated levels of stress and 30% had signs of depression (10) using a self-report questionnaire. An increase in registration at the mental health care institutions took place simultaneously with mental complaints as a result of the COVID-19 pandemic. This increased workload even more, next to the pressure of the lengthening of waiting time for admission. The shift from face to face to telehealth and the confrontation with social differences among the clients and as a consequence conspiracy thinking in the treatment room brought unknown topics of conversation and made a big appeal to the mental healthcare worker (3). Other studies amongst HCW collaborate these results and reported mood and sleep disturbances (11) and post-traumatic stress symptoms (12, 13). Besides these symptoms, also higher levels of psychological distress (14) were reported as a result of the pandemic in another study. These results corroborate the need for preventing MHCW to develop mental health problems and evaluate how to support MHCW.

Based on the findings of a recent scoping review (15) preventing MHCW from mental health problems and maintain sustainable employment during pandemic waves, it is pivotal to use a systematic mental health tool frequently. Screening MHCW with regards to mental health problems provides early protection and realizes the opportunity to signalize future problems and prevent MHCW from sick leave and/or even resigning. The DFY-study (Do not Forget Yourself-study) intends to provide some signals to the government by frequently monitoring of mental health status of MHCW.

This current study reports about the comparison of two groups of MHCW on the experience of mental health related to the workplace and challenges. The first during a period of uncertainty (lockdown and unknown course of COVID-19 in the autumn of 2021) and the second post-pandemic in the autumn of 2022. A repeated measurement design was used to focus on MHCW and following objectives: (i) to assess the experience of increased symptoms of anxiety, sadness, levels of stress, sadness, and anger over time, (ii) to identify challenges regarding work/private life balance, (iii) exploring experience of sick leave, taken days off, and absenteeism, and (iv) exploring considerations about re-organizing work (e.g., working less hours, quitting their job). We hypothesize that levels of mental symptoms decrease over time but the amount of mental health symptoms remains high. Also we hypothesize that some signs of resilience are reflected in the results of our study (e.g., restore of balance between private life and work).

2. Materials and methods

2.1. Study design

In order to compare the results of the previous survey regarding mental health amongst health care professionals (10), we repeated this survey in the same way. We used social media (LinkedIn) and contact within (large) mental health institutions in the Netherlands to distribute the questionnaire online, using Qualtrics using LinkedIn platform and emailing several mental health care institutions situated in the Netherlands with a personal invitation to participate in the study. Hence the character of this study, internet access was an inclusion criterion, as well as Dutch reading and writing capability. Furthermore, respondents had to be employed within mental health care. The questionnaire was finished in less than 15 min by all participants. Because of the distribution of the internet survey, we did not know how many participants we invited with our request to complete the questionnaire. Therefore, we are unfortunately unable to provide response rates. All participants that started the questionnaire completed the assessment.

We aimed to reach any employee within mental health institutions so all employees that responded were considered 'professional' in this article. For the current study we compare two measurements, a recent measure (October–December 2022) versus a previous measure (August–September 2021) referred to as during-pandemic sample and post-pandemic sample, respectively (in the Netherlands, October–December 2022 was declared post-pandemic and all safety measures were discontinued in this period). Our scientific board approved of repeating the current survey in light of the previous survey (CWO 2021–35).

2.2. Survey questions

The current survey was identical to the questions in previous survey (10). These questions consisted of questions regarding mental health status regarding symptoms such as sadness, anger, anxiety, and levels of stress. Three questions regarding work/private life balance were included to explore the ability to balance life working from home. Furthermore, three questions were asked related to absenteeism (sick leave, taken days off, and absenteeism). Lastly, we explored whether the respondents were considering working less hours or quitting their job (i.e., re-organizing their work). In order to obtain as much responses as possible, we anonymously obtained all responses so did not ask for sociodemographic variables. Between 13th of October 2022 till the 4th of December 2022, 503 responses were registered. 2 (0.4%) respondents did not start the survey; hence the total sample existed of 510 respondents.

2.3. Statistical analyses

First, mental health symptoms and work-related matters based on the post-pandemic survey will be described. Second, reported mental health symptoms and work-related outcomes between the two samples

were compared. Categorical variables were presented by means of frequency tables for both samples (pre- and post-pandemic). We explored distribution differences between categorical variables with Chi-Square test (for trend) and used Cramer's V as effect size. Analyses were conducted using the Statistical Package for the Social Sciences (SPSS) version 27 with an alpha level of 0.05.

3. Results

3.1. Mental health symptoms post-pandemic

Table 1 shows the results of mental health symptoms and balance work/private and Table 2 shows the results of work-related questions regarding absenteeism and re-organization of work. In general, most respondents stated that they did not experience more/not less symptoms of anxiety, depression, stress, sadness and/or anger. Nevertheless, 35.7% of the respondents ($n = 182$) reported *"more symptoms"* of stress and 20.6% ($n = 105$) of the respondents experienced more symptoms of depression compared to during the pandemic. Between 5.1 and 6.9% of the respondents experienced less mental health symptoms compared to during the pandemic. Row 11–19 of Table 1 describes the results regarding questions focusing on working from home and balancing work and private. 7.5% ($n = 38$) to 22.9% ($n = 117$) stated that *"the balance between work and private tipped towards work due to working from home,"* respectively. 10.2% ($n = 52$) to 29.2% ($n = 149$) reported that they were less able to *"effectively balance work and private."* Finally, 2.4% ($n = 12$) to 17.3% ($n = 88$) were not able to *"balance work and private (anymore)."*

With regards to work absenteeism, 16.3% ($n = 83$) to 17.3% ($n = 88$) stated that the (partly agree/agree) had *"taken more sick leave compared to during the pandemic."* 9.2% ($n = 47$) to 15.3% ($n = 78$) stated they *"took more days off"* and 13.1% ($n = 67$) to 13.3% ($n = 68$) stated they *"were more absent."* With regards to reorganizing work, 9 respondents (1.8%) were considering *"quitting working in health care,"* 46 (9.0%) were considering *"working less hours,"* 144 (28.2%) were considering *"working more from home"* whereas 306 (60.0%) respondents were *"not considering reorganizing work."*

3.2. Comparison between sample (during and post-pandemic)

Tables 3A,B shows the comparison during pandemic and post-pandemic with regards to the questions about mental health symptoms (Table 3A) and ability to balance work and absenteeism (Table 3B).

With regards to the differences between experiencing mental health symptoms during and post-pandemic (Table 3A), the degree in which mental symptomatology was experienced differed significantly for all symptoms (e.g., anxiety, depression, levels of stress, sadness, and anger). More specifically, levels of anxiety ($X^2 = 41.97$, $p < 0.001$, $V = 0.15$), depression ($X^2 = 27.2$, $p < 0.001$, $V = 0.12$), levels of stress ($X^2 = 24.37$, $p < 0.001$, $V = 0.11$), sadness ($X^2 = 13.99$, $p < 0.001$, $V = 0.09$), and anger ($X^2 = 12.94$, $p = 0.002$, $V = 0.08$) were significantly higher and/or more prevalent during pandemic compared to post-pandemic.

The results in Table 3B show that respondents pointed out that the work/private balance had tipped the scale towards work during the pandemic, more than compared post-pandemic ($X^2 = 9.16$, $p = 0.047$, $V = 0.07$). Furthermore, they were *"less able to effectively balance work and private during the pandemic compared to post-pandemic"* ($X^2 = 17.14$, $p = 0.002$, $V = 0.10$). Moreover, respondents replied that they had taken *"more sick leave post-pandemic*

TABLE 1 Mental health symptoms and balance work and private reported post-pandemic (N=510).

Questions						
Compared to before the COVID-19 pandemic, I experience						
	More symptoms of *n* (%)		Not more/not less symptoms of *n* (%)		Less symptoms of *n* (%)	Missing *n* (%)
Anxiety	51 (10.0)		416 (81.6)		35 (6.9)	8 (1.6)
Depression	105 (20.6)		366 (71.8)		28 (5.5)	11 (2.2)
Higher levels of stress	182 (35.7)		294 (57.6)		29 (5.7)	5 (1.0)
Sadness	49 (9.6)		425 (83.3)		26 (5.1)	10 (2.0)
Anger	96 (18.8)		379 (74.3)		28 (5.5)	7 (1.4)
Compared to before the COVID-19 pandemic:						
Due to working from home, work and private balance has tipped the scale towards work						
	Agree *n* (%)	Partly agree *n* (%)	Neutral *n* (%)	Partly disagree *n* (%)	Disagree *n* (%)	Missing *n* (%)
	38 (7.5)	117 (22.9)	123 (24.1)	72 (14.1)	154 (30.2)	6 (1.2)
I can less effectively balance work and private						
	Agree *n* (%)	Partly agree *n* (%)	Neutral *n* (%)	Partly disagree *n* (%)	Disagree *n* (%)	
	52 (10.2)	149 (29.2)	107 (21.0)	58 (11.4)	139 (27.3)	5 (1.0)
I cannot balance (anymore) between work and private						
	Agree *n* (%)	Partly agree *n* (%)	Neutral *n* (%)	Partly disagree *n* (%)	Disagree *n* (%)	
	12 (2.4)	88 (17.3)	122 (23.9)	93 (18.2)	190 (37.3)	5 (1.0)

Missing values are displayed in last column and reflect missed responses on the according question and are calculated using the total sample of respondents (N=510).

TABLE 2 Work-related questions regarding absenteeism, sick leave, and reorganization of work.

Questions – Which statement holds true regarding sick leave and/or absenteeism during the COVID-19 pandemic?		
	I have taken more sick leave *n* (%)	Missing values *n* (%)
Agree	88 (17.3)	
Partly agree	83 (16.3)	
Neutral	37 (7.3)	
Partly disagree	36 (7.1)	
Disagree	262 (51.4)	
		4 (0.8)
	I have taken more days off *n* (%)	
Agree	47 (9.2)	
Partly agree	78 (15.3)	
Neutral	72 (14.1)	
Partly disagree	47 (9.2)	
Disagree	263 (51.6)	
		3 (0.6)
	I was more absent *n* (%)	
Agree	67 (13.1)	
Partly agree	68 (13.3)	
Neutral	53 (10.4)	
Partly disagree	36 (7.1)	
Disagree	282 (55.3)	
		4 (0.8)
	Due to the COVID-19 pandemic, I consider to reorganize my work *n* (%)	
No, I do not consider reorganizing my work	306 (60.0)	
Yes, I consider working more from home	144 (28.2)	
Yes, I consider quitting working in health care	9 (1.8)	
Yes, I consider working less hours	46 (9.0)	
		5 (1.0)

Missing values are displayed in last column and reflect missed responses on the according question and are calculated using the total sample of respondents ($N = 510$).

compared to during the pandemic" ($X^2 = 55.57$, $p < 0.001$, $V = 0.17$), had taken more days off ($X^2 = 29.11$, $p < 0.001$, $V = 0.13$), and "*were more absent post-pandemic compared to during the pandemic*" ($X^2 = 39.58$, $p < 0.001$, $V = 0.15$). The amount of respondents that replied to "*not be able to balance (anymore) between work and private*" did not differ significantly during pandemic and post-pandemic.

Table 4 shows the comparison of reorganization of work during pandemic and post-pandemic. Significant differences were found ($X^2 = 9.06$, $p = 0.029$, $V = 0.07$), more specifically a higher amount of respondents replied that they "*were not considering reorganizing their work post-pandemic compared to during the pandemic*" whereas more respondents "*were considering working more from home*" (31.5% vs. 28.5%) or "*were considering quitting working in health care*" (4.2% vs. 1.8%) during the pandemic compared to post-pandemic. Post-pandemic, more respondents (9.1%) "*were considering working less hours*" compared to during the pandemic (7.5%).

4. Discussion

The current study repeated a national-based online survey and reported the prevalence of mental health status of 510 employees in mental healthcare in Netherlands, post-pandemic. In this way the study created the possibility to compare these outcomes to the former study with a sample of 1,372 respondents during the pandemic, with regard to mental health symptoms. In general, employees stated that their mental symptoms slightly improved after the pandemic. More specifically, the experienced symptoms of mental health complaints were significantly higher during compared to post-pandemic. It became clear that respondents were less able to maintain work/life balance during the pandemic and even reported a shift to work. However, the majority of respondents indicated that they had restored this balance post-pandemic. Moreover, more sick leave was reported post-pandemic than during the pandemic and more frequent absences post-pandemic. As hypothesized, mental symptoms decreased over time. However, the amount or degree of mental health symptoms

TABLE 3A Comparison of mental health symptoms during pandemic (N=1,372) and post-pandemic (N=510).

I experience...				X	p	V
	More symptoms of n (%)	Not more/not less symptoms of n (%)	Less symptoms of n (%)			
Anxiety				41.97	<0.001	0.15
During pandemic	262 (19.4)	1,055 (78.3)	31 (2.3)			
Post-pandemic	51 (10.2)	416 (82.9)	35 (7.0)			
Depression				27.20	<0.001	0.12
During pandemic	409 (30.3)	911 (67.5)	29 (2.1)			
Post-pandemic	105(21.0)	366 (73.3)	28 (5.6)			
Higher levels of stress				24.37	<0.001	0.11
During pandemic	658 (48.5)	650 (47.9)	49 (3.6)			
Post-pandemic	182 (36.0)	294 (58.2)	29 (5.7)			
Sadness				13.99	<0.001	0.09
During pandemic	190 (14.2)	1,119 (83.4)	33 (2.5)			
Post-pandemic	49 (9.8)	425 (85.0)	26 (5.2)			
Anger				12.94	0.002	0.08
During pandemic	318 (23.6)	994 (73.8)	35 (2.6)			
Post-pandemic	96 (19.1)	379 (75.3)	28 (5.6)			

remains high. Furthermore, the results indicate some sort of resilience with regards to restore of balance between private life and work.

Moreover, the comparison during- and post-pandemic in terms of work reorganization showed significant differences: namely, more respondents indicated that they were no longer considering changing their work compared to during the pandemic. However, more respondents reported working from home or leaving health care during the pandemic than post-pandemic. Respondents indicated that they will work fewer hours post-pandemic compared to during the pandemic.

Our results suggest slight recovery on several fronts. As we found less percentages of symptoms of mental health problems and progression in recovery with respect to work/life balance within the respondents, we became curious about the resilience of the respondents (16). In a review Fletcher et al. (16) stated that "*resilience is constructed in a variety of ways where most definitions are based around two concepts: adversity and positive adaptation. Resilience should have been required in response to different adversities, ranging from ongoing daily hassles to major life events, and that positive adaptation must be conceptually appropriate to the adversity examined in terms of the domains assessed and the stringency of criteria used.*" Moreover, Fletcher wonders whether resilience can be seen as either a trait or a process and conceptualizes resilience as the interactive influence of psychological characteristics within the context of the stress process. There are several studies that suggest that resilience makes people resistant to stress (17). Koelmel et al. (18), stated that with healthcare workers, resilience can be expressed in their possibility to show perseverance and well-functioning self-control by continuously adapting and adjusting to new complex situations and pressure. The higher the level of mental resilience, the more confidence and courage a person has in dealing with difficult situations and circumstances (19). In parallel, if the level of mental health increases, psychological resilience will increase, making people less vulnerable to unexpected or stressful events (20, 21). Resilience refines the relation between perceived risk and potential mental health issues (22). According to Norful et al. (23) and Rieckert et al. (24) better communication, mitigating the stress of Healthcare workers and focusing on improving work- patterns and- conditions supports in building resilience. Preparing young professionals during training how to require resilience in response to some adversities and organizing targeted training on increasing adaptability is recommended. Prior, or during, the development of such training, one should address stigma of being treated by a colleague thus creation of a safe environment, requires clear organizational strategies for mental health status of the staff, consistent and clear communication (10).

This is the first study that explored mental health status longitudinally of Dutch MHCW. The number of respondents was large. One limitation of our sample includes the lack of demographic variables which restrains us in carefully describing the study sample. However, we believe that this anonymity ensured the high response rate in a fairly short amount of time. Furthermore, due the aforementioned limitation, we were unable to explore changes on an individual level. Future studies should continue to focus on the current topic. Furthermore, future studies should incorporate a theoretical framework in order to thoroughly explore adaptability of MHCW with regards to mental health problems. Lastly, we were unable to control for any possible bias (such as early versus late bias, or common method bias) because we did not collect information regarding demographics which we could use to conduct non-response analyses. However, this method did ensure a high(er) response because of the anonymity (e.g., respondents were not required to address their age, gender and so on).

Working in healthcare is stressful, which is stressed by the results of our study. Even though mental symptoms improved after the pandemic, the prevalence rates of depression, anxiety and stress is fairly high. Therefore, institutional meddling to prevent development

TABLE 3B Comparison of ability to balance work and private and questions regarding absenteeism during pandemic (*N*=1,372) and post-pandemic (*N*=510).

						X	*p*	*V*
	Agree *n* (%)	Partly agree *n* (%)	Neutral *n* (%)	Partly disagree *n* (%)	Disagree *n* (%)			
Due to working from home, work and private balance has tipped the scale towards work						9.16	0.047	0.07
During pandemic	127 (9.4)	331 (24.6)	387(28.7)	157 (11.7)	345 (25.6)			
Post-pandemic	38 (7.5)	117 (23.2)	123 (24.4)	72 (14.3)	154 (30.6)			
I can less effectively balance work and private						17.14	0.002	0.10
During pandemic	213 (15.7)	457 (33.7)	264 (19.5)	126 (9.3)	295 (218)			
Post-pandemic	52 (10.3)	149 (29.5)	107 (21.2)	58 (11.5)	139 (27.5)			
I cannot balance (anymore) between work and private						9.27	0.055	0.07
During pandemic	49 (3.6)	224 (16.7)	403 (30.0)	213 (15.8)	455 (33.9)			
Post-pandemic	12 (2.4)	88 (17.4)	122 (24.2)	93 (18.4)	190 (37.6)			
I have taken more sick leave						55.57	<0.001	0.17
During pandemic	154 (11.3)	122 (9.0)	109 (8.0)	47 (3.5)	925 (68.2)			
Post-pandemic	88 (17.4)	83 (16.4)	37 (7.3)	36 (7.1)	262 (51.8)			
I have taken more days off						29.11	<0.001	0.13
During pandemic	101 (7.5)	168 (12.4)	137 (10.1)	70 (5.2)	875 (64.8)			
Post-pandemic	47 (9.3)	78 (15.4)	72 (14.2)	47 (9.3)	263 (51.9)			
I was more absent						39.58	<0.001	0.15
During pandemic	120 (8.8)	106 (7.8)	119 (8.8)	57(4.2)	954 (70.3)			
Post-pandemic	67 (13.2)	68 (13.4)	53 (10.5)	36 (7.1)	282 (55.7)			

TABLE 4 Comparison of reorganization of work during pandemic (*N*=1,372) and post-pandemic (*N*=510).

					X	*p*	*V*
	No, I do not consider reorganizing	Yes, I consider working more from home	Yes, I consider quitting working in health care	Yes, I consider working less hours			
					9.06	0.029	0.07
During pandemic	767 (56.9)	425 (31.5)	56 (4.2)	101 (7.5)			
Post-pandemic	306 (60.6)	144 (28.5)	9 (1.8)	46 (9.1)			

of these symptoms in for instance burn-out and/or sick leave is pivotal. Especially since we know from the current literature that such feeling are associated with other mental health challenges such as sleep disturbances, occupational impairment, behavioral issues and others. Besides their own responsibility, institutions and governments have responsibility in order to protect employees in healthcare. Especially psychological support is necessary. Promotion of self-care is advised as well as social support (inside and outside of work context). In this sense, providing healthcare to co-workers or colleagues can be part of a psychosocial support program that will increase resilience within an institution. Furthermore, training young professionals to cope with stressful experiences is key and will prevent the development of mental symptoms and ultimately burn-out. The development of such programs needs to be addressed and stimulated.

5. Conclusion

This follow-up study, in which a comparison took place between two measurements, a recent measure (October–December 2022, with *N*=510) versus a previous measure (August–September 2021, *N*=1,372) referred to as during-pandemic sample and post-pandemic sample, showed a decrease in mental health problems; a better work-life balance; a better work-life ratio; an increase in sick leave and absences post-pandemic and a decrease in people in need of reorganizing work. These results suggest that healthcare professionals are resilient. However, the increase in absenteeism and absence post pandemic is striking.

Implications for policy, practice, and research could be that there will be a change of focus. From combating mental health problems, to prevention and focusing on increasing resilience including the need to carefully manage individuals' immediate environment, and to

search for the protective and promotive factors that individuals can proactively use to build resilience. To prepare healthcare workers and our healthcare system for ongoing demands and possible additional demands such as a next pandemic, research focusing on interventions that will improve mental well -being of healthcare workers and support mental healthcare workers to reduce burnout, sick leave and absenteeism and enhance resilience is necessary. Preparation of the healthcare professionals for future crisis and even a pandemic will contribute to the continuity, availability and quality of health care.

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 CWO GGz Breburg. The patients/participants provided informed consent to participate in this study.

Author contributions

LV and AB were equally involved in designing the research, data collection, data-analysis, writing drafts, and final editing. All authors contributed to the article and approved the submitted version.

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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Stress and influencing factors of public health and preventive medicine students in the post-pandemic period: a cross-sectional study in Changsha, China

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Objectives: Little is known about the stress levels and associated factors of public health and preventive medicine students in the post-pandemic period. This study aims to investigate the stress levels of these students in the post-COVID-19 era and to determine the association of personal background, employment attitude, and psychological state with stress.

Methods: A cross-sectional survey was conducted in March 2023 among 620 public health and preventive medicine students from two universities in Changsha, China. The survey included demographic characteristics, employment attitudes, perceived stress scale 10, general anxiety disorder 7, the University of California at Los Angeles loneliness scale 20, and the PTSD checklist-civilian version. Two-sided *t*-tests and ANOVA tests were used to compare the differences in PSS scores among variables, and multiple hierarchical regression analysis was used to evaluate the associated factors with stress.

Results: The survey was completed by 504 students (mean age: 21.5 ± 2.6 years, 69.2% female). 24.8% of the students were screened for a high level of stress. 69.0% thought the epidemic positively impacted employment while 18.5% believed it had a negative impact. The results of regression analysis showed that older age ($B = 0.42$, $p = 0.001$), higher grade ($B_1 = 3.59$, $p < 0.001$, $B_2 = 4.57$, $p < 0.001$), having internship experiences ($B = 1.16$, $p = 0.006$), having anti-epidemic experiences ($B = 1.77$, $p < 0.001$), believing that COVID-19 has a negative impact on employment ($B = 2.56$, $p < 0.001$), and having higher GAD scores ($B = 0.64$, $p < 0.001$) and UCLA scores ($B = 0.07$, $p = 0.002$) were significantly associated with high-stress levels. Conversely, being female ($B = -1.64$, $p < 0.001$) and believing that the pandemic had a positive impact on employment ($B = -1.98$, $p = 0.001$) were associated with low-stress levels.

Conclusion: Public health and preventive medicine students in Changsha, China, experienced a high-stress level in the post-pandemic period, which was influenced by age, gender, grade, employment attitude, internship experience, anxiety, and loneliness. As one of the main guardians of the epidemic, these students should be given more attention and psychological interventions in the future.

KEYWORDS
post-COVID-19 era, public health, preventive medicine, stress, influence factor

1. Introduction

Since the coronavirus disease 2019 (COVID-19) was formally declared a global pandemic by the World Health Organization (WHO) in February 2020 (1), people all over the world have been fighting it for more than 3 years, but it has not completely left the human arena, and some countries are experiencing multiple waves of raised infections (2). As of March 2023, COVID-19 had caused more than 760 million confirmed cases and more than 6.9 million deaths worldwide (3), and the numbers continue to increase. In addition to posing a great threat to the physical health of individuals, the pandemic has also caused a series of psychological problems such as anxiety in the global population, affecting mental health outcomes, and even leading to cases of stereotyping and discrimination (4–6).

College students have inevitably developed various psychological problems during the pandemic. Since the pandemic has changed the original curriculum and increased concerns about future employment, medical students, as the main body of future clinical works, have been paid wide attention (7, 8). Even in the late stage of the pandemic, their psychological problems are still widely reported (9). A study involving 418 medical students showed that 93.2% of the students experienced anxiety, depression, and loneliness during the pandemic (10). An Australian study confirmed that 68% of medical students reported that their mental health deteriorated after the outbreak due to concerns about social relationships, study, and employment (11). Studies from China showed that the epidemic had affected the employment attitudes of medical students, students in hard-hit or high-incidence areas were less willing to choose epidemic-related majors (12), and 3.4% of college students reported symptoms of post-traumatic stress disorder in the post-pandemic era (9). However, these studies did not divide medical students in a more detailed way, and most of them focused on clinical medicine and nursing students, while studies on public health and preventive medicine students were scarcely reported.

In fact, public health and preventive medicine students have been hit hard by the pandemic, but they did not seem to receive much attention. Studies have confirmed that during the severe phase of the epidemic, COVID-19 elicits a strong psychological response among public health workers (13). In China, although they rarely directly work with clinical patients, most of them are involved in epidemic prevention and control at primary health organizations, the Centers for Disease Control (CDC), and hospital administrations. Over the past 3 years, personnel at these agencies have been primarily responsible for the epidemiology, viral etiology testing, data collection, and reporting of patients with confirmed and suspected COVID-19. The outbreak of the epidemic has brought a huge burden to their daily works, increased the detection rate of psychological problems, and reduced their professional identities and stabilities (14). Although the pandemic is much better, there are still many uncertainties and the long-term harm of the pandemic may persist, which is undoubtedly a challenge for public health and preventive medicine students who are going to engage in public health, and they may face high employment pressure and many psychological problems for a long time. Thai et al. (15) first reported that 80% of public health and preventive medicine students had a certain level of stress during COVID-19, but they did not identify the associated factors behind the stress, so there was no way to intervene. The purpose of this study was to understand the pressure of the COVID-19 pandemic on public health and preventive medicine students in terms of employment and career selection. Our hypothesis was that some of these students were hesitant to pursue a career in public health because the pandemic is not completely over. Understanding the stress level and related factors was an important prerequisite for finding ways to stabilize the public health workforce.

2. Materials and methods

2.1. Participants and procedures

The study was conducted through a cross-sectional online survey in March 2023 in Changsha, Hunan Province, China, which had seen multiple COVID-19 outbreaks in the past 3 years, involving every administrative district. We identified 2 universities, Central South University and Hunan Normal University, which were the only universities in Changsha to offer public health and preventive medicine majors. Both of which have independent schools or departments of public health, and both confer bachelor's and master's degrees. There were 620 students in the 2 universities and all students were invited to participate in the survey.

This study was approved by the Ethics Committee of Hunan Normal University School of Medicine (approval number: 2022-332;), and an informed consent was attached to the questionnaire to ensure that each student participated voluntarily. According to the lists provided by the 2 universities, we sent electronic questionnaires to each student by email and issued regular reminders. Students who did not reply more than three times were regarded as declined. All surveys were conducted anonymously, and no personal information would be seen in the background except IP address, and no personal information would be divulged. All items in the questionnaire were required. If any items were omitted, the questionnaire cannot be submitted. If a student was consistent in the choice of some variables (e.g., all 1), or had obvious logical errors, the questionnaire was considered invalid. The data in this study were all self-reported, which may introduce some bias and limit the ability to draw causal conclusions, but the setting of the census was still expected to identify some of the problems with these students.

2.2. Instruments

2.2.1. Demographic characteristics and employment attitude

A self-made questionnaire was developed to collect participants' demographic characteristics and employment attitudes. The former includes age, gender, grade, major, family residence, household income, intern experience, and COVID-19 vaccination. The latter includes whether they study their major voluntarily, their preferred

employment intention, views on the impact of COVID-19 on employment, whether they want to change careers and the reasons for it, and whether they or others around them have been diagnosed or participated in the fight against COVID-19.

2.2.2. Stress

The perceived stress scale 10 (PSS-10) was used to assess students' perceived stress in the last month. The scale consists of 10 questions and is scored on a five-point scale from 0 (never) to 4 (often) (16). The highest score is 40, with higher scores indicating higher levels of stress, and scores of 13 and 26 were used as cut-offs for low, moderate, and high stress levels. The reliability and validity of the scale had been widely confirmed to be within the acceptable range, with an overall Cronbach's alpha value of 0.82, the test-retest reliability coefficient of 0.69, and an internal consistency of 0.68–0.78. The scale was also found to be strongly correlated with PSS-4 ($R = 0.95$). In order to identify students' stress levels after the pandemic, we highlighted in the questionnaire instructions: In the past month, how often have you experienced the following due to COVID-19?

2.2.3. Anxiety

The general anxiety disorder 7 (GAD-7) was used to assess students' anxiety symptoms after COVID-19. This is a validated screening tool for major anxiety disorders such as generalized anxiety disorder or panic disorder based on the seven-item symptoms (17). Students rated the frequency of these symptoms over the past 2 weeks. The severity of anxiety was classified according to the score as minimal or none (0–4), mild (5–9), moderate (10–14), and severe (≥15). The scale's internal consistency coefficient was 0.92, the test-retest reliability was 0.83, and the correlation R with the Beck anxiety inventory (BAI) and the symptom check list-90 (SCL-90) were 0.72 and 0.74, respectively (18, 19).

2.2.4. Loneliness

We used the University of California at Los Angeles loneliness scale 20 (UCLA-20) to assess students' loneliness after the COVID-19 pandemic. The scale consisted of 20 items, and students were asked to choose 1 from 4 answers (1 = I have never felt this way, 4 = I have always felt this way). Nine items were scored in reverse order, and higher scores indicate higher loneliness. The scale divides loneliness into 5 levels: high loneliness (≥45), moderately high loneliness (39–44), moderate loneliness (34–38), moderately low loneliness (28–33), and low loneliness (0–27). The scale with an internal consistency of 0.89–0.94 and a test-retest reliability of 0.73 (20).

2.2.5. Post-traumatic stress disorder

The PTSD checklist-civilian version (PCL-C) was used to assess for post-traumatic stress disorder (PTSD) after the COVID-19 pandemic (21). Students reported the degree of impact from the stressful life event during the past month on a scale from 1, indicating "not at all," to 5, indicating "extremely." This resulted in a total score that ranged from 17 to 85. Results were recorded dichotomously based on a cutoff score of 38.

2.3. Statistical analysis

Descriptive statistics (i.e., frequencies, percentages, means, SD) were calculated to describe students' demographics, employment attitudes, and scores on psychometric scales. Two-sided t-tests or ANOVA tests were used to examine differences in PSS scores among multiple variables. Pearson correlations were calculated to examine associations between scores on psychological scales. A hierarchical multiple regression with 4 consecutive steps was used to detect factors associated with stress. Step 1 includes demographic variables. In step 2, we examined the association of employment attitudes with stress after controlling for demographic variables. In steps 3 and 4, we tested the association of anxiety and loneliness symptoms with stress after controlling for demographic variables and employment attitudes, respectively, PTSD was not included in the regression because it was homogeneous with stress. At each step, a backward procedure was used to remove relevant factors that did not significantly increase the prediction of stress. Before conducting the regression analysis, collinearity tests and Durbin–Watson (DW) tests were incorporated. All analyses were performed using SPSS 22.0 (SPSS/IBM, Armonk, NY, United States), and a p-value <0.05 was considered statistically significant.

3. Results

3.1. Sample characteristics

A total of 620 questionnaires were distributed and 539 were returned, with a recovery rate of 86.9%. Out of the returned questionnaires, 504 were valid, leading to an effective recovery rate of 93.5%. As shown in Table 1, the age of the students ranged from 18 to 26 years old (21.5 ± 2.6), 69.2% were female and 39.9% were only children. Students majoring in public health and preventive medicine were 38.9% and 61.1%, respectively. A total of 154 students (30.6%) had off-campus internships and all students (100%) had received COVID-19 vaccines. There were 103 (20.4%) students showing severe anxiety, 83 (16.5%) reported high levels of loneliness, 42 (8.3%) and 125 (24.8%) were detected with PTSD and high-stress levels.

3.2. Employment attitudes

A total of 84.7% of the students indicated that they voluntarily enrolled in this major. Among the employment intentions, most students chose to go to the hospital (37.3%), followed by CDC (23.0%), and only 0.8% were willing to go to primary health institutions. 18.5% hold that the epidemic had a negative impact on employment, and 12.5% had the idea of changing careers, mainly because they were worried about the increase in workload caused by the epidemic (8.1%). 96.6% of the students said that they or those around them had been diagnosed with COVID-19, and 28.8% participated in epidemic prevention and control (Table 2).

3.3. Comparison of different variables on PSS scores

The outcomes showed that the PSS scores of students had statistically significant differences in age, gender, grade, major, household monthly income, internship experience, the voluntary

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TABLE 1 Demographic characteristics ($N = 504$).

Variable	Frequency	Prevalence (%)
Age, years		
≤20	220	43.7
21–24	225	44.6
≥25	59	11.7
Gender		
Male	155	30.8
Female	349	69.2
Grade		
1–2	94	18.7
3–4	232	46.0
≥5	178	35.3
Major		
Public health	196	38.9
Preventive medicine	308	61.1
Family residence		
Rural	237	47.0
Urban	267	53.0
Only child		
No	303	60.1
Yes	201	39.9
Household income/month (¥)		
<4,000	135	26.8
4,000–8,000	200	39.7
>8,000	169	33.5
Intern experience		
Without	350	69.4
Have	154	30.6
Receive COVID-19 vaccine		
No	0	0
Yes	504	100.0
GAD score		
<15	401	79.6
≥15	103	20.4
UCLA score		
<45	421	83.5
≥45	83	16.5
PTSD score		
<38	462	91.7
≥38	42	8.3
PSS core		
<26	379	75.2
≥26	125	24.8

TABLE 2 Employment attitudes during COVID-19 pandemic ($N = 504$).

Variable	Frequency	Prevalence (%)
Volunteer to study this major		
No	77	15.3
Yes	427	84.7
Preferred employment intention		
Primary health institutions	4	0.8
Hospital	188	37.3
CDC[a]	116	23.0
Schools/research institutes	107	21.2
Pharmaceutical enterprises	14	2.8
Enter a higher school	60	11.9
Other	15	3.0
Impact of COVID-19 on employment		
Negative impact	93	18.5
No impact	63	12.5
Positive impact	348	69.0
Idea of changing careers		
Without	244	48.4
Have	63	12.5
Not sure	197	39.1
Reasons for wanting to change careers		
Worried about the workload of the corresponding majors under the epidemic	41	8.1
Worried about limited career prospects	19	3.8
The wishes of the parents	3	0.6
Diagnosis of COVID-19 in oneself or someone close to you		
Without	17	3.4
Have	487	96.6
Participate in COVID-19 prevention and control work by oneself or someone close to you		
Without	359	71.2
Have	145	28.8
Forms of participation in the fight against COVID-19		
Publicize knowledge of epidemic prevention and control offline and online	32	6.3
Participate in volunteer activities for epidemic prevention and control	293	58.1
Other	34	6.7

[a]Centers for Disease Control.

study of the major, the impact of the epidemic on employment, the idea of changing careers, and the participation in epidemic prevention and control ($p < 0.05$). In contrast, there were no statistically significant differences in family residence, only child, and diagnosis of COVID-19 ($p > 0.05$) (Table 3). Based on Pearson correlations, there were significant positive correlations among the GAD score, UCLA score, PTSD score, and PSS score (Table 4).

TABLE 3 Comparison of PSS score among variables during COVID-19 pandemic ($N = 504$).

Variable	Mean	SD	t/F	p
Age, years				
≤20	20.1	3.5	19.800	<0.001
21–24	24.7	4.4		
≥25	24.8	6.4		
Gender				
Male	26.3	7.7	4.658	<0.001
Female	23.3	3.8		
Grade				
1–2	20.2	2.9	38.812	<0.001
3–4	24.6	6.4		
≥5	25.9	4.0		
Major				
Public health	25.2	2.7	2.850	0.005
Preventive medicine	23.6	4.5		
Family residence				
Rural	23.8	4.4	−1.758	0.079
Urban	24.6	6.3		
Only child				
No	24.2	4.2	−0.283	0.778
Yes	24.3	7.1		
Household income/month				
<4,000	26.4	8.1	15.589	<0.001
4,000–8,000	23.5	3.3		
>8,000	23.3	4.6		
Intern experience				
Without	23.6	4.4	−3.475	0.001
Have	25.7	7.2		
Volunteer to study this major				
No	25.3	2.8	3.383	0.001
Yes	23.8	6.0		
Impact of COVID-19 on employment				
Negative impact	25.6	6.8	6.793	0.001
No impact	23.9	4.6		
Positive impact	22.5	3.4		
Idea of changing careers				
Without	23.4	6.5	3.321	0.037
Have	25.4	3.8		
Not sure	24.3	5.0		
Diagnosis of COVID-19 in oneself or someone close to you				
Without	25.3	9.6	0.334	0.743
Have	24.2	5.0		
Participate in COVID-19 prevention and control work by oneself or someone close to you				
Without	23.9	6.2	−2.928	0.004
Have	25.1	2.9		

PSS, perceived stress scale.

3.4. Multivariate hierarchical regression analysis of student stress

The results of the collinearity test and DW test showed that the tolerance of all variables was greater than 0.1, and the variance inflation factor (VIF) was less than 10, indicating that there was no multicollinearity between variables. The value of DW was 1.6, meaning that the residuals were independent. As shown in Table 5, in step 1, the results showed that higher grade ($B_1 = 5.73$, $p < 0.001$, $B_2 = 7.74$, $p < 0.001$), and internship experience ($B = 1.14$, $p = 0.026$) were significantly associated with higher stress levels while being female ($B = -2.92$, $p < 0.001$), majoring in preventive medicine ($B = -1.85$, $p < 0.001$), and higher monthly household income ($B_1 = -2.12$, $p < 0.001$, $B_2 = -2.09$ $p < 0.001$) were negatively related to stress levels. In step 2, after controlling for demographic variables, those who believed that COVID-19 had a negative impact on employment ($B = 3.94$, $p < 0.001$) and participated in epidemic prevention and control ($B = 1.29$, $p = 0.019$) were associated with higher levels of stress. And those who hold that COVID-19 had a positive impact on employment ($B = -2.98$, $p < 0.001$) showed lower stress level associations. In step 3, after controlling for demographic variables and employment attitudes, higher GAD scores ($B = 0.68$, $p < 0.001$) showed a significant correlation with higher stress levels. In step 4, after controlling for all the above variables, the UCLA score detected a significant association with stress ($B = 0.07$, $p = 0.002$).

4. Discussion

This study focused on a detailed investigation of stress levels and related factors among students majoring in public health and preventive medicine in the post-pandemic period. We found that quite a few students experienced various degrees of psychological problems. 20.4% of the students reported anxiety symptoms, higher than the anxiety level of Chinese medical students (regardless of major) (22). Students' anxieties were related to the impact of the outbreak on their studies, such as changes in curriculum and the increase of online courses (23), as well as concerns about future employments (24). 16.5% of students reported a high level of loneliness. Although loneliness has a certain relationship with individual personality traits, it is highly context-dependent, and the lockdown measures during the epidemic were a special situation that caused these students to reduce a lot of original social contacts. A research has confirmed that social isolation due to COVID-19 lockdowns resulted in a marked increase of loneliness among emerging adults aged 18–25 years old (25). Although only 8.3% of the students were detected with PTSD, the rate was higher than the 3.4% of the average college student in China in the post-COVID-19 era (9). This might be related to the large investment of public health personnel during the outbreak, and the higher attention and participation of public health and preventive medicine students compared with ordinary college students. The average PSS score of students in this study was 24.2, similar to the outcomes of a previous study from 31 provinces in China, which showed that the PSS score of medical students during the COVID-19 was 24.1, higher than the 22.6 of non-medical students (26). This is probably because that medicine is a highly practical discipline and medical students are under greater

TABLE 4 Associations between scores of several psychological scales.

	GAD score	UCLA score	PTSD score	PS score
GAD score	1	0.350**	0.246**	0.637**
UCLA score	0.350**	1	0.117**	0.351**
PTSD score	0.246**	0.117**	1	0.548**
PSS score	0.637**	0.351**	0.548**	1

**$p < 0.01$.

academic and employment pressures, especially for those with a wide range of responsibilities (27).

Different from other medical majors, students majoring in public health and preventive medicine have more opportunities to directly face the impact of the epidemic in theoretical learning and practice, including the accurate understanding of the harm of the novel coronavirus, the uncertainty of the safety of nucleic acid testing, and the high workload of epidemiological investigation. Some students were even directly involved in local epidemic prevention and control before graduation, thus showing more psychological problems and higher-stress levels. We found that anxiety, loneliness, and PTSD were positively associated with students' stress levels, which is similar to the findings of Ye et al. (26). Stress is closely related to negative psychology such as anxiety and loneliness, which could lead adolescent students to avoid coping, thereby increasing the severity of psychological stress (27, 28). Thai et al. (15) confirmed that even though public health students indicated using positive and approaching coping strategies, they still showed a high prevalence of stress during the COVID-19 pandemic.

In the employment intentions of the students, 37.3% expressed their willingness to work in a hospital, which was in line with the overall positive attitude of all medical students towards the medical profession (29, 30). However, we noticed that only 0.8% of the students indicated that they would like to work in primary health care institutions after graduation, which seemed depressing because primary health care institutions, mainly community health service centers, played a very important role in epidemic prevention and control. In the past 3 years, the vast majority of COVID-19 vaccination and nucleic acid testing in China had been conducted by community health service centers, which were also responsible for epidemiological investigation and data collection of infected and potentially infected patients. In addition, 18.5% of the students believed that the epidemic had a negative impact on employment, higher than the 14.8% reported in domestic research which targeted all medical students (31). Our interpretation was that there were not only worries about not being able to find a job but also concerns about the content and workload of future work. Although the global epidemic has stabilized, the virus has not completely disappeared, and its future development is still full of uncertainty. In China, the efforts and sacrifices made by public health personnel in the process of fighting against the epidemic were no less than those of clinical medical staff, which will undoubtedly affect the employment attitude and behavior of these students. We also found that 12.5% of the students had the idea of changing careers and were mainly worried that the excessive workload during the epidemic might indirectly confirm our hypothesis.

This study found that older age, higher grades, and male students were significantly associated with higher stress levels. Age and grade increased synchronously. The closer to graduation, the more pressure on students would naturally increase. On the one hand, they have to complete the graduation examination from school, and on the other hand, they have to face the pressures of employment and career selection, both of which would be affected by the epidemic. Higher stress levels in male students might be attributable to social expectations that they take on more responsibilities and experience more economic stress (32), or boys usually suffer more negative life events and receive less social support (29).

According to our findings, students with internship and pandemic prevention experiences were associated with higher levels of stress. Previous studies also agreed that medical interns were more stressed than non-interns (33). Combined with the particularities of specialties, medical interns needed to avoid errors in their daily work, while the safety of throat swab collection and medical procedures has been uncertain during the outbreak period (26). The internships of public health and preventive medicine students mainly focused on community health service centers, CDCS, or hospitals, which were the main institutions to fight against COVID-19. When students participated in epidemic prevention and control in these departments, they would feel the difficulties and potential risks of work in advance. Coupled with the overwork caused by the lack of manpower during the epidemic, students' concerns about future employment and their stress levels would be further increased.

There were 18.5% of the students believed the epidemic had a negative impact on employment and was significantly associated with higher stress levels. The COVID-19 epidemic undoubtedly provided more employment opportunities for these students, because it was an inevitable trend that countries needed to develop their public health systems in the post-pandemic era. However, in the situation of high morbidity and certain mortality, making everyone feel comfortable working in the industry is a challenge. A qualitative study revealed that overly positive attitudes towards the healthcare industry could be challenged by demanding and potentially risky working conditions close to reality (34). Although studies have confirmed that medical students' attitudes to practice have not significantly changed as a result of the pandemic (29, 30), few studies had further compared differences among different medical students, whose willingness to practice varies according to the scope, content, and risk of their work. Whether COVID-19 leaves or permanently coexists with human beings, the necessity for the development of public health cannot be ignored, and the psychological stress of practitioners needs more attention. Therefore, relevant departments should provide psychological interventions to these students as early as possible based on the results of this study.

There were three shortcomings in this study. First, the design of the cross-sectional study made it impossible to establish a causal relationship. Second, sampling and response biases may persist because of low responses due to Internet connectivity and limitations in self-reported data. Third, the data were obtained at only 2 universities in one province, which has experienced several severe outbreaks. However, the severity of outbreaks varies from region to region, and the results reported by subjects from different regions might be biased, so conclusions beyond the scope of the investigation should be drawn with caution. Expanding the study area, increasing the sample size, and maximizing random sampling are the directions for improving these issues and our future research efforts.

TABLE 5 Hierarchical regression analysis for factors associated with the PSS score in the post-pandemic period ($N = 504$).

Variable	Step 1				Step 2				Step 3				Step 4			
	Initial		Final[a]		Initial		Final[a]		Initial		Final[a]		Initial		Final[a]	
	B	*p*	*B*	*p*	*B*	*p*	*B*	*p*	*B*	*p*	*B*	*p*	*B*	*p*	*B*	*p*
Age, years	0.48	0.003	0.54	0.001	0.68	<0.001	0.58	<0.001	0.32	0.010	0.33	0.009	0.42	0.001	0.42	0.001
Gender	−2.68	<0.001	−2.92	<0.001	−2.81	<0.001	−2.89	<0.001	−1.79	<0.001	−1.84	<0.001	−1.64	<0.001	−1.64	<0.001
Grade																
3–4	5.52	<0.001	5.73	<0.001	5.31	<0.001	5.36	<0.001	3.53	<0.001	3.60	<0.001	3.59	<0.001	3.59	<0.001
≥5	7.46	<0.001	7.74	<0.001	7.64	<0.001	7.57	<0.001	4.29	<0.001	4.40	<0.001	4.57	<0.001	4.57	<0.001
Major	−1.77	<0.001	−1.85	<0.001	−1.26	0.009	−1.22	0.010	−0.32	0.424	—	—	—	—	—	—
Family residence	0.39	0.500	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Only child	0.68	0.270	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Household income/month																
4,000–8,000	−2.38	<0.001	−2.12	<0.001	−2.27	<0.001	−1.89	0.001	−0.46	0.326	—	—	—	—	—	—
>8,000	−2.51	<0.001	−2.09	<0.001	−2.38	<0.001	−1.98	0.001	−0.95	0.044	−0.65	0.090	—	—	—	—
Intern experience	1.09	0.035	1.14	0.026	1.24	0.021	1.05	0.043	0.98	0.021	0.99	0.020	1.16	0.006	1.16	0.006
Volunteer to study this major	—	—	—	—	−0.78	0.21	—	—	—	—	—	—	—	—	—	—
Impact of COVID-19 on employment																
Negative impact	—	—	—	—	3.81	<0.001	3.94	<0.001	2.57	<0.001	2.53	<0.001	2.56	<0.001	2.56	<0.001
Positive impact	—	—	—	—	−2.96	<0.001	−2.98	<0.001	−1.85	0.002	−1.83	0.002	−1.98	0.001	−1.98	0.001
Idea of changing careers																
Have	—	—	—	—	0.77	0.330	—	—	—	—	—	—	—	—	—	—
Not sure	—	—	—	—	1.02	0.051	—	—	—	—	—	—	—	—	—	—
Diagnosis of COVID-19 in oneself or someone close to you																
Have	—	—	—	—	1.26	0.34	—	—	—	—	—	—	—	—	—	—
Participate in COVID-19 prevention and control work by oneself or someone close to you																
Have	—	—	—	—	1.02	0.045	1.29	0.019	1.97	<0.001	1.90	<0.001	1.77	<0.001	1.77	<0.001
GAD score	—	—	—	—	—	—	—	—	0.68	<0.001	0.68	<0.001	0.64	<0.001	0.64	<0.001
UCLA score	—	—	—	—	—	—	—	—	—	—	—	—	0.07	0.002	0.07	0.002
R^2	0.248		0.243		0.302		0.292		0.521		0.519		0.526		0.526	
Adj R^2	0.232		0.226		0.281		0.276		0.509		0.507		0.516		0.516	

B: linear regression coefficient. The reference group of variables are as follows: gender: male; grade: 1–2; major: public health; family residence: rural; only child: no; household income/month: <4,000; intern experience: without; volunteer to study this major: no; impact of COVID-19 on employment: no impact; idea of changing careers: without; diagnosis of COVID-19 in oneself or someone close to you: without; participate in COVID-19 prevention and control work by oneself or someone close to you: without. GAD, general anxiety disorder; UCLA University of California at Los Angeles loneliness scale; PSS, perceived stress scale.

[a]Final models dropped nonsignificant variables using the backward procedure.

5. Conclusion

In conclusion, students majoring in public health and preventive medicine in Changsha, China experienced higher stress levels in the post-pandemic period, which was influenced by age, grade, gender, internship experience, anti-epidemic experience, employment attitude, anxiety symptoms, and loneliness symptoms. Conducting fundamental courses on COVID-19, one-on-one psychological counseling, and inviting successful public health professionals to share their experiences were expected to alleviate the stress. Although the COVID-19 pandemic seemed to be coming to an end, the pandemic has been a wake-up call. Strengthening the attention and intervention of potential public health personnel, that is, students of public health

and preventive medicine, is an important prerequisite to defend against any future major 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 Biomedical Research Ethics Committee, Hunan Normal University, 2022(332). The patients/participants provided their written informed consent to participate in this study.

Author contributions

XW: designed the study and wrote the initial draft. JZ and NY: analyzed the data and interpreted results. PH: contributed content to subsequent drafts. XW, JZ, NY, MZ, and PH critically reviewed and approved the final draft. 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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Depression and academic engagement among college students: the role of sense of security and psychological impact of COVID-19

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Background: The negative consequences of depression in college students have garnered global attention, especially in relation to academic achievement during the COVID-19 pandemic, which need critical assessment.

Aim: This study investigated whether a sense of security mediated the relationship between depression and academic engagement among college students during the pandemic and whether the moderating psychological impact of COVID-19 has a moderating effect on this relationship.

Methods: In this cross-sectional study, we recruited 466 college students from 30 provincial-level administrative regions in China via the Internet and used established scales to measure depression, academic engagement, a sense of security, and the psychological impact of COVID-19. The mediating and moderating effects were tested using the bootstrap method.

Results: Depression was found to negatively influence academic engagement, with a sense of security partially mediating this relationship. Moreover, the psychological impact of COVID-19 was shown to have a moderating effect on this mediating process.

Conclusion: This study could aid in crafting pertinent strategies to mitigate the adverse effects of depression on learning amid unexpected public health crises and foster better mental health among college students.

KEYWORDS

academic engagement, college students, COVID-19, depression, psychological impact of COVID-19, sense of security

1. Introduction

The COVID-19 pandemic, an unprecedented public health crisis, not only posed a grave threat to people's physical safety, but also cast a significant shadow on their mental wellbeing (1, 2). This was particularly detrimental to those already in a fragile psychological state, such as those suffering from depression, which exacerbated their condition (3). College students, who are a high-risk group for depression, faced significant challenges during the ongoing waves of the virus (4), with a rapid global rise in depressive symptoms reported among young adults, typically those with lower resilience to psychological stress (5). This deterioration in mental health is a cause of concern, and the question of how to intervene and reduce the negative psychological aftermath following such pandemic events has become a focal point of research. Analysis of depression among college students is

often tied to their academic commitment, which is central to their lives (6). Academic struggles caused by depression may, in turn, impact mental health, potentially exacerbating anxiety and depressive states, thus creating a vicious cycle (7). Some college students feel hopeless and distressed, often exhibiting confusion and avoidance in their studies (8). Investigating the mechanisms by which depression affects college students' academic engagement is of paramount importance. Not only can it provide fresh insights for more effective interventions targeting student depression, but it can also improve student learning, thus laying a solid foundation for promoting students' mental health and academic progress.

Depression is an emotional disorder characterized by frequent experiences of intense feelings such as pain, emptiness, and hopelessness (9–12). It often disrupts people's mental states and leads to an array of difficulties in their studies and lives, with severe cases resulting in self-harm and other harmful consequences (13). As an unprecedented public health crisis, the pandemic caused an incalculable disruption to students' lives and studies, coupled with increased uncertainty about their future, which increased their susceptibility to depression (14). For students with a predisposition to depression or a history of illness, the pandemic undoubtedly acted as an adverse stimulus, potentially leading to heightened feelings of despair and sorrow (15). During the pandemic, home isolation measures may have confined students to a single space for extended periods, preventing them from engaging in outdoor activities, possibly heightening their feelings of repression and irritability, and triggering more frequent depressive episodes (16). With the pandemic having increased the prevalence of depression, understanding the mechanisms through which depression affects academic engagement can provide a reference for better targeted interventions. Such interventions would not only be beneficial in addressing students' academic problems, but also in promoting their mental health.

Academic engagement refers to the interest or enthusiasm that students hold toward their studies, coupled with the time and energy they dedicate to learning (17–19). Pandemic-related pressures burdened students in dealing with issues in terms of academic setbacks, lifestyle inconveniences, and future uncertainties (20). These pressures not only brought about distress among the student population, but also potentially affected students' academic engagement (21) given the unprecedented number of issues arising during the pandemic (22). For instance, some students reported increased fatigue during study sessions, whereas others experienced diminished interest in learning, even to the point of actively avoiding it (23). The interplay between mental health issues and learning problems became evident during this pandemic (24), with both a rapid increase in the number of students exhibiting symptoms of depression and a noticeable decline in their academic engagement compared with pre-pandemic levels (25).

Investigating the mechanisms affecting academic engagement and identifying the variables that could serve as mediators or moderators during the pandemic can aid in understanding the complex interplay between depression and other factors under such novel circumstances. Determining the mediating or moderating mechanisms is likely to provide a more profound theoretical understanding of depression issues faced by adolescents, especially from an educational perspective, which is likely to be beneficial for formulating effective interventions.

Some students grappled with the profound grief of losing friends and family to COVID-19, coupled with significant setbacks in their academic and personal lives (26), which could potentially exacerbate depressive states. The pandemic drastically reduced students' interest in outdoor activities and social interactions, leading to extended periods of emptiness and loneliness (27). Additionally, economic support for college students was severely affected by the pandemic, with some students' family financial circumstances deteriorating rapidly (28). In addition to dealing with boredom due to social isolation and an uncertain future, the modes of learning for these students underwent considerable changes. Online learning became the dominant mode of emergency education worldwide. However, this abrupt shift in learning modalities left many students feeling lost, thereby intensifying their anxiety (29). This situation may have led to an increased prevalence of depressive disorders, making students more susceptible to mental health issues (30), which, in turn, may have exacerbated their already difficult predicaments. Therefore, it is imperative to study depression-related issues, particularly how depression influences academic engagement, and determine appropriate interventions.

Academic engagement reflects the level and willingness of students to invest in various learning resources (31), often involving a strong desire for knowledge, proficiency in applying various effective learning strategies, and a sense of achievement in their studies. These qualities may positively contribute to mental health (32). However, during the pandemic, students' academic engagement was severely affected (33). Students faced the challenges of online, home-based, and isolated learning due to substantial changes in their learning environments (34). Discomforting feelings, including anxiety and unease, may have dampened students' enthusiasm for learning, making it difficult for them to concentrate and causing them to lose interest in their studies (35).

Depression may influence students' academic engagement through three potential pathways. During the pandemic, college students may have experienced serious psychological distress, particularly negative emotions and feelings of hopelessness triggered by depressive symptoms (36), leading to a lack of interest and an inability to gain a sense of achievement in their studies (37). The pandemic forced students to change their learning methods in a short period, and educators may have struggled to provide sufficient support through new online teaching methods, leading to potential learning burnout due to adaptation difficulties in the online learning environment (38). Some students may have significantly altered their lifestyles due to the pandemic, such as indulging in Internet use and excessively focusing on negative news about the pandemic, intensifying their negative feelings toward the pandemic (39), which could in turn have make it more difficult for them to concentrate on their studies. Therefore, it can be conjectured that college students' academic engagement may have been more influenced by depression during the pandemic.

A sense of security refers to the affirmative and positive sensations related to experiences of trustworthiness, reliability, and tranquility that arise due to one's active ability to tackle issues,

have a comprehensive understanding of individuals or events, and to effectively engage with familiar environments (40–43). Among college students, insecurity is a common psychological issue (44), stemming from their lack of experience in dealing with external environments and their perceived lack of sufficient ability and resources to resolve multiple complex problems (45). Particularly during the pandemic, college students faced unprecedented events such as health threats, disruptions in their learning status, and future employment difficulties, which could have made them feel helpless (46). Under these circumstances, many students may have experienced feelings of insecurity. Among students who already had poor psychological conditions or emotional disorders, this insecurity could have potentially exacerbated their psychological issues (47), thereby severely affecting their regular learning.

During the pandemic, a sense of security among college students may have served as a mediating variable between depression and academic engagement. First, depression among college students could have potentially increased the frequency of feelings of insecurity (48). Depression is often characterized by excessive pessimism toward external matters, which can trigger worry or even panic. Moreover, long-term experiences of insecurity can negatively impact mental health, leading to increased negativity and suppression (49). Hence, there may be a strong correlation between depression and sense of security. For some students, insecurity stems mainly from the uncertainty and risks of the external environment, requiring them to expend more energy dealing with threats and risks, making it difficult to concentrate on academic challenges (50). Other students may feel insecure because of inadequacies or difficulties in their academic abilities, which may have led to potential stagnation in their learning during the pandemic, thereby exacerbating academic problems (51). These factors foster anxiety rather than enthusiasm in learning, potentially leading to a reluctance to learn. Therefore, there may be a correlation between students' sense of security and academic engagement (52). While depression in college students may have been directly linked to academic engagement during the pandemic, it may also have influenced academic engagement through feelings of insecurity, which involve distinct and intense negative emotional experiences that often directly affect students' life status and learning behavior (53). Students' depression may further amplify their feelings of insecurity, which may negatively impact their academic engagement. Based on these considerations, we inferred that a sense of security might serve as a mediator between depression and academic engagement.

The psychological impact of COVID-19 refers to psychological problems, such as distress and avoidance, caused by the pandemic (54, 55). The pandemic disrupted people's normal lives, causing some to have strong emotional reactions (56), with prolonged negative psychological effects as well as sometimes triggering anorexia, frequent nightmares, and insomnia (57). Some college students may have been prone to feelings of panic and evasion as well as a strong aversion to pandemic-related matters (58). Such increased psychological stress likely posed more challenges to their academic pursuits (59).

When the psychological impact of COVID-19 was high, college students' psychological states and normal learning may have been affected. Their mental health already faced many challenges, especially for those with depression who were struggling with emotional regulation (60). Excessive worry about the pandemic might have induced more feelings of insecurity, thereby impacting academic engagement (61). Furthermore, the psychological impact of COVID-19 may not only have potentially increased the psychological pressure on students but also affected academic engagement by diminishing learning motivation and draining energy, leading to student fatigue or a sense of futility toward studying (62). From this perspective, the psychological impact of COVID-19 may have moderated the mediating effect of a sense of security between depression and academic engagement.

Previous research has reported an association between depression and academic engagement (63, 64). While academic engagement may be adversely affected by depression directly (65, 66), it has also been reported that this relationship is contingent on specific conditions, suggesting the existence of mediating variables (67). Further studies are needed to improve understanding of the association between these factors.

Existing research has reported an association between depression and a sense of security, with individuals in depressed groups being more prone to feelings of insecurity (68–70). Academic performance is strongly correlated with student insecurity (71, 72). Individuals experiencing insecurity have been found to have their energy and interest in learning negatively affected (73, 74). Furthermore, while insecurity has been reported to mediate between psychological problems and learning (75), further investigation is required to establish whether a sense of security acted as a mediator between depression and academic engagement during the pandemic.

The psychological effects of COVID-19 could potentially have become a risk factor (76–78), possibly exacerbating adverse emotional effects (79, 80), and negatively affecting students' learning (38, 81, 82). These studies suggest that the psychological impact of COVID-19 may have served as a moderating variable.

Based on an analysis of previous related research and to help ensure better targeted interventions for depression and enhance the mental wellbeing of college students, we considered it of fundamental importance to investigate how depression affected academic engagement among college students during the COVID-19 pandemic and whether a sense of security played a mediating role under the conditions of the pandemic. Additionally, while the psychological impact of COVID-19 could potentially have acted as a moderator in this mediating relationship, this area remains relatively unexplored in existing research; therefore, we also investigated this factor. The three hypotheses of this study are as follows:

Hypothesis 1. Depression can negatively predict college students' academic engagement.

Hypothesis 2. A sense of security in college students mediated the relationship between depression and academic engagement.

Hypothesis 3. The psychological impact of COVID-19 moderated the relationship between depression and academic engagement.

The research hypothesis model diagram is shown in Figure 1.

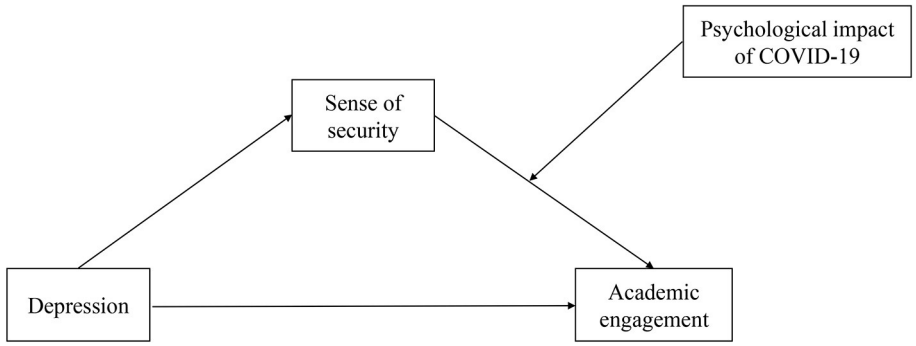

FIGURE 1
Research hypothesis model diagram.

2. Methods

2.1. Process and participants of the survey

2.1.1. Design

This study focused on college students aged 18 years and older studying in China. This study adopted a cross-sectional design to assess the current state and associations of variables in a single time point. The sample was composed of currently enrolled, full-time college students from diverse academic disciplines across China. Inclusion criteria were: being a college student, being 18 years of age or older, currently residing in China, and being willing to participate in an online survey. Exclusion criteria included: students who were not currently enrolled, those under the age of 18, those who did not currently reside in China, and those who did not provide informed consent to participate. However, during the pandemic period in China, it was challenging to conduct offline surveys of college students from different regions across the country. Convenience sampling was therefore adopted. College students were recruited using various online platforms. College students viewed recruitment information online and voluntarily participated in the survey, with participation covering multiple regions.

2.1.2. Procedure

The survey was conducted in December 2022 when normal life was affected in China due to the ongoing COVID-19 pandemic. Prior to conducting the survey, our institution conducted an ethical review and approved the study. A professional online questionnaire research platform was used to recruit college students from 30 provinces across China. We provided the participants with informed consent forms and participation was dependent on these being completed. A total of 471 people completed the questionnaire, five of whom were excluded because their response time was <3 min, and 466 questionnaires were retained. The questionnaire included four scales and collected basic demographic information. Monte Carlo analysis revealed that the sample size needed to exceed 232 for 0.8 statistical power (83). Therefore, the sample size was adequate.

2.1.3. Sample characteristics

Of the final 466 questionnaire respondents included in this study, 355 were female, 111 were male, with ages ranging from 18 to 32 years (average, 21.1 $\pm$ 1.97 years), and comprising 381 undergraduates (81.76%), 76 master's students (16.31%), and 9 doctoral students (1.93%).

2.2. Measurement

Depression was assessed using a scale developed by Spitzer et al. (84). The Chinese version of this scale has proven reliable (85). A 4-point Likert scale is used to score each of the nine items in the scale, such as "Over the past 2 weeks, have you experienced a loss of appetite or overeating?," where a higher total score indicates a greater level of depression. In this study, the Cronbach's α coefficient was 0.85, the McDonald's omega coefficient was 0.885, and the Kaiser-Meyer-Olkin (KMO) coefficient was 0.885.

Academic engagement was evaluated using a scale developed by Schaufeli et al. (86). The reliability of the Chinese version of this scale has been verified (87). This scale includes nine items, such as "Does your study inspire you?," rated on a 7-point Likert scale, with a higher score reflecting higher levels of academic engagement. In this study, the Cronbach's α coefficient was 0.93, the McDonald's omega coefficient was 0.945, and the KMO coefficient was 0.932.

A sense of security was measured using a scale developed by Cong and An (87). The reliability of this scale in its Chinese version has been verified (88). The scale consists of 16 items, for instance, "Do you often feel unlucky?," scored on a 4-point Likert scale, where a higher cumulative score signifies a stronger sense of security. The Cronbach's alpha, McDonald's omega, and KMO coefficients for this study were 0.881, 0.901, and 0.866, respectively.

The psychological impact of COVID-19 was measured using a scale developed by Vanaken et al. (89). The reliability of this scale has been verified (90). This scale includes 15 items, such as "Have you had dreams about the pandemic in the past week?," rated on a 5-point Likert scale, with the interpretation being that a higher total score indicates a greater psychological impact of COVID-19. The Cronbach's alpha, McDonald's omega, and KMO coefficients for this study were 0.872, 0.894, and 0.898, respectively. For the questionnaire used in this study, we computed the composite

reliability (CR) index, which came out to be 0.875, indicating a high degree of validity. We also carried out a confirmatory factor analysis, and found that the Parsimony Goodness of Fit Index (PGFI) was 0.586, the Parsimony Normed Fit Index (PNFI) was 0.625, the Parsimony Comparative Fit Index (PCFI) was 0.645, and the Standardized Root Mean Square Residual (SRMR) was 0.091. These model fit indices reflect a good overall fit of the model.

2.3. Data analysis

The scores of the college students on the four scales of academic engagement, depression, sense of security, and the psychological impact of COVID-19 were tallied, and their means (*M*) and standard deviations (*SD*) were calculated. Pearson's correlation coefficients were used to analyze the correlations. Given that the sample size was >300, kurtosis and skewness values were used to estimate the multivariate normal distribution. To test the moderated mediation effect, we used Model 14 of the microprocess plugin developed by Hayes (91) for the mediation analysis and moderation effect. A moderated mediation effect can be considered when the bootstrap confidence interval excludes zero.

3. Results

A normality test was conducted on the data of the four variables: academic engagement, depression, a sense of security, and the psychological impact of COVID-19. The skewness values were 0.426, −0.166, −0.008, and 0.170, respectively, and the kurtosis values were −0.326, −0.523, −0.162, and −0.134 respectively, indicating that all the variables conformed to a normal distribution. In addition to the skewness and kurtosis assessments, visual inspection of the histograms also confirmed the normal distribution, further substantiating that all four variables exhibited essential normality. Analysis of the correlations among the four variables revealed a negative correlation between depression and academic engagement ($r = -0.457$, $p < 0.01$) and a negative correlation with a sense of security ($r = -0.258$, $p < 0.01$). A significant correlation was also found between a sense of security and academic engagement ($r = 0.297$, $p < 0.01$). The specifications are listed in Table 1.

Regression analysis showed that depression could significantly negatively affect a sense of security ($B = -0.5669$, $t = -5.7535$, $p < 0.001$). A sense of security ($B = 0.1741$, $t = 0.0379$, $p < 0.001$) and depression ($B = -0.8084$, $t = -9.7212$, $p < 0.001$) significantly affected academic engagement ($R^2 = 0.2430$, $F = 74.3092$, $p < 0.001$). These results suggest that depression negatively affected academic engagement and that this relationship was mediated by a sense of security. Furthermore, depression ($B = -1.028$, $t = -11.969$, $p < 0.001$), a sense of security ($B = -0.246$, $t = -1.893$, $p = 0.059$), the psychological impact of COVID-19 ($B = -0.267$, $t = -1.446$, $p = 0.149$), and the interaction between a sense of security and the psychological impact of COVID-19 ($B = 0.012$, $t = 3.419$, $p < 0.001$) significantly affected academic engagement ($R^2 = 0.317$, $F = 53.4556$, $p < 0.001$). The test results of the mediated model with moderation proposed in this study are shown in Figure 2. In this model, the interaction between a sense of security and the psychological impact of COVID-19 was significant (95% confidence interval [CI] = [0.0051,0.0191]), indicating that a sense of security and academic engagement were moderated by the psychological impact of COVID-19 (See Table 2).

When analyzing the moderating effect of the psychological impact of COVID-19, it was found that at a low level of impact ($M - 1SD$) with an effect value of −0.042 and 95%CI = [−0.110,0.010], there was no mediation. However, the mediation was significant at both *M* and high *M* levels ($M + 1SD$) in relation to the psychological impact of COVID-19, with effect values of −0.098 and −0.154, and 95%CIs of [−0.168, −0.042] and [−0.251, −0.068], respectively (See Table 3). Therefore, the mediating role of a sense of security varied at different levels in terms of the psychological impact of COVID-19, indicating moderated mediation.

Simple slope analysis revealed that under high levels of the psychological impact of COVID-19, as the level of depression increased, the level of academic engagement was noticeably poorer compared to the group with low levels (See Figure 3). This finding indicates that the psychological impact of COVID-19 significantly moderated the mediating role of depression and academic engagement.

4. Discussion

This study found that depression negatively influenced college students' academic engagement during the COVID-19 pandemic, with a sense of security playing a mediating role and the psychological impact of COVID-19 having a moderating effect. As a result of these findings, hypothesis 1 and hypothesis 3 were both supported, and hypothesis 2 was partially supported. Notably, theoretical understanding of how depression affects college students in the context of sudden public health crises has been strengthened by this new insight into the relationship between depression and academic engagement.

This study found that college students' depression was negatively associated with academic engagement, supporting the first hypothesis, which accords with previous studies reporting that college students' depression affects their academic engagement (92, 93). However, in this study conducted during the pandemic, college students' depression was found to have a stronger effect on academic engagement. This finding implies that, in the context of new environmental variables, the risk factors for college students' depression affecting academic engagement are likely to be exacerbated, such as psychological difficulties, academic challenges, and financial issues, which could intensify this relationship (94).

Several factors may explain why depression negatively affects college students' academic engagement. First, depression severely affects students' psychological and emotional states (95). This emotional instability and the frequent experience of low mood can compromise learning effectiveness (35) and significantly undermine academic self-efficacy in the long run (96). Second, an enthusiastic attitude toward learning is crucial for academic engagement (97). Depression can lead to a loss of interest in learning and doubts about its importance, especially during crises such as the pandemic when students faced an uncertain future, further diminishing their enthusiasm for learning (98).

TABLE 1 Correlation analysis of the four variables.

	Mean	Standard deviation	Depression	Learning engagement	Sense of security	Psychological impact of COVID-19
Depression	18.779	5.32	1			
Academic engagement	37.277	10.571	−0.457**	1		
Sense of security	48.867	11.688	−0.258**	0.297**	1	
Psychological impact of COVID-19	34.594	8.183	0.403**	0.028	−0.132**	1

**$p < 0.01$.

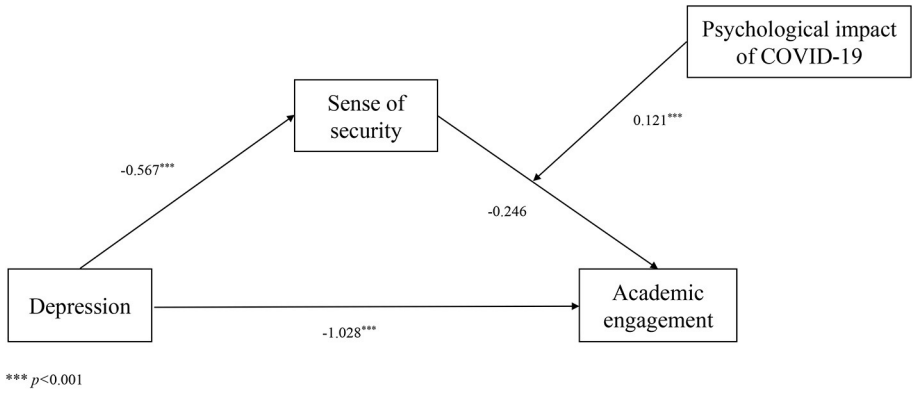

FIGURE 2
Test results of the mediator model with moderation. ***$p < 0.001$.

TABLE 2 Summary of regression models.

	Academic engagement				Sense of security			
	β	SE	*t*	*p*	β	SE	*t*	*p*
Constant	57.549	6.995	8.228	$p < 0.001$	59.513	1.923	30.948	$p < 0.001$
Depression	−1.028	0.086	−11.969	$p < 0.001$	−0.567	0.099	−5.754	$p < 0.001$
Impact of COVID-19	−0.267	0.184	−1.446	$p = 0.149$				
Sense of security	−0.246	0.13	−1.893	$p = 0.059$				
Sense of security × Psychological impact of COVID-19	0.012	0.004	3.419	$p = 0.001$				
R^2	0.317				0.067			
F	$F = 53.456, p < 0.001$				$F = 33.103, p < 0.001$			

TABLE 3 Results of the conditional indirect effect.

Mediating variable	Level	Level values	Effect	BootSE	BootLLCI	BootULCI
Sense of security	Low level (M − 1SD)	26.412	−0.042	0.031	−0.11	0.01
	Mean	34.594	−0.098	0.033	−0.168	−0.042
	High level (M + 1SD)	42.777	−0.154	0.047	−0.251	−0.068

Additionally, students had to deal with sudden shifts to online learning, prolonged Internet usage, and an inability to consult teachers face-to-face. Among those with depression, these substantial learning challenges and unprecedented pressures could have become overwhelming, possibly leading to avoidance or refusal to learn (99). Depression among college students during the pandemic could have intensified, significantly affecting their sleep quality and mental states and making it difficult for them to concentrate on academic issues (100). Therefore, students' academic engagement was more likely to be significantly affected by depression, with the pandemic having a further exacerbating effect.

This study found that under certain levels of psychological impact of COVID-19, a sense of security partially mediated the relationship between depression and academic engagement,

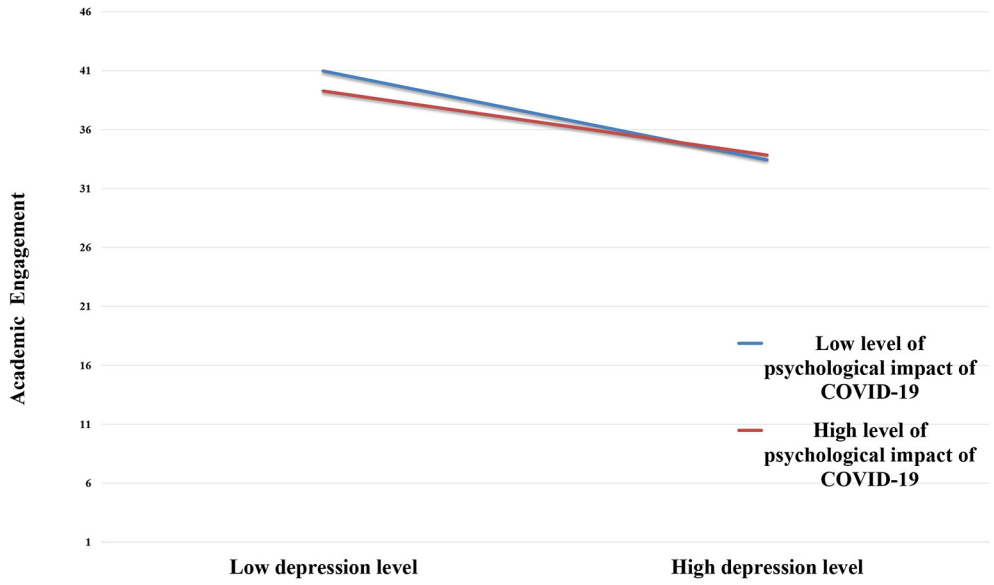

FIGURE 3
Mediating moderating effect between depression and academic engagement.

partially confirming the second hypothesis. Previous research has suggested that depression may influence feelings of insecurity (101), which aligns with the results of the present study. This study also found a correlation between college students' sense of security and academic engagement, further corroborating previous studies (102, 103).

Symptoms of depression in college students usually form over a long period owing to the combined influence of various factors, and their impact on students' learning and life may require other elements to unfold further (104, 105). Depression in college students is often characterized by significant emotional issues (106), which alter their perceptions of and attitudes toward their surroundings. During the pandemic, students exhibiting depressive symptoms were more likely to worry about their personal safety and future prospects (107), which negatively affected their passion for learning. Students' heightened sense of insecurity during the pandemic indicates that they faced challenges in terms of adapting and problem-solving, which may have disrupted their learning mindset. In the complex pandemic environment, college students required a calm and stable mindset for academic engagement (108). The greater insecurity induced by depression imposed enormous pressure on some of them, preventing them from focusing on their studies (109). Importantly, depression makes students more susceptible to perceived threats. When students are highly anxious and fearful, learning is not a priority in their subconscious, especially during crises such as the pandemic when they had to divide their attention (110). Consequently, the psychological resources that can be allocated to learning naturally decrease, thereby affecting academic engagement.

This study found that depression and academic engagement in college students were moderated by the psychological impact of COVID-19, thereby verifying the third hypothesis. There was a greater likelihood that depression would affect academic engagement among those who experienced a high level of psychological impact from COVID-19, supporting previous findings (111–114). This finding suggests that in college students with depression, sudden major public health crises may further disrupt mental states; therefore, along with routine depression interventions, it is crucial to address heightened emotional stress due to crises such as the pandemic.

There are several key reasons why the psychological impact of COVID-19 mediated the relationship between depression and academic engagement. First, the psychological impact of COVID-19 involved short-term and intense negative emotions (115). These types of emotion could have amplified negative feelings among depressed college students, causing them to experience more anxiety and pressure, which depleted their energy for learning. Second, among those experiencing strong pandemic-related stress, their ability to regulate emotions may have been significantly affected (116), with emotional dysregulation becoming more severe. This outcome could have weakened their ability to manage their feelings of insecurity, thereby reducing their enthusiasm for learning. Good cognitive abilities are necessary for academic engagement. In groups that reacted excessively to the pandemic, their cognitive abilities might have been further weakened (117), thus exacerbating the negative influence of depression on academic engagement.

4.1. Main contributions

This study provides novel theoretical insights. First, it was found that college students' sense of security partially mediated the relationship between depression and academic engagement. The degree to which COVID-19 impacted students psychologically was also found to moderate this mediating effect. This study offers a fresh perspective on the mechanisms underlying the interaction

between depression and learning among college students. Second, the analysis of the psychological impact of COVID-19 provides new evidence for understanding depression-related issues during major public health crises. Finally, this study enhances understanding of the mechanisms underlying the negative effects of depression, which can help generate new ideas for the development of better targeted intervention strategies.

4.2. Practical implications

In accordance with the findings of this study, during critical events such as the COVID-19 pandemic, the mental health support for college students should be brought to the forefront. It has been observed that during such severe public health crises, not only does the prevalence of depression among college students significantly rise, but mental health of already depressed individuals is further impacted. Hence, a concerted effort to educate college students about their mental health, as well as the provision of timely psychological counseling support, becomes vital. Firstly, in the face of the pandemic, institutions should ramp up their psychological aid services to assist students in handling the mental pressures triggered by the crisis. This would include proffering counseling and targeted assistance, incorporating both individual and group psychological therapies. Secondly, educational institutions should proactively disseminate pandemic-centric mental health education. This can take the form of online mental health seminars, aimed at enlightening students about the psychological repercussions of the pandemic, equipping them with methods to assuage the mental stress incited by the situation, and instructing them on preserving their academic engagement amidst these arduous circumstances. Additionally, fostering tighter collaboration between an institution's mental health services department and its basic academic units can be beneficial. This partnership, expressed through the organization of relevant activities, can boost students' psychological resilience, enhance their mental health literacy, and arm them with the tactics to effectively navigate through similar crises. Moreover, the institutions bear the responsibility of ensuring a secure environment for the students' living and learning needs. For those students whose in-person learning has been obstructed due to the pandemic, schools should guarantee a safe, stable online platform to ensure the seamless continuation of their studies. It would also be advantageous to schedule frequent online social events, allowing students to experience the warmth and support of their community, even while confined at home. Lastly, and most importantly, institutions need to create an exhaustive protocol to manage student mental health crises during public health emergencies. This could entail setting up mental health records, offering active interventions for students grappling with depression during ordinary times, and emphasizing the provision of psychological counseling services, online learning resources, and flexible academic policies in the event of sudden public health emergencies. In doing so, institutions can secure students' sense of safety and academic involvement during crises, thereby mitigating the potential risks associated with depression. This study uncovered that the academic engagement of college students was severely challenged during the pandemic. This necessitates focused interventions to ensure these students receive additional attention and assistance, fostering a supportive learning environment that diminishes feelings of insecurity and encourages active academic involvement. It underlines that during unexpected public health crises, students should be offered counseling and specific assistance to address their psychological needs. Overall, these steps can significantly contribute to the mitigation of adverse effects on learning due to depression and foster better mental health among college students.

4.3. Limitations

This study had some limitations. The data collected in the research were derived from self-reporting, which may have resulted in bias as students may have avoided providing truthful responses due to perceived social conformity constraints. Future studies should employ multiple data collection methods to obtain more comprehensive and accurate datasets. All participants in this study were from China and, because of cultural differences, the findings may not be generalizable to other cultures. Further validation of these findings in other countries is warranted. This study used convenience sampling. Although a wide range of students from different regions was recruited online to increase the breadth of the sample, future studies should employ more systematic sampling methods for a more accurate representation of Chinese college students. Female participants constituted a large proportion of the investigation, which might have introduced some bias. Future studies could control for the gender ratio of the participants. In addition to a sense of security and the psychological impact of COVID-19, other factors and mechanisms may have been involved in terms of the relationship between depression on student engagement, which should be explored further in future studies. In addition, the investigation was cross-sectional; therefore, causal inferences could not be made, suggesting the need for experimental or longitudinal research designs in future investigations.

5. Conclusion

This study revealed that during the COVID-19 pandemic, depression among college students negatively affected their academic engagement. A sense of security partially mediated this relationship, with the psychological impact of COVID-19 found to moderate this mediating effect. Furthermore, the indirect negative effect of depression on academic engagement through a sense of security was found to be stronger in students who experienced a higher psychological impact from COVID-19. These findings provide new insights into the mechanisms through which depression affects academic engagement among college students and new evidence of the negative impact of depression on students. This study can help inform the development of more effective intervention strategies during crisis events such as the pandemic that can reduce the negative effects of depression and promote students' academic engagement.

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 Academic Committee of Shenzhen University's College of Social Sciences. The patients/participants provided their written informed consent to participate in this study.

Author contributions

YT responsible for the execution of the methodology, securing the required funding, and drafting the original document. WH conducts formal analysis, provides review and editing of the manuscript, and manages the project. The investigation aspect has seen contributions from both YT and WH.

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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 influence of perceived stress of Chinese healthcare workers after the opening of COVID-19: the bidirectional mediation between mental health and job burnout

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Objective: To explore the current status and interaction of perceived stress, job burnout and mental health among healthcare workers after the opening of COVID-19 which occurred in December 2022.

Methods: A cross-sectional study of 792 healthcare workers from three tertiary hospitals in Wuxi was conducted from January 2023 to February 2023. Sociodemographic questionnaire, Perceived Stress Scale, Burnout Scale and Mental Health Self-Assessment Questionnaire were used for investigation. SPSS 26.0 was used to conduct data analysis. The significance of mediation was determined by the PROCESS macro using a bootstrap method.

Results: The results showed that (1) The average scores of the participants for perceived stress, mental health and job burnout were 22.65 (7.67), 3.85 (4.21) and 1.88 (1.03), respectively. (2) The perceived stress score, mental health score and job burnout score of healthcare workers were positively correlated ($r = 0.543–0.699$, $p < 0.05$). (3) Mental health partially mediated the relationship between perceived stress and job burnout with a mediating effect of 17.17% of the total effect. Job burnout partially mediated the correlation between perceived stress and mental health with a mediating effect of 31.73% of the total effect.

Conclusion: The results of this study suggested that perceived stress had an impact on job burnout and mental health, either directly or indirectly. Healthcare managers should intervene to reduce perceived stress to protect healthcare workers' mental health, thereby alleviating burnout under the opening COVID-19 pandemic environment.

KEYWORDS

healthcare workers, perceived stress, mental health, job burnout, the bidirectional mediation

1. Introduction

The COVID-19 pandemic has caused a crisis in the physical and mental health of healthcare workers (1), leading to symptoms such as fear, depression, anxiety, and stress (2–4). A recent study in Spain showed a significant increase in the prevalence of physical and mental health problems among healthcare workers due to the COVID-19 pandemic, especially depression at 30.2%, anxiety at 46.5% and a high level of burnout reaching 51% (5). A survey of healthcare workers in Italy during the COVID-19 pandemic found that 31% of participants suffered from burnout, 12% participants experienced anxiety, and 7% participants experienced depression (6). In China, the prevalence of mental and emotional disorders among healthcare workers during the COVID-19 pandemic ranged from 48 to 63% (7, 8). World Health Organization (WHO) emphasizes that the COVID-19 pandemic is a long-term stressful event and stressor. In December 2022, China fully opened up its epidemic prevention and control measures. As China has been the country with the longest anti-epidemic period and the latest overall opening, the stress levels of Chinese healthcare workers are higher than those of other countries. Therefore, it is important to focus on the changes in stress levels and burnout among healthcare workers after the opening of epidemic prevention and control measures, as well as how to protect their physical and mental health.

Perceived stress refers to a psychological reaction that results from individuals' cognitive evaluation of internal or external pressure events and threatening stimulus. The presence and intensity of stress are subjective to the individual (9). Healthcare workers are considered to experience higher levels of stress compared to other professions according to the nature of their work, such as high risk, high workload, and high levels of mental stress (10). The sources of stress for healthcare workers mainly include complex working environment, disproportion between income and effort, high pressure for promotion, conflicts between work and family, escalating doctor-patient conflicts, complicated interpersonal relationship (11). Since the outbreak of the COVID-19 pandemic, the stress level of healthcare workers had dramatically increased. During the early stage of the comprehensive opening of epidemic prevention and control in December 2022, external pressures on healthcare workers increased sharply due to events such as shortage of medical resources, surge in severe cases, and increased work intensity, as well as the stimulation of anxiety, tension, and sleep deprivation, which further increased perceived stress. High levels of stress tend to poor work performance, negative emotions, low occupational efficacy and job satisfaction, which seriously affects the provision of good healthcare services, sows the potential for doctor-patient conflict, and also affects the sustainable and healthy development of the medical talent team (12, 13). Therefore, attention to the stress level of Chinese healthcare workers and its impact on individuals and society is one of the current focal issues of social concern.

Job burnout refers to a state of persistent dysfunction that occurs after a long-term exposure to chronic stress and is a progressive psychological response (14). In 1981, Maslach and Jackson proposed a definition of job burnout that included three aspects: emotional exhaustion, depersonalization, and low personal accomplishment. Adverse job-related exposures, such as complex work environments, prominent personal and social conflicts, and unmet personal needs, often increase external pressure and lead to job burnout (15). The Conservation of Resources Theory (COR) emphasizes that people have the ability to seek, protect and renew personal resources to adapt to and regulate stress, and stress is a comprehensive stress response that is overloaded and subjectively perceived when personal resources are unstable, threatened, or even disappear (16). Based on this theory, Crawford proposed that stress increased when work demands were out of bounds, resources which needed for work were deprived, resources for routine tasks were forced to decrease, and burnout occurred when resource consumption continued to exist (17). The risk of work-related stress among young physicians is twice that of other physicians. Job burnout occurs early in young physicians' career possibly due to their high workload and continuous consumption of work resources (18).

Mental health problems are typically described as negative emotions such as depression, anxiety, and panic. Perceived stress leads to poorer mental health (19). Manning et al. confirmed that perceived stress was significantly associated with symptoms of anxiety under the COVID-19 pandemic, additionally, specific stressors could significantly predict symptoms of anxiety, depression, and panic (20). The stress-cognitive vulnerability theory suggested that stress initiated negative cognitive-emotional processing by activating cognitive biases, which exacerbated negative emotions and behaviors (21). Shen et al. proposed that the relationship between stress and mental health depended on cognitive function (22). When cognitive resources to deal with stressors are depleted, physical and mental fatigue emerge. This led to impaired physical and/or cognitive function, and sustained stress usually results in severe fatigue, which in turn leads to mental health problems.

Previous research before the COVID-19 pandemic found that emotional disorders and stress could lead to occupational burnout (23). During the outbreak of COVID-19, it had also been observed that experiencing perceived pressure could lead to occupational burnout and fatigue, and it could significantly predict symptoms of anxiety, depression, and panic (20, 24, 25). Studies had shown that healthcare workers who experienced burnout may have suicidal tendencies, which possibly was related to depression (26, 27). Han et al. suggested that burnout could cause severe psychological damage among healthcare workers, which manifested as a feeling of exhaustion after the end of a shift. This study confirmed burnout significantly predicts mental health (28). Therefore, the relationship between perceived stress, mental health, and burnout has been confirmed both before and during the pandemic. Additionally, it is hypothesized that the relationship between job burnout and mental health is not only one-way, but also influenced by perceived stress in a two-way manner.

Although the relationships of stress-burnout, stress-mental health, and burnout-mental health have been discussed in different time, the mechanisms of their interactions have not been specifically clarified, the changes and associations among the three facets after the opening of the COVID-19 pandemic in China may have new findings, and the relationship between burnout and mental health still need further research and exploration. In summary, this study aimed to explore the interrelationships and interact mechanism among perceived stress, job burnout and mental health of clinical healthcare workers in China after the opening of the COVID-19 epidemic, hoping to provide empirical evidences and new theoretical references for healthcare managers to take targeted interventions to improve the mental health and reduce the burnout of healthcare workers.

The following hypotheses were developed based on the literature reviewed above.

H1: Perceived stress, mental health, and job burnout are correlated.

H2: Mental health can mediate the relationship between perceived stress and job burnout.

H3: Job burnout can mediate the relationship between perceived stress and mental health.

The hypothetical model is shown in Figure 1.

2. Methods

2.1. Participants

A convenient sample of 792 healthcare workers from three tertiary hospitals in Wuxi City were surveyed from January 2023 to February 2023. The inclusion criteria were possession of a nurse's license/physician's qualification certificate, in-service nurses/physicians, and engaged in clinical work for ≥1 year. The exclusion criteria were intern nurses/physicians and nurses/physicians in further education or training. The study was approved by the Ethics Committees of Wuxi Maternity and Child Health Care Hospital, and all participants were informed consent (No 2023-01-0721-33).

2.2. Measuring scale

2.2.1. Sociodemographic characteristics

The demographic questionnaire included age, gender, marital status, education level, job title, employment status, monthly salary level, and whether they had been front-line anti-epidemic workers.

2.2.2. Perceived stress

The Perceived Stress Scale (PSS), developed by COHEN et al. (13) in 1983 and introduced and culturally adapted by YANG Tingzhong (29), was used to assess perceived stress levels. The scale consists of 14 items, including two dimensions of tension and loss of control, using a 5-point Likert scoring method. The total score ranges from 14 to 70, and the higher the score, the greater the perceived stress. In this study, Cronbach's α of this entire scale was 0.845, and Cronbach's α for two subscales were 0.826 and 0.886, respectively.

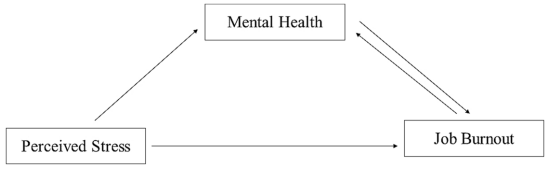

FIGURE 1
The hypothesized model.

2.2.3. Job burnout

The Maslach Burnout Inventory-General Survey (MBI-GS), compiled by MASLACH (30), and translated and revised by Chinese scholars, LI Chaoping (31), was used to assess job burnout. The scale includes three dimensions of emotional exhaustion, depersonalization, and low personal accomplishment, with a total of 15 items. The scale uses a 7-point Likert scoring method, ranging from 0 (never) to 6 (every day). The score of job burnout is calculated as follows: emotional exhaustion dimension score × 40% + depersonalization dimension score × 30% + low personal accomplishment dimension score × 30% (32). In this study, Cronbach's α for three subscales in this study were 0.95, 0.93, and 0.95, respectively.

2.2.4. Mental health

The Mental Health Self-Reporting Questionnaire-20 (SRQ-20) (33), published by the World Health Organization, was used to assess mental health. It consists of 20 items, each with a 2-point score. The answers are "yes" (1 point) or "no" (0 point). The highest score is 20 points, with a higher score indicating more prominent symptoms of mental disorders. A score of 7 or higher is generally accepted as emotional distress and need for professional help.

2.3. Data analysis

SPSS 26.0 was used to conduct descriptive statistical analysis, t-tests or analysis of variance, correlation analysis, and linear regression analysis. We used the method proposed by Wen Zhonglin and Ye Baojuan (34) to test the mediation effect, if the path coefficient from the predictor variable to the outcome variable is significant in both the direct effect model and the mediation effect model, but is reduced in the mediation effect model, then the mediator plays a partial mediating role, if the path coefficient from the predictor variable to the outcome variable is significant in the direct effect model, but not significant in the mediation effect model, then the mediator plays a complete mediating role. Model 4 in the PROCESS macro for SPSS developed by Hayes was used to identify the mediation effects. We used bootstrapping methods to test whether the mediating effect was statistically significant and performed 5,000 bootstrap resamples to determine the 95% confidence intervals of the various effects. The significance of mediating effects depends on whether the 95% confidence intervals include zero, and if the confidence interval does not contain 0, then the mediating effect is significant.

3. Results

3.1. Comparison of perceived stress, mental health, and job burnout scores among healthcare workers with different sociodemographic and work-related characteristics

Socio-demographic and job-related characteristics were shown in Table 1. Among the 792 healthcare workers surveyed, 96 (12.1%) were male and 696 (87.9%) were female, 79 (10%) had a junior college

TABLE 1 Differences in perceived stress, mental health, and job burnout scores among healthcare workers on socio-demographic factors and job-related factors.

Demographic variables	*N* (%)	Perceived stress (M ± SD)	*t/F*	Mental health (M ± SD)	*t/F*	Job burnout (M ± SD)	*t/F*
Age(years old)			2.884*		1.700		3.486*
<26	144(18.2)	22.36 ± 7.26		3.53 ± 4.00		1.86 ± 0.92	
26–35	249 (31.5)	23.04 ± 7.53		3.80 ± 4.23		1.95 ± 0.98[a]	
36–45	127 (16.0)	24.05 ± 7.76[a]		4.59 ± 4.94		2.05 ± 1.20[a]	
>45	272 (34.3)	21.78 ± 7.87		3.71 ± 3.91		1.73 ± 1.02	
Gender			0.002		2.958		0.600
Male	96 (12.1)	22.61 ± 6.68		3.16 ± 4.12		1.80 ± 0.95	
Female	696 (87.9)	22.65 ± 7.80		3.94 ± 4.22		1.89 ± 1.04	
Marital status			1.560		1.012		5.090*
Married	618 (78)	22.47 ± 7.68		3.77 ± 4.13		1.83 ± 1.02	
Unmarried	174 (22)	23.29 ± 7.61		4.13 ± 4.49		2.03 ± 1.04	
Education level			3.430*		3.332*		4.647**
College and below	79 (10)	21.76 ± 7.91[b]		2.78 ± 3.78[b]		1.57 ± 0.98[bc]	
Bachelor's degree	510 (64.4)	22.23 ± 7.68[b]		3.77 ± 4.16[b]		1.85 ± 1.04[b]	
Master's degree	184 (23.2)	24.21 ± 7.57		4.52 ± 4.47		2.07 ± 0.99	
Doctor's degree	19 (2.4)	22.32 ± 5.03		3.74 ± 3.89		1.83 ± 0.83	
Job Title			3.557*		1.470		5.316**
Junior and below	377 (47.6)	22.92 ± 7.74[d]		3.69 ± 4.40		1.93 ± 1.05[d]	
Intermediate	242 (30.6)	22.65 ± 7.06[d]		3.96 ± 4.00		1.92 ± 0.94[d]	
Associate senior	131 (16.5)	23.04 ± 8.15[d]		4.36 ± 4.34		1.84 ± 1.11[d]	
Positive senior	42 (5.3)	18.95 ± 8.06		2.98 ± 3.08		1.28 ± 0.85	
Employment			2.834		6.984**		1.019
Permanent	479 (60.5)	23.02 ± 7.76		4.17 ± 4.24		1.91 ± 1.04	
Contract	313 (39.5)	22.08 ± 7.49		3.36 ± 4.13		1.83 ± 1.01	
Monthly salary (RMB, yuan)			2.831*		1.099		5.227**
<3,000	6 (0.8)	23.33 ± 4.46		2.00 ± 2.45		1.99 ± 0.77	
3,000–6,000	206 (26)	23.26 ± 7.57[e]		3.98 ± 4.38		1.93 ± 1.05[e]	
6,000–10,000	461 (58.2)	22.84 ± 7.75[e]		3.94 ± 4.33		1.94 ± 1.01[e]	
>10,000	119 (15)	20.82 ± 7.45		3.34 ± 3.45		1.54 ± 1.01	
Whether they had been front-line anti-epidemic workers			2.938		5.409*		0.009
Yes	197 (24.9)	23.46 ± 7.36		4.45 ± 4.42		1.87 ± 0.97	
No	595 (75.1)	22.38 ± 7.75		3.65 ± 4.13		1.88 ± 1.05	

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, [a]compared with >45 $p < 0.05$, [b]compared with Master's degree $p < 0.05$, [c]compared with Bachelor's degree $p < 0.05$, [d]compared with Positive senior $p < 0.05$, [e]compared with >10,000 $p < 0.05$.

degree or below, 510 (64.4%) had a bachelor's degree, 184 (23.2%) had a master's degree, and 19 (2.4%) had a doctor's degree, and 377 (47.6%) were at a junior level or below, 242 (30.6%) were at an intermediate level, 131 (16.5%) were associate senior, and 42 (5.3%) were positive senior. Among the participants, married healthcare workers were the majority at 78, and 60.5% of the participants were permanent employment. Healthcare workers who earned 6,000-10000RMB were the majority at 58.2%.

3.1.1. Sex, marital status, and employment

According to the results shown in Table 1, unmarried healthcare workers ($p = 0.024$) reported significantly higher scores of job burnout than married ones ($p<0.05$), healthcare workers with permanent employment ($p = 0.008$) reported significantly higher scores of mental health than the contract ones ($p<0.01$). Gender differences in the scores of perceived stress, mental health, and job burnout were not statistically significant ($p > 0.05$).

3.1.2. Age, job title, monthly salary, education, and other factors

Table 1 also displayed healthcare workers aged 36–45 ($p = 0.006$) reported significantly higher scores of perceived stress than those aged over 45 ($p<0.05$), while healthcare workers aged 26–35 ($p = 0.014$) and aged 36–45 ($p = 0.004$) had significantly higher scores of job burnout than those with aged over 45 ($p<0.05$). Healthcare workers with the job title of associate senior and below had significantly higher scores in the perceived stress and job burnout than those with a positive senior job title (average $p<0.05$). Healthcare workers with monthly salaries of 3,000-10000RMB had significantly higher scores in the perceived stress and job burnout than those with monthly salary of 10000RMB or more (average $p<0.05$). Healthcare workers with a master's degree reported significantly higher scores of perceived stress, mental health, and job burnout than those with a college degree or lower and those with a bachelor's degree (average $p<0.05$). Furthermore, the result in Table 1 showed that healthcare workers who had worked as front-line anti-epidemic workers ($p = 0.02$) had significantly higher scores in mental health than those who had not ($p<0.05$).

3.2. Correlation analysis of variables

The average scores of the participants for perceived stress, mental health and job burnout were 22.65 (7.67), 3.85 (4.21) and 1.88 (1.03), respectively. Correlation analysis(see Table 2) showed that perceived stress score and each dimension score of healthcare workers were positively correlated with mental health score ($r = 0.332–0.603$, $p<0.05$), perceived stress score and each dimension score were positively correlated with job burnout score and each dimension score ($r = 0.194–0.699$, $p<0.05$), mental health score was positively correlated with job burnout score and each dimension score ($r = 0.212–0.558$, $p<0.05$), perceived stress score, mental health score and job burnout score were positively correlated($r = 0.543–0.699$, $p<0.05$).

3.3. Mediation effect analysis

3.3.1. The mediating effect analysis of mental health between perceived stress and job burnout

The results of regression analysis (Table 3) showed that perceived stress had a significant positive predictive effect on job burnout ($\beta = 0.699$, $p<0.05$), perceived stress can also positively predict mental health ($\beta = 0.583$, $p<0.05$), but the effect of perceived stress on job burnout decreased after mental health and perceived stress were entered into the regression equation ($\beta = 0.579$, $p<0.05$), indicating that mental health played a partial mediating role between perceived stress and job burnout. The results of the bootstrapping methods (Table 4) showed that the mediating effect of mental health between perceived stress and and job burnout was significant with a 95% confidence interval of (0.077, 0.162), excluding 0, and the mediating effect accounted for 17.17% of the total effects.

3.3.2. The mediating effect analysis of job burnout between perceived stress and mental health

Similarly, as shown in Table 5, we found that perceived stress had a significant positive predictive effect on mental health ($\beta = 0.583$, $p<0.05$), but this effect decreased after job burnout and perceived stress was entered into the regression equation ($\beta = 0.398$, $p<0.05$), indicating that job burnout played a partial mediating role between perceived stress and mental health. The Bootstrap test (Table 6)

TABLE 2 Means, standard deviations and correlation coefficients for all variables.

Variables	M ± SD	T	LOC	PS	MH	EX	D	LPA	JB
T	10.72 ± 4.48	1							
LOC	11.92 ± 5.32	0.218**	1						
PS	22.65 ± 7.67	0.736**	0.821**	1					
MH	3.85 ± 4.21	0.603**	0.332**	0.583**	1				
EX	2.09 ± 1.26	0.679**	0.281**	0.592**	0.558**	1			
D	1.50 ± 1.21	0.543**	0.308**	0.531**	0.507**	0.760**	1		
LPA	1.97 ± 1.48	0.194**	0.578**	0.515**	0.212**	0.197**	0.349**	1	
JB	1.88 ± 1.03	0.607**	0.495**	0.699**	0.543**	0.841**	0.875**	0.651**	1

*$p<0.05$, **$p<0.01$, ***$p<0.001$; T, tension; LOC, loss of control; PS, perceived stress; MH, mental health; EX, emotional exhaustion; D depersonalization; LPA, low personal accomplishment; JB, job burnout.

TABLE 3 The mediating effect of job mental health between perceived stress and job burnout.

Regression equation		Fitting index		Coefficient significance	
Outcome variables	Predictive variables	R^2	F	β	t
Job burnout	Perceived stress	0.488	753.100**	0.699	27.443**
Mental health	Perceived stress	0.340	406.291**	0.583	20.157**
Job burnout	Perceived stress	0.516	420.498**	0.579	18.990**
	Mental health			0.206	6.744**

**$p<0.01$.

TABLE 4 Mediating model examination by bootstrap (mental health as the mediator).

Effect Type	Path	Effect	SE	LL 95% CI	UL 95% CI
Direct effect	Perceived stress → Job burnout	0.579	0.031	0.519	0.639
Indirect Effect	Perceived stress → Mental health → Job burnout	0.120	0.022	0.077	0.162
Total effect		0.699	0.026	0.649	0.749

TABLE 5 The mediating effect of job burnout between perceived stress and and mental health.

Regression equation		Fitting index		Coefficient significance	
Outcome Variables	Predictive variables	R^2	F	β	t
Mental health	Perceived stress	0.340	406.291**	0.583	20.157**
Job burnout	Perceived stress	0.488	753.100**	0.699	27.443**
Mental health	Perceived stress	0.376	237.329**	0.398	10.111**
	Job burnout			0.265	6.744**

**$p < 0.01$.

TABLE 6 Mediating model examination by bootstrap (job burnout as the mediator).

Effect Type	Path	Effect	SE	LL 95% CI	UL 95% CI
Direct effect	Perceived stress → Mental health	0.398	0.039	0.320	0.475
Indirect effect	Perceived stress → Job burnout → Mental health	0.185	0.033	0.120	0.251
Total effect		0.583	0.029	0.526	0.640

revealed that the mediating effect of job burnout between perceived stress and mental health was significant, with a 95% confidence interval of (0.120, 0.251), excluding 0, and the mediating effect accounted for 31.73% of the total effects.

Therefore, by integrating the two mediation models mentioned above, this study tested a bidirectional mediation model with perceived stress as the independent variable, mental health and job burnout as the mutually mediating variables and the outcome variable.

4. Discussion

This study focuses on healthcare workers in the context of the opening and outbreak of COVID-19. This study found that the scores of perceived stress, mental health and job burnout were significantly positively correlated, supporting hypothesis 1. Our findings corroborated our hypothesis 2 and 3 that mental health could mediate the relationship between perceived stress and job burnout, and job burnout could mediate the relationship between perceived stress and mental health. In the mediated model, mental health and job burnout acted as each other's mediators.

4.1. Current status of perceived stress, mental health, and job burnout in healthcare workers

The results of this cross-sectional study showed that the average scores of the participants for perceived stress, mental health and job burnout were 22.65 (7.67), 3.85 (4.21) and 1.88 (1.03), respectively. The level of perceived stress among healthcare workers was significantly higher than that of the general population (35), indicating that the special nature of clinical medical work (high technology and high risk) makes healthcare workers more sensitive to stress. The mental health status of healthcare workers was at a moderate level, mainly due to the increase in symptoms such as depression, anxiety, and insomnia after the outbreak of COVID-19, which led to a decline in their mental health status (36). The level of job burnout among healthcare workers was significantly higher than that of other populations (37), as healthcare workers are vulnerable and prone to job burnout due to the large workload, tedious content, monotonous form, high repetitiveness, and tense doctor-patient relationship. The occurrence of job burnout not only affects their physical and mental health, but also has a negative impact on medical quality, their own career development, and stability (38). The emotional exhaustion dimension had the highest score, which was consistent with the findings of Soler et al. (39), indicating that emotional exhaustion was the main manifestation of job burnout among healthcare workers. This was mainly due to the long-term exposure to the pain and suffering of patients, which can lead to vicarious trauma and empathy fatigue. In addition, the complex doctor-patient relationships exacerbate emotional exhaustion.

Our study also found that young healthcare workers with a master's degree, permanent employment, low income and associate senior job title generally experienced more perceived stress, mental health problems, and job burnout. These results were consistent with previous studies (40). The concentrated outbreak of COVID-19 also had a certain impact on the mental health status of healthcare workers, especially those who were the main force in medical services and carried heavy

workloads and great risks. This group of people was undoubtedly challenged in their ability to withstand stress and fatigue, as well as their ability to control and regulate their emotions. Therefore, healthcare management should focus on young healthcare workers with a master's degree, low income, long working hours, and those who have participated in epidemic prevention and control work. This could be achieved by strengthening the screening of mental health problems, optimizing the allocation of medical services, improving the healthcare professional environment, enhancing support for healthcare talents and teams. And we suggest that healthcare workers can adopt a task-oriented approach to directly and efficiently address and handle problems (41), believe in one's own abilities and enhance self-efficacy in order to reduce the stress on healthcare workers, prevent work burnout and mental health problems (42).

4.2. The correlation among perceived stress, mental health and job burnout of healthcare workers

In this study, the perceived stress score and each dimension score, mental health score and job burnout score and each dimension score of healthcare workers were positively correlated with each other, which was similar to the previous study (43). This suggested that medical work, as a high-stress profession, involved not only high-risk medical treatment, but also the pressure of career development, such as promotion, disciplinary development, and continuing education. After the outbreak of the epidemic, healthcare workers also had to undertake a large amount of prevention and treatment work, which could easily cause stress due to prolonged working hours, poor temporary working conditions, and long-term tension (44). When the level of perceived stress increases, it could easily induce tension and a sense of loss of control, leading to psychological and physiological dysfunction. This not only resulted in psychological problems such as somatization, anxiety, or terror, but also triggered job burnout and even intentions to leave the profession. Additionally, there was a mutual influence between mental health and job burnout. Healthcare workers with mental health problems tended to have negative emotions, difficulty in mobilizing positive resources and social support under difficult circumstances, and a lack of ability to cope with and solve problems, leading to a gradual loss of work enthusiasm and personal sense of achievement, and job burnout occurred. Healthcare workers experiencing job burnout often appeared tired, passive, and even learned helplessness, which undoubtedly exacerbates negative emotions such as anxiety, depression, and fear. To sum up, job burnout could have a spillover effect, affecting mental health removed from the work situation, correspondingly, workers with improved mental health could attenuate their symptoms of job burnout.

4.3. The bidirectional mediating effect of mental health and job burnout

Firstly, it was found that there was a predictive relationship between mental health and job burnout. This suggested that promoting mental health can not only reduce job burnout, but also potentially be a outcome of reducing it. Thus, reducing job burnout was not only a goal or outcome, but also a possible pathway to achieve mental health. This result was an innovative and improved contribution to the existing research on unidirectional effects, proving the interaction between psychological and environmental factors, and a remedy for the deficiency in previous practice of emphasizing mental health over burnout. In particular, improving the job burnout of healthcare workers could explore a new path for screening, assessment, and intervention in their mental health.

Subsequently, this study validated a bidirectional mediating model of mutual mediation between mental health and job burnout under the influence of perceived stress. On the one hand, mental health partially mediated the relationship between perceived stress and job burnout. On the other hand, job burnout partially mediated the relationship between perceived stress and mental health. This not only confirmed the expected hypothesis, but also enriched the COR and complemented the stress-cognitive vulnerability theory. In this bidirectional mediating mechanism, the concept and idea of the interaction among individuals, society, and the environment were reflected, and the positive cognition and adaptation of people to society and the environment were demonstrated. This also suggested that efforts to reduce job burnout and promote mental health among healthcare workers required reducing stressors, developing stress reduction courses and programs aimed at healthcare workers, improving the ability to actively cope with stress and utilize resources, and implementing effective coping strategies and mechanisms.

Given the previous experiences of scholars in coping strategies, for example, Koh et al. (45) identified coping mechanisms to reduce burnout: physical health, clinical diversity, setting boundaries, transcendence, enthusiasm for work, realistic expectations, and organizational activities. Whitebird et al. (46) found that reducing burnout could also be achieved by physical exercise and social support. Perez et al. (47) and Maresca et al. (48) both discovered three effective stress coping strategies, such as self-care, social and emotional support, and emotional and physical detachment from work. In addition, healthcare workers also spontaneously proposed some intervention measures: mind–body skills training, stress education, cognitive skills, real-time implementation of brief strategies, learning resilience-enhancing skills, etc. (47). Therefore, in order to promote the healthy development of human resources in healthcare teams and improve the overall quality of healthcare services, various measures can be taken to reduce sources of stress, prevent work burnout, and ensure physical and mental health: healthcare institutions can strengthen screening for stress factors, flexibly arrange work content and intensity, reduce the triggers of perceived stress (49), regularly implement screening and intervention strategies for mental health status. Healthcare workers can strengthen their own physical and mental health, seek social and emotional support resources, take necessary breaks to achieve work-life balance (47), timely release negative emotions (50), regularly engage in mindfulness therapy (51), stress inoculation training (52), and activities of the Balint group (53).

5. Limitations

Despite we found a two-way mediating role between mental health and job burnout under the influence of perceived stress, our study had some limitations that pave the way for future research. Firstly, the research was conducted only in Wuxi, resulting in geographical results. Given the difference of areas, is there a possible

different relationship among perceived stress, mental health and job burnout based on more Chinese samples? Future studies need further broaden the scope of research objects and adopt a multi-center cross-provincial research method. Secondly, this study was a cross-sectional study, and longitudinal research was necessary in the future to investigate the longitudinal effects of perceived stress on other variables and the causal relationships between variables.

6. Conclusion

Mental health can mediate the relationship between perceived stress and job burnout. Job burnout can mediate the relationship correlation between perceived stress and mental health. Bidirectional mediation mechanism interacted between mental health and job burnout. Healthcare managers should take actions to reduce and release stress among Chinese healthcare workers to improve their mental health level, and reduce their sense of job burnout. This was beneficial to higher quality of healthcare services and better evaluation and recognition of the entire society toward the medical industry.

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

The studies involving humans were approved by The Ethics Committees of Wuxi Maternity and Child Health Care Hospital. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

MJ implemented this study and was responsible for data collection and provided assistance in reviewing the manuscript. MJ collaborated with ZL to complete data analysis, manuscript writing and revising. XZ and ML supported investigation and data collation. YF guided the study design, manuscript revising, and editing. 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.2023.1252103/full#supplementary-material

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Psychology, stress, insomnia, and resilience of medical staff in China during the COVID-19 policy opening: a cross-sectional survey

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Background: Since 8 January 2023 China has liberalized its control of COVID-19. In a short period of time, the infection rate of COVID-19 in China has risen rapidly, which has brought a heavy burden to medical staff. This study aimed to investigate the psychological status, stress, insomnia, effort-reward imbalance, resilience, and influencing factors of medical staff in China during the period of epidemic policy liberalization.

Methods: This survey was conducted from 6 February to 27 March 2023 with non-random sampling. An online questionnaire survey was conducted using HADS, PSS-14, ISI, ERI, and the resilience assessment scale for medical staff. The levels of psychological, stress, insomnia, effort-reward imbalance, and resilience of medical staff during the pandemic policy opening period were measured.

Results: A total of 2,038 valid questionnaires were collected. 68.5% and 53.9% of medical staff had different degrees of anxiety and depression, respectively. Excessive stress, insomnia, and high effort and low reward were 40.2%, 43.2%, and 14.2%, respectively. Gender, Profession, education level, and age are important factors that lead to anxiety and depression. Women, nurses, higher education, longer working years and hours, high effort, and low reward are risk factors for the above conditions. There was a certain correlation among the five scales, among which anxiety, depression, stress, insomnia, effort-reward imbalance, and other factors were positively correlated, while resilience was negatively correlated with these factors.

Conclusion: This study found that anxiety, depression, stress, insomnia, and other psychological problems of medical staff in China during the policy opening period of COVID-19 were more serious than before. At the individual and organizational levels, it is necessary to improve the well-being of medical staff, optimize the allocation of human resources, and promote the mental health of medical staff with a focus on prevention and mitigation, with the entry point of improving resilience and preventing the effort-reward imbalance.

KEYWORDS

COVID-19, medical staff, psychology, stress, insomnia, resilience

1. Introduction

In recent years, frequent occurrences of public health emergencies, especially sudden major infectious diseases, have posed a huge threat and impact on the medical and health system (1). By March 2023, 676 million people had been infected with COVID-19, including 6.88 million deaths (2). For nearly 3 years, from December 2019 to 2022, China adopted the "dynamic zero COVID-19" strategy to deal with this complex epidemic. In view of the differences between the Omicron variant of COVID-19 and the early SARS-CoV-2 prototype strain and other variants (3), its clinical manifestations are significantly shortened incubation period, significantly increased spread rate, asymptomatic and mild patients accounting for the vast majority, and significantly reduced pathogenicity and fatality rate (4). Since 8 January 2023, China has significantly adjusted its epidemic prevention policy against COVID-19 (5). No more quarantine measures would be imposed on those infected with COVID-19, no more close contacts would be identified, and high-or low-risk areas would no longer be divided. Graded and categorical admission and treatment of people infected with the virus and adjusted medical security policies would be implemented in a timely manner. The detection policy was adjusted to "Voluntary inspection."

Within a short period of time after the major policy adjustment, China's COVID-19 infection rate is significantly higher than in previous periods. Due to the huge population base and the problem of an aging population (6, 7), COVID-19 patients with severe disease, mainly the older adult, have brought a heavy burden to medical staff. In the face of this large-scale infectious public health event, the medical staff are under great pressure due to high work intensity, high risk of infection, uncertain medical technology, and personal capacity. Previous studies have shown that persistent stressful events can lead to anxiety, depression symptoms, insomnia, and other mental health problems for medical staff. Previous surveys during the pandemic found that 36.9% of medical staff in Wuhan, China, had subthreshold mental health disorders (8). The levels of depression and anxiety among medical staff in Shanghai were significantly higher than the norm (9). Medical staff had higher levels of anxiety (13.1%/7.6%) and depression (24.7%/16.0%) than non-medical staff (10), and 25% of medical staff reported poor sleep quality (11). At least 20% of medical staff have been diagnosed with post-traumatic stress disorder (12), and some medical staff also suffer from empathy fatigue and burnout (13, 14). The anxiety, depression, insomnia, and other conditions of medical staff will further affect and change their psycho-emotional and behavioral patterns, including job dissatisfaction, reduced professional efficiency and personal achievement, chronic fatigue, sleep disorders, negative emotional states (e.g., anxiety and depression), and gastrointestinal problems (15). If they go without timely psychological support and intervention, it will not only affect the mental health of medical staff, reduce the quality of medical services, and threaten medical safety, but also affect the prevention and control of the epidemic (11, 16). Therefore, the investigation and improvement of the psychological health of the clinical first-tier medical staff during the period is very important.

Resilience is the ability to help medical staff cope with adversity and recover from stressful experiences quickly and effectively to adapt and cope with changeable situations such as crises, workloads, trauma, and other adversities (17). Studies have shown that people with high levels of resilience can easily adapt to setbacks and recover from adverse work environments such as high stress and high load. In the context of the COVID-19 pandemic, resilience can serve as a potential capacity for medical staff to protect themselves (18), helping them effectively manage and deal with stressful situations caused by the pandemic, in order to cope with disasters and survive crises (19). The effort-reward imbalance (ERI) model suggests that medical staff experience job burnout and stress response when the effort invested (e.g., time, effort, and responsibility) does not match the rewards they receive (e.g., pay, respect, and career opportunities) (20–22). When they feel over-committed, they have unrealistic expectations of their work and put in inappropriate effort (23). Due to the constant change between rewards and effort, when over-invested medical staff are in a high-effort and low-reward environment, it will aggravate the occurrence of anxiety, depression, stress, insomnia, and other psychological conditions. Studies have shown that people with high effort and low reward have a significantly higher risk of anxiety and depression than people with low effort and high reward (21, 24).

Studies have shown that medical staff, one of the main groups affected by the pandemic, caring for COVID-19 patients have moderate or high levels of burnout, stress, and anxiety compared to other healthcare Settings (13). In addition, due to the significant increase in the workload of medical staff in the short period of time after policy adjustments, physical exhaustion, high risk of transmission, ethical decision-making issues in the allocation of medical resources, and the effort-reward imbalance may further damage their resilience and exacerbate the impact on their physical and mental health, resulting in stress, anxiety, depression, and insomnia (14). Therefore, it is urgent and necessary to investigate the mental health of medical staff during this period.

Presently, although studies of mental health problems among medical staff during the pandemic have been reported in Wuhan, Shanghai, and other places in China, the survey has focused on local areas and the broader context of outbreak nationwide lock-down, and results vary by time and location (16). Based on the post-epidemic era and the major adjustment of epidemic prevention policy in China, this study investigated the current situation and influencing factors of anxiety, depression, stress, insomnia, resilience, and ERI among medical staff in this period, which can provide a reference for the future routine management of epidemic and intervention measures of large-scale public health emergencies.

2. Methods

2.1. Study design and participants

The survey was conducted from 6 February to 27 March 2023, based on a non-random sample design. The online questionnaire administered by the web-based survey platform surveyed medical staff working in hospitals during the epidemic. The inclusion criteria are as follows: (a) age range from 18 to 65 years; (b) Medical staff; (c) Voluntary participation in the survey. Exclusion criteria: (a) Have a history of certain psychiatric and physical disorders; (b) Have taken sleep regulation medications; (c) Not engaged in front-line clinical medical work. During the investigation, the researcher explained the research purpose to the respondents and obtained informed consent. Respondents scanned the QR code of the online questionnaire through mobile terminals, logged in, and filled out the questionnaire

according to the authorization of their social accounts. Only one answer can be provided by the same IP address, and all items are set as required answers. The questionnaire can only be submitted after all items have been completed. Otherwise, the system automatically records the result as incomplete. The test time was set by the pre-test results, and questionnaires whose filling time was less than 200 s and longer than 1,800 s were deleted. We set confidence coefficient z = 1.96, expected incidence $p = 0.5$, allowable error d = 0.05, 95% confidence interval. By the following formula, we calculated n = 384. Considering a loss factor of 10%, the final sample size was 423.

$$N = Z^2 \times \frac{P \times (1 - P)}{d^2}$$

2.2. Outcome measures

2.2.1. Demographics

Social demographic data included gender, profession, age, department, education level, working years, professional title grade, etc. Other questions included whether they had been vaccinated, when and where they were infected, Symptom duration, Rest time after infection, treatment, when they returned to work, and working hours during the pandemic.

2.2.2. Assessment scales

2.2.2.1. Hospital anxiety and depression scale

This scale was developed by Zigmond and Snaith and used to screen for symptoms of non-psychotic anxiety and depression (25). The scale was A 14-item self-rating scale consisting of 2 subscales with 7 items each for anxiety (HDS-A) and depression (HDS-D). Each item was scored at Likert Level 4 (0~3 points), and the score range of each subscale was 0~21 points. The scores were divided into 0 to 7 as asymptomatic. Suspicious symptoms are 8 to 10, and the 11 to 21 range were definite symptoms. The Cronbach's α of the total volume scale was 0.890, and the Cronbach's α of the anxiety and depression subscales were 0.820 and 0.807, respectively.

2.2.2.2. Perceived stress scale

The PSS is used to measure the degree of an individual's perception of stress. This scale has five options for each entry: never, almost never, sometimes, often, and always, with a score of 0 to 4. Among them, items 4, 5, 6, 7, 9, 10, and 13 belong to the negative items (26). Hewitt et al. named this dimension as "perceived coping ability." Items 1, 2, 3, 8, 11, 12, and 14 belong to the positive items, which is named "perceived distress" (27). The score ranges from 0 to 56 points, with a higher score indicating greater stress, and more than 25 is considered to be excessive stress and in a state of health risk. The scale of Cronbach's α is 0.954 (28).

2.2.2.3. The effort-reward imbalance

The ERI scale consists of three parts: effort, reward, and over-commitment, with 23 items (29). Six items measured "effort" scores of 6 to 30, 11 items measured "reward" scores of 11 to 55, and 6 items measured "over-commitment" scores of 6 to 24. The ratio is computed by the formula: e/(r*c). "e" defines the score of the effort scale, "r" defines the score of the reward scale, and "c" defines the ratio of the number of effort items and the number of reward items (6/11). In the results, if ERI is greater than 1, it is considered to be the group with high effort and low reward, while ERI less than or equal to 1 is considered to be the group with low effort and high reward, meaning a balance of effort and reward. Those with scores in the top third of the over-commitment factor were considered over-committed. Cronbach's α of effort, reward, and over-commitment were 0.78, 0.81, and 0.74, respectively (30).

2.2.2.4. Insomnia severity index

This scale was developed by Bastien to assess the severity of individual subjective insomnia (31). A higher score indicates a more severe level of insomnia. The scale consists of 7 items, each of which is scored at level 0 to 4, the total score ranges from 0 to 28 points. Insomnia is considered to exist if more than 7 points are scored, which can be divided into no significant insomnia (0 to 7 points), sub-insomnia (8 to 14 points), clinical insomnia (15 to 21 points), and severe insomnia (>21 points; Cronbach's α = 0.93) (32).

2.2.2.5. Medical staff resilience scale:

This scale was compiled by Zhu et al. (33) to assess the level of resilience of Chinese medical staff (33). The scale included decision coping (6 items), interpersonal connection (4 items), rational thinking (4 items), and flexible adaptation (4 items), with a total of 18 items in 4 dimensions. All Likert 5 points were scored, and 1–5 points were assigned from completely disagree to completely agree. The total score ranges from 18 to 90, with higher scores indicating higher levels of stress resistance. The Cronbach's α coefficient of the scale is 0.907, 0.866, 0.797, 0.696, and 0.786 for the four dimensions, respectively.

2.2.3. Statistical analysis

The SPSS 27.0 program was used to statistically analyze the data. Qualitative variables were described by frequency distribution and percentage, while quantitative variables were described by the mean and standard deviation. Independent sample *T*-test and one-way analysis of variance were used. Pearson's correlation analysis was used to examine associations between anxiety, depression, stress, insomnia, and resilience. Binary logistic regression was used to analyze the relevant influencing factors, and the OR value was calculated. All statistical tests were two-tailed, and a *p*-value of $p < 0.05$ was considered statistically significant.

3. Results

3.1. Demographic characteristics

A total of 2,530 pieces of data were collected, excluding 142 data with answer times less than 200 s and more than 1,800 s, 283 non-front-line clinical staff, and 67 invalid questionnaires, and finally retained 2,038 data, and the effective rate of questionnaire responses was 80.6%. Female medical staff (79.4%), doctors (52.6%), and nurses (47.4%) account for a relatively balanced proportion and most of them were under 35 years old (61.2%). We found 88.6% of medical staff were infected with the virus during this period, and 48.9% of infections occurred in hospitals. Specific general information and the results of the scales are shown in Table 1.

TABLE 1 Demographic characteristics ($n = 2,038$).

Variables	*N*	(%)		HDS-A	HDS-D	PSS	ISI	Resilience	ERI
Gender			*p*	<0.001***	0.342	<0.001***	0.007**	0.083	0.562
Male	420	20.6		8.22 ± 1.92	7.96 ± 2.10	19.95 ± 7.81	6.55 ± 5.41	77.47 ± 11.67	0.77 ± 0.60
Female	1,618	79.4		8.66 ± 1.90	8.07 ± 2.02	22.54 ± 7.56	7.36 ± 5.51	76.37 ± 10.86	0.75 ± 0.55
Profession			*p*	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
Doctors	1,071	52.6		8.42 ± 1.90	7.85 ± 2.00	20.68 ± 7.80	6.39 ± 5.12	77.69 ± 10.78	0.71 ± 0.5
Nurses	967	47.4		8.73 ± 1.92	8.26 ± 2.05	23.49 ± 7.27	8.08 ± 5.76	75.38 ± 11.19	0.80 ± 0.62
Age (years)			*p*	0.829	0.756	<0.001***	0.157	<0.001***	0.638
18–35	1,248	61.2		8.56 ± 1.95	8.07 ± 2.02	22.31 ± 7.52	7.37 ± 5.48	75.87 ± 10.93	0.75 ± 0.54
36–50	747	36.7		8.59 ± 1.87	8.00 ± 2.05	21.78 ± 7.84	6.94 ± 5.53	77.54 ± 11.12	0.77 ± 0.59
51–65	43	2.1		8.42 ± 1.84	8.12 ± 2.28	17.16 ± 7.89	6.40 ± 5.60	81.40 ± 10.28	0.70 ± 0.45
Department			*p*	0.006**	0.006**	0.003**	<0.001***	0.004**	0.05
Emergency	98	4.8		8.80 ± 1.90	8.53 ± 1.86	22.99 ± 6.35	8.79 ± 5.18	73.78 ± 10.71	0.78 ± 0.53
ICU	58	2.8		9.43 ± 2.33	8.74 ± 2.28	25.29 ± 7.03	9.97 ± 6.41	71.95 ± 12.33	0.91 ± 0.57
Infectious disease	40	2		8.58 ± 1.77	8.45 ± 2.21	20.58 ± 8.36	5.93 ± 5.53	77.93 ± 11.27	0.63 ± 0.28
Respiratory medicine	28	1.4		8.29 ± 2.09	7.71 ± 1.92	18.43 ± 8.76	6.79 ± 6.05	77.57 ± 9.57	0.67 ± 0.26
Clinical laboratory	60	2.9		8.87 ± 2.13	8.37 ± 1.96	21.82 ± 7.63	8.62 ± 4.60	75.68 ± 11.07	0.59 ± 0.28
Radiological department	76	3.7		8.25 ± 1.92	8.07 ± 2.10	22.20 ± 7.62	6.26 ± 5.40	77.29 ± 11.54	0.72 ± 0.60
other	1,678	82.3		8.53 ± 1.88	7.98 ± 2.03	21.93 ± 7.71	7.03 ± 5.46	76.88 ± 10.95	0.76 ± 0.57
Education level			*p*	0.315	0.113	0.003**	0.013*	0.085	0.176
Below	11	0.5		7.64 ± 2.11	8.09 ± 2.66	19.27 ± 8.76	5.09 ± 4.99	80.82 ± 12.55	0.57 ± 0.23
Technical secondary school	7	0.3		7.86 ± 2.19	8.14 ± 1.95	20.86 ± 7.65	7.14 ± 4.91	78.43 ± 11.93	0.40 ± 0.19
Junior	114	5.6		8.44 ± 1.79	8.34 ± 2.20	21.93 ± 7.41	7.03 ± 5.26	78.97 ± 10.28	0.68 ± 0.58
Bachelor	1,426	70		8.59 ± 1.90	8.09 ± 2.02	22.45 ± 7.47	7.47 ± 5.62	76.58 ± 11.24	0.77 ± 0.59
Master	410	20.1		8.59 ± 1.97	7.89 ± 2.07	20.80 ± 8.26	6.40 ± 5.19	76.18 ± 10.59	0.73 ± 0.43
Doctor	70	3.4		8.29 ± 1.99	7.60 ± 1.75	20.84 ± 8.02	6.69 ± 4.91	74.74 ± 9.81	0.80 ± 0.58
Working years			*p*	0.003**	<0.001***	<0.001***	<0.001***	0.522	<0.001***
<3	311	15.3		8.20 ± 1.84	7.64 ± 1.82	19.69 ± 7.53	5.94 ± 4.93	76.33 ± 10.33	0.64 ± 0.40
3–5	267	13.1		8.52 ± 2.11	8.03 ± 2.04	22.03 ± 7.72	6.80 ± 5.41	76.26 ± 11.05	0.77 ± 0.58
5–10	511	25.1		8.66 ± 1.91	8.22 ± 2.09	23.12 ± 7.41	7.79 ± 5.50	76.21 ± 11.06	0.76 ± 0.50
>10	949	46.6		8.65 ± 1.87	8.09 ± 2.06	22.17 ± 7.71	7.39 ± 5.64	76.99 ± 11.24	0.79 ± 0.62
Professional title grade			*p*	0.153	0.063	<0.001***	0.631	0.433	0.056
Junior	1,007	49.4		8.51 ± 1.92	8.12 ± 2.03	22.13 ± 7.40	7.26 ± 5.46	76.92 ± 10.94	0.72 ± 0.54
Middle	853	41.9		8.67 ± 1.93	8.04 ± 2.04	22.35 ± 7.75	7.20 ± 5.54	76.2 ± 11.17	0.77 ± 0.57
Sub-Senior	166	8.1		8.37 ± 1.75	7.67 ± 2.02	19.68 ± 8.62	6.87 ± 5.66	76.51 ± 11.00	0.84 ± 0.62
Senior	12	0.6		8.83 ± 2.52	7.67 ± 1.97	20.42 ± 7.87	5.58 ± 4.48	79.33 ± 9.21	0.73 ± 0.37
Vaccine injection			*p*	0.563	0.901	0.843	0.682	0.559	0.981
Yes	2,008	98.5		8.56 ± 1.91	8.05 ± 2.04	22.01 ± 7.68	7.19 ± 5.49	76.58 ± 11.03	0.75 ± 0.56
No	30	1.5		8.77 ± 1.99	8.00 ± 1.58	21.73 ± 7.88	7.60 ± 6.12	77.77 ± 11.49	0.76 ± 0.78
Whether infected or not			*p*	0.046*	0.108	0.103	0.02*	0.091	0.099
Yes	1,810	88.8		8.59 ± 1.93	8.07 ± 2.04	22.11 ± 7.64	7.29 ± 5.54	76.45 ± 11.05	0.76 ± 0.57
No	228	11.2		8.34 ± 1.77	7.84 ± 1.98	21.23 ± 7.93	6.39 ± 5.11	77.76 ± 10.84	0.70 ± 0.45
Location of infection			*p*	0.437	0.403	0.472	0.145	0.023*	0.366

(Continued)

TABLE 1 (Continued)

Variables	*N*	(%)		HDS-A	HDS-D	PSS	ISI	Resilience	ERI
Uninfected	228	11.2		8.34 ± 1.77	7.84 ± 1.98	21.23 ± 7.93	6.39 ± 5.11	77.76 ± 10.84	0.70 ± 0.45
Department	818	40.1		8.61 ± 1.94	8.10 ± 1.94	21.97 ± 7.43	7.25 ± 5.50	75.86 ± 10.80	0.75 ± 0.53
Other parts of the hospital	177	8.7		8.54 ± 1.95	8.01 ± 2.06	21.98 ± 8.36	7.74 ± 5.74	78.18 ± 10.85	0.74 ± 0.48
At home	764	37.5		8.60 ± 1.92	8.08 ± 2.15	22.31 ± 7.61	7.26 ± 5.51	76.79 ± 11.25	0.77 ± 0.63
Outdoors	51	2.5		8.51 ± 1.87	7.76 ± 1.92	21.84 ± 9.10	7.04 ± 5.96	74.84 ± 12.12	0.83 ± 0.64
Symptom duration			*p*	<0.001***	0.322	0.004**	<0.001***	0.219	0.068
Uninfected	228	11.2		8.34 ± 1.77	7.84 ± 1.98	21.23 ± 7.93	6.39 ± 5.11	77.76 ± 10.84	0.70 ± 0.45
<3 days	608	29.8		8.37 ± 1.83	7.99 ± 2.09	21.31 ± 7.72	6.63 ± 5.36	77.01 ± 11.02	0.79 ± 0.65
3–5 days	658	32.3		8.67 ± 1.94	8.16 ± 2.05	22.76 ± 7.55	7.37 ± 5.42	76.04 ± 11.06	0.73 ± 0.50
5–7 days	329	16.1		8.65 ± 1.93	8.06 ± 1.95	21.87 ± 7.82	7.98 ± 5.84	76.11 ± 11.48	0.73 ± 0.53
>7 days	215	10.5		8.91 ± 2.12	8.06 ± 2.02	22.72 ± 7.25	7.89 ± 5.78	76.66 ± 10.45	0.82 ± 0.60
Rest time after infection			*p*	0.007**	0.284	0.023*	0.035*	0.152	0.336
Uninfected	228	11.2		8.34 ± 1.77	7.84 ± 1.98	21.23 ± 7.93	6.39 ± 5.11	77.76 ± 10.84	0.7 ± 0.45
<3 days	616	30.2		8.41 ± 1.91	8.00 ± 1.95	21.65 ± 7.83	7.10 ± 5.63	76.96 ± 11.34	0.75 ± 0.56
3–5 days	467	22.9		8.60 ± 1.94	8.13 ± 2.03	21.87 ± 7.60	7.01 ± 5.42	76.45 ± 11.03	0.75 ± 0.62
5–7 days	460	22.6		8.74 ± 1.86	8.03 ± 2.08	22.31 ± 7.59	7.68 ± 5.55	75.65 ± 10.62	0.78 ± 0.57
>7 days	267	13.1		8.76 ± 2.04	8.21 ± 2.19	23.23 ± 7.31	7.56 ± 5.51	76.67 ± 11.15	0.79 ± 0.52
Treatment			*p*	<0.001***	0.241	0.015*	<0.001***	0.182	0.004**
Uninfected	228	11.2		8.34 ± 1.77	7.84 ± 1.98	21.23 ± 7.93	6.39 ± 5.11	77.76 ± 10.84	0.70 ± 0.45
Self-healing at home	1,626	79.8		8.65 ± 1.93	8.09 ± 2.04	22.27 ± 7.57	7.35 ± 5.52	76.36 ± 11.03	0.76 ± 0.58
Hospitalization	10	0.5		8.40 ± 2.22	8.10 ± 2.38	23.20 ± 6.75	12.80 ± 5.77	80.40 ± 10.15	1.27 ± 1.36
Untreated	174	8.5		8.05 ± 1.82	7.89 ± 2.09	20.57 ± 8.27	6.48 ± 5.51	77.10 ± 11.31	0.69 ± 0.42
Time of return to work			*p*	0.268	0.592	0.02*	0.007**	0.007**	<0.001***
Uninfected	228	11.2		8.34 ± 1.77	7.84 ± 1.98	21.23 ± 7.93	6.39 ± 5.11	77.76 ± 10.84	0.70 ± 0.45
Return to work with symptoms	739	36.3		8.60 ± 1.97	8.08 ± 1.97	22.18 ± 7.66	7.63 ± 5.74	75.41 ± 11.09	0.79 ± 0.61
1–3 days after recovery	600	29.4		8.55 ± 1.90	8.08 ± 2.02	21.60 ± 7.41	6.77 ± 5.14	77.23 ± 10.94	0.69 ± 0.46
3–7 days after recovery	244	12		8.56 ± 1.86	8.07 ± 2.23	21.94 ± 7.88	7.47 ± 5.82	77.15 ± 10.69	0.76 ± 0.55
>7 days after recovery	227	11.1		8.74 ± 1.96	8.01 ± 2.14	23.38 ± 7.85	7.39 ± 5.53	77.02 ± 11.41	0.85 ± 0.71
Working hours			*p*	0.035*	0.022*	0.055	<0.001***	0.015*	<0.001***
<8 h	577	28.3		8.41 ± 1.87	7.83 ± 1.98	21.48 ± 7.76	6.44 ± 5.23	77.71 ± 10.79	0.68 ± 0.48
8–10 h	905	44.4		8.59 ± 1.89	8.13 ± 2.02	22.24 ± 7.35	7.29 ± 5.45	76.44 ± 11.13	0.75 ± 0.55
11–12 h	107	5.3		8.95 ± 2.07	8.28 ± 2.18	23.48 ± 8.03	7.82 ± 5.39	74.92 ± 11.46	0.87 ± 0.63
>12 h	449	22		8.61 ± 1.97	8.10 ± 2.09	21.87 ± 8.09	7.81 ± 5.86	75.89 ± 10.94	0.82 ± 0.64

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

3.2. The proportion of anxiety, depression, insomnia, stress, and ERI

In the evaluation of anxiety, depression, insomnia, 68.5% and 53.9% of the medical staff had different degrees of anxiety and depression, and 43.2% and 40.2% of the medical staff had insomnia and excessive stress. In the measurement of the ERI, high-effort and low-reward accounted for 14.2%, and low-effort and high-reward accounted for 85.8% (see Table 2).

3.3. Analysis of factors related to anxiety, depression, insomnia, stress, and ERI

In this study, women were risk factors for anxiety (OR = 1.360, $p < 0.05$) and stress (OR = 1.334, $p < 0.05$). Higher age was a protective factor for insomnia (OR = 0.709, $p < 0.01$) and stress (OR = 0.760, $p < 0.05$). Nurses (OR = 1.298, $p < 0.05$), higher education (OR = 1.242, $p < 0.05$), and long working years (OR = 1.247, $p < 0.001$) were risk factors for anxiety. To the

TABLE 2 The proportion of anxiety, depression, insomnia, stress and ERI.

	Anxiety	Depression	Insomnia		Stress		ERI			
Asymptomatic	642 (31.5%)	940 (46.1%)	No significant insomnia	1,158 (56.8%)	Excessive stress	820 (40.2%)	High-effort and low-reward	290 (14.2%)	Not over-commitment	1,092 (53.6%)
Mild	1,078 (52.9%)	843 (41.4%)	Sub insomnia	677 (33.2%)						
Moderate	312 (15.3%)	248 (12.2%)	Clinical insomnia	188 (9.2%)	No stress	1,218 (59.8%)	Low-effort and high-reward	1,748 (85.8%)	Over-commitment	946 (46.4%)
Severe	6 (0.3%)	7 (0.3%)	Severe insomnia	15 (0.7%)						

contrary, high professional title grade was a protective factor for anxiety (OR = 0.831, $p < 0.05$) and depression (OR = 0.750, $p < 0.001$). Being a nurse, longer working life, and longer working hours during the pandemic are risk factors for depression, insomnia, and stress. Non-infection with COVID-19 (OR = 0.486, $p < 0.05$) and prolonged symptoms of COVID-19 (OR = 1.152, $p < 0.01$) were protective and risk factors for insomnia, respectively. In addition, this study found that nurses (OR = 1.465, $p < 0.05$), higher education (OR = 1.476, $p < 0.001$), and longer working hours were more likely to show the ERI (OR = 1.312, $p < 0.001$; see Table 3).

3.4. Correlation analysis of HAD, PSS-14, ISI, resilience, and ERI

Pearson's correlation analysis found that there was a certain correlation between HAD, PSS-14, ERI, ISI, and the results of the stress assessment scale. Among them, anxiety, depression, stress, insomnia, and ERI are positively correlated ($p < 0.001$), while resilience is negatively correlated with anxiety, depression, stress, insomnia, and ERI ($p < 0.001$; see Table 4).

3.5. Effects of ERI on HAD, PSS-14, ISI, and resilience

With ERI results as grouping variables and scores of HAD, PSS-14, ISI, and resilience as test variables, an independent sample *T*-test was conducted. It was found that the high-effort and low-reward group and the over-commitment group had higher scores of anxiety, depression, stress, and insomnia and lower scores of resilience and its dimensions than the low-effort and high-reward group and the no over-commitment group, respectively. The difference was statistically significant ($p < 0.001$; see Table 5).

4. Discussion

Within a short period of time after the epidemic policy was opened, more than 50% of medical staff suffered from anxiety and depression to varying degrees, and more than 40% of medical staff suffered from excessive stress and insomnia. At the same time, the investigation showed that there was a certain correlation between the five scales of HAD, PSS-14, ERI, ISI, and resilience, and the relevant influencing factors mainly included gender, profession, education level, work years, professional title grade, working hours during the epidemic period, etc. The study also found that ERI has some effect on anxiety, depression, stress, insomnia severity, and resilience.

Anxiety, depression, and insomnia among medical staff found in this study accounted for 42% of anxiety and 33% of depressive symptoms reported in Aymerich et al. 's meta-analysis (34). Plus, Lai et al. reported that the prevalence rates of anxiety, depression, and insomnia among medical staff were 44.6%, 50.4%, and 34.0%, respectively (35). The reason may be that there has never been a large-scale outbreak nationwide in China's epidemic prevention process in the past, and the major adjustment and opening of the epidemic policy this time is nationwide and timely. However, given China's huge population base and limited medical resources, this undoubtedly brings a heavy burden on hospitals and medical staff in a short period of time. In addition, the study found that infection and symptom duration were risk factors for insomnia, with nearly 80% of infected medical staff self-medicating at home to treat and relieve symptoms. However, after nearly 50% of medical workers were infected with COVID-19 in hospital, more than 35% of them stayed on their posts to ensure the normal operation of hospitals to treat patients, and nearly 30% were back to work 3 days after infection. It may also be one of the important causes of their anxiety and insomnia. Working hours are also a risk factor for depression, insomnia, and stress, with more than 70 percent of medical staff working more than 8 h a day and 22 percent working more than 12 h a day. Previous evidence has also shown that the overwhelming workload pressure in the COVID-19 pandemic can cause great psychological stress and mental disorders for medical staff, especially increased anxiety responses, depressive symptoms, and stress, which is consistent with the findings of this study (36).

In this study, we found that during the COVID-19 pandemic, women were more likely to experience anxiety, depression, stress, and insomnia than men. Nurses were more likely to experience stress than doctors, which is consistent with the results of previous studies (37, 38). At the same time, it was found that compared with doctors, nurses had lower resistance and scores of all dimensions, and were more likely to have ERI. This may be due to the fact that nurses, most of whom are female, are directly responsible for nucleic acid collection and care of COVID-19 patients (39), face a greater risk of infection and workload, but are lower than doctors in terms of professional identity, social status, and salary (40), thus making them more prone to psychological symptoms and ERI. Therefore, more mental health support, social support, and well-being need to be provided to nurses during the response to major public health events (18, 41).

Unlike previous studies, high education level was found to be a risk factor for anxiety and the ERI in this study, but not a protective

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TABLE 3 Analysis of factors related to anxiety, depression, insomnia, stress, and ERI.

	Anxiety		Depression		Insomnia		Stress		ERI	
	OR (95%CI)	*P*	OR (95%CI)	*P*	OR (95%CI)	*P*	OR (95%CI)	*P*	OR (95%CI)	*P*
Gender	1.360 (1.066,1.735)	0.013*	0.847 (0.669,1.073)	0.168	1.039 (0.816,1.323)	0.758	1.334 (1.037,1.718)	0.025*	0.760 (0.547,1.057)	0.103
Profession	1.298 (1.039,1.620)	0.021*	1.391 (1.131,1.712)	0.002**	1.397 (1.131,1.725)	0.002**	1.738 (1.404,2.151)	<0.001***	1.465 (1.066,2.012)	0.019*
Age	0.905 (0.716,1.143)	0.402	0.926 (0.745,1.151)	0.488	0.709 (0.568,0.886)	0.002**	0.760 (0.607,0.951)	0.017*	0.786 (0.571,1.083)	0.141
Education level	1.242 (1.042,1.480)	0.016*	1.063 (0.899,1.257)	0.475	1.156 (0.968,1.381)	0.109	1.146 (0.953,1.379)	0.147	1.476 (1.133,1.924)	0.004**
Working years	1.247 (1.110,1.400)	<0.001***	1.244 (1.114,1.388)	<0.001***	1.278 (1.141,1.432)	<0.001***	1.333 (1.187,1.498)	<0.001***	1.104 (0.939,1.299)	0.230
Professional title grade	0.831 (0.692,0.998)	0.047*	0.750 (0.631,0.891)	<0.001***	0.865 (0.725,1.031)	0.106	0.860 (0.718,1.030)	0.101	1.230 (0.965,1.567)	0.094
Whether infected or not	0.591 (0.291,1.200)	0.146	1.143 (0.592,2.207)	0.691	0.486 (0.249,0.947)	0.034*	0.823 (0.464,1.462)	0.507	0.850 (0.332,2.181)	0.736
Symptom duration	1.103 (0.992,1.227)	0.069	1.042 (0.945,1.148)	0.414	1.152 (1.044,1.270)	0.005**	1.075 (0.976,1.184)	0.141	1.031 (0.899,1.181)	0.665
Working hours	1.048 (0.957,1.147)	0.309	1.112 (1.022,1.211)	0.014*	1.159 (1.064,1.262)	<0.001***	1.112 (1.021,1.212)	0.015*	1.312 (1.170,1.471)	<0.001***

Age, education level, working years, professional title grade, and working hours during the epidemic period are regarded as continuous variables. Doctors: 0, nurses: 1; Uninfected: 0, infected: 1. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

TABLE 4 Correlation analysis of HAD, PSS-14, ISI, resilience and ERI.

	Mean	SD	Anxiety	Depression	Stress	Insomnia	Resilience	ERI
Anxiety	8.57	1.91	1	0.288***	0.495***	0.374***	−0.271***	0.345***
Depression	8.05	2.04	0.288***	1	0.365***	0.307***	−0.188***	0.216***
Stress	22.01	7.68	0.495***	0.365***	1	0.484***	−0.414***	0.444***
Insomnia	7.19	5.50	0.374***	0.307***	0.484***	1	−0.325***	0.411***
Resilience	76.60	11.03	−0.271***	−0.188***	−0.414***	−0.325***	1	−0.388***
ERI	0.75	0.56	0.345***	0.216***	0.444***	0.411***	−0.388***	1

Pearson's correlation analysis, ***$p < 0.001$.

factor for insomnia (42). The reason may be that the public already has a clear understanding of COVID-19, and the awareness of COVID-19 varies according to different levels of education, so anxiety, depression, insomnia, and other conditions caused by it are not the main reason. The reason is more likely to be that the higher well-being expected by highly educated medical staff has not been achieved, because the ERI only led to anxiety, and the level of psychological disorders has not yet led to depression and insomnia. In regression analysis, we found that advanced age was a protective factor for stress and insomnia, and higher professional title grade was a protective factor for anxiety and depression, as found by Zhou and Irene Teo et al. (43, 44). Because anxiety is highly associated with burnout, older and higher professional title-grade medical staff tended to have more experience and lower levels of burnout, they are more adept at coping with emergencies than younger medical staff, and they have even participated in the prevention and control of SARS (44–46). At the same time, working years were found to be a risk factor for anxiety, depression, stress, and insomnia. A long working life does not mean a match for a higher professional title grade, and medical workers with higher working years are more likely to suffer from anxiety, pressure, and other psychological disorders due to job burnout when dealing with the high workload of the epidemic (47).

Further analysis showed that medical staff working in departments that were in close contact with COVID-19 patients, such as intensive care units, emergency departments, respiratory departments, and infectious disease departments, showed more psychological disorders such as anxiety, depression, and stress than clinical staff in other departments, consistent with the results of Lu et al. (48). In addition, due to the need to monitor a large number of nucleic acid specimens, compared with other departments above, the laboratory department has more prominent problems in insomnia and ERI.

In the correlation analysis, there was a certain correlation between the five scales; anxiety, depression, stress, insomnia, and the ERI were all positively correlated, while stress resistance was

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TABLE 5 Effects of ERI on HAD, PSS-14, ISI, and resilience.

ERI	Anxiety	Depression	Perceived coping ability	Perceived distress	Stress	Insomnia	Decision coping	Interpersonal connection	Rational thinking	Flexible adaptation	Resilience
High-effort and low-reward	9.44 ± 2.17	8.66 ± 2.31	13.2 ± 4.92	13.59 ± 4.88	26.78 ± 6.78	10.91 ± 6.09	24.12 ± 4.03	16.08 ± 2.78	15.54 ± 2.97	14.97 ± 3.26	70.71 ± 11.17
Low-effort and high-reward	8.42 ± 1.83	7.94 ± 1.97	11.33 ± 5.43	9.89 ± 4.36	21.22 ± 7.53	6.57 ± 5.15	25.95 ± 3.77	17.58 ± 2.41	17.07 ± 2.68	16.97 ± 2.71	77.58 ± 10.7
T	7.616	5.006	5.496	13.139	12.735	11.471	−7.596	−9.603	−8.859	−9.913	−10.057
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
Not over-commitment	8.14 ± 1.78	7.72 ± 1.89	10.62 ± 5.5	9.11 ± 4.32	19.73 ± 7.62	5.59 ± 4.85	26.07 ± 3.76	17.78 ± 2.37	17.27 ± 2.66	17.28 ± 2.63	78.39 ± 10.55
Over-commitment	9.06 ± 1.94	8.42 ± 2.13	12.72 ± 5.04	11.92 ± 4.51	24.64 ± 6.87	9.04 ± 5.63	25.25 ± 3.93	16.9 ± 2.61	16.37 ± 2.82	16 ± 3.01	74.53 ± 11.22
T	−11.207	−7.755	−8.925	−14.332	−15.275	−14.667	4.774	7.975	7.362	10.224	8.009
P	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***

***$p < 0.001$.

negatively correlated with anxiety, depression, stress, insomnia, and ERI. Under the influence of long-term negative events, people tend to be more vulnerable, and medical staff with higher stress levels tend to suffer from anxiety, depression, insomnia, and other symptoms (16, 49). Consistent with previous studies, high resilience means that individuals are more likely to bounce back and adapt quickly to adversity (50, 51). People with higher resilience are more likely to proactively cope with setbacks or difficulties, have greater resilience to stress, greater social adjustment, and have higher levels of self-evaluation and self-confidence (52). Therefore, resilience can not only serve as an important buffer against psychological trauma, stress, insomnia, and psychological distress. Individuals' mental resilience can also be assessed to predict mental health status, stress perception, and sleep quality (19). However, it is worth noting that the results of a comprehensive review showed that while medical staff exhibited moderate levels of resilience on average during the COVID-19 pandemic, they were not immune to the negative psychological effects of working during the pandemic (53). Therefore, how to maintain and improve the resilience of medical staff to cope with large-scale public health emergencies needs further study.

This study also found that when the ERI occurred among medical staff, the high effort and low reward group and the over-commitment group were more prone to anxiety, depression, stress, and insomnia than the low-effort and high-reward group and the non-over-commitment group, respectively. Nursing, higher education level, and working hours are risk factors for the ERI. Previous studies have shown that a lack of reciprocity between the time and effort individuals invest in their work and the money, respect, recognition, and career opportunities they receive can lead to negative emotions, which in turn affect the autonomic nervous system's sustained stress response, leading to insomnia and mental health problems (21, 22, 54). At present, many studies have confirmed that ERI is positively correlated with adverse mental state and perceived stress, and people in situations of high effort and low reward have more adverse physical health conditions and mental health problems (54), which is consistent with the results of this study. Therefore, this study believes that, when dealing with major public health emergencies, improving the social support and well-being of medical staff and improving the imbalance of reward may effectively improve their resilience and reduce their anxiety, depression, and other psychological disorders, stress, insomnia, and other symptoms. On the other hand, attention should also be paid to the working hours and the contribution of nurses and highly educated medical staff in responding to such incidents. Because in the long run, nurses and highly educated medical staff are under pressure to work long hours, exert greater effort for lower reward, and may use self-protection strategies to distance themselves emotionally, which in turn negatively affects the quality of medicine and care (22). We need to focus not only on the mental health and well-being needs of medical staff from an individual perspective. It is also necessary to rationally allocate medical and health human resources at the organizational level, reduce the overworked state of medical staff, design scientific and reasonable salary systems and performance evaluation indicators, and reflect the value of technical labor of medical staff. In addition, we also need to continuously optimize and improve the evaluation effectiveness of psychological, stress, sleep, burnout, and other scales, and try to use new procedures and tools to detect the psychological condition of medical staff more timely and

accurately, because prevention and remission are far more important than cure (55–57).

5. Conclusion

This study found that anxiety, depression, stress, insomnia, and other conditions of medical staff in China during the period of policy opening to COVID-19 were higher than those in previous studies. Women, nurses, higher education level, more working years and working hours, high effort and low reward are risk factors for anxiety, depression, stress, and insomnia. Attention should be paid to the influence of the above factors on the psychological status of medical staff. There are positive correlations among anxiety, depression, stress, insomnia, and ERI, and they affect each other. Resilience acts as an important buffer for psychological trauma, stress, insomnia, and the ERI, and can be used to predict and improve the mental health status, stress perception, and sleep quality of medical personnel. This study calls for improving the well-being of medical staff, optimizing the allocation of human resources, focusing on prevention and mitigation, and maintaining the mental health and sleep quality of medical staff in response to major public health emergencies at the individual and organizational levels, so as to promote the improvement of the quality of medicine and care.

5.1. Limitations

Some limitations of this study should be noted. First, this study is a single-center study with a non-probability sample survey rather than a random sample survey. In addition, the survey was conducted online rather than face-to-face. Despite these limitations, this study is very important for understanding the psychological status of medical staff in response to major public health emergencies in the future and can provide some reference value for them to formulate psychological care strategies and related epidemic prevention policies.

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. The study was conducted in accordance with the World Medical Association Code of Ethics (Declaration of Helsinki) with the informed consent of all participants.

Author contributions

ZhC: study design, data collection, interpretation, analysis, and drafted manuscript. YT: data collection, interpretation, analysis, and revision. TL: investigation, study coordination, and manuscript revision. SH: investigation, data collection, and data analysis. YC: investigation and data collection. LS: project administration, study design, and manuscript revision. ZoC: guarantor of integrity of the entire study, study design, and manuscript revision. 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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Predictors of mental well-being over the first lockdown period due to the COVID-19 pandemic in France. A repeated cross-sectional study

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Introduction: Numerous studies have investigated the positive and negative effects of potential predictors of well-being during lockdowns due to COVID-19. Yet, little is known on whether these effects significantly changed with time spent in lockdown. In the current study, we described the association of mental well-being with a large number of background characteristics (e.g., socio-demographic or health-related factors), COVID-related factors, and coping strategies, over the duration of the first lockdown due to COVID-19 in France.

Methods: A nationwide online survey was conducted over 7 of the 8 weeks of the 1st lockdown in France, i.e., from 25 March 2020 to 10 May 2020. The level of mental well-being was reported using the Warwick-Edinburgh Mental Well-Being Scale (WEMWBS). We also measured various background characteristics (e.g., age, sex, education, health issues), COVID-related factors (e.g., health and economic risks, agreement with lockdown), and coping strategies. Our analytical strategy enabled us to disentangle effects aggregated over the study period from those that linearly vary with time spent in lockdown.

Results: Our final dataset included 18,957 participants. The level of mental well-being dropped gradually from the third to the eighth week of lockdown [49.7 (sd 7.9) to 45.5 (sd 10.6)]. Time in lockdown was associated with a decrease in well-being (for each additional 10 days of lockdown: B = −0.30, 95%CI: −0.62, −0.15). Factors that showed significantly negative and positive effects on well-being as time in lockdown progressed were (for each additional 10 days of lockdown): having current psychiatric problems (B = −0.37; 95%CI: −0.63, −0.04), worries about having access to personal protective equipment (B = −0.09; 95%CI: −0.18, −0.01), coping by having positive beliefs about the future of the pandemics (B = 0.29; 95%CI: 0.04, 0.62), being supported by neighbors (B = 0.24; 95%CI: 0.04, 0.44), and being involved in collective actions (B = 0.23; 95%CI: 0.04, 0.46).

Discussion: Participants from our sample saw a drop in their mental well-being throughout the first period of COVID-19 lockdown. Policymakers should be mindful of factors contributing to greater deterioration of mental well-being over time, such as having current psychiatric issues. Promoting collective actions and local support from neighbors may alleviate the deterioration of mental well-being over time.

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KEYWORDS

COVID-19, mental health, well-being, lockdown, public health

1. Introduction

When the World Health Organization (WHO) declared the coronavirus disease 2019 (COVID-19) outbreak a pandemic on 11 March 2020, severe lockdown restrictions were implemented by the governments of several countries worldwide to prevent the uncontrolled spread of the virus. The French government introduced strict social distancing rules on 16 March 2020. Like many other countries all over the world, this was the first time the population of France had ever been subjected to a lockdown to minimize the spread of infectious disease. For over 2 months, under stay-at-home orders, people's home became the only places where they could sleep, eat, work, do sport (within a 1 km perimeter), and socialize.

The fear of the virus triggered in the minds of virtually everyone who heard about it. Yet, beyond the epidemic itself, measures used to control the spread of the virus and ensuing lifestyle disruptions, uncertainty and loss of control, have also been shown to have a negative impact on mental health (1–4). A number of mental health-related outcomes deteriorated during lockdown, such as affective symptoms (e.g., depressive and anxiety symptoms), quality and quantity of sleep, or quality of life (5). As a result, the use of at least one psychotropic drug increased by 20% compared to pre-lockdown (5). In France, the early phase of COVID-19 containment led to widespread increases in addiction-related habits in the surveyed populations (6), increased anxiety (7) and decreased well-being (8).

The WHO describes mental well-being as a state in which an individual realizes his or her own abilities, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to his or her community (9). Well-being is usually conceptualized with two main components: subjective or hedonic well-being on the one hand, and eudaimonic or psychological well-being on the other hand (10). Hedonic well-being includes life satisfaction, positive emotions, and a low level of negative emotions. Eudaimonic well-being may be described as less subjective, and more related to psychological functioning, including dimensions such as self-acceptance, personal growth, purpose in life, positive relations with others, environmental mastery, autonomy (11). While hedonic well-being is usually associated with "feeling good," eudaimonic well-being is associated with "functioning well" (12). Overall, both these dimensions have been shown to be highly correlated with one-another, depending on a single underlying factor (13).

The level of an individual's well-being depends on a number of elements, such as demographic characteristics (age, sex, marital status), social factors (socio-economic status, having children, social contacts), personality traits, life events, health, and activities (14). For the purpose of this study, we chose to classify factors influencing well-being during COVID in three different categories: background characteristics (socio-demographic and health-related factors), COVID-related factors (and especially distress linked to COVID policies or related economic consequences), and coping strategies.

First, background characteristics have been related to well-being during COVID-19 lockdown. For instance, female gender (5, 15–17), young age (18, 19), not being in a relationship (20, 21), being a smoker (5), living in a small place, without outdoor space or in an urban area (22–26), or less intuitively having longer periods of physical activity before lockdown (5), have been considered as significant risk factors of decreased well-being during lockdowns. Similar effects were found for students (27), those with low educational attainment (20) and those who are unemployed (28, 29). The effect of lockdown and social distancing on mental health in individuals with pre-existing medical or mental illness has also been demonstrated (17, 30, 31).

Second, well-being may be impacted by a range of factors related to the pandemic itself. The risk of being exposed to the virus is a threat to mental health (32), but perhaps not as highly as expected (33, 34). Other COVID-related factors may be at stake such as a lower trust in, as well as lack of agreement or satisfaction with governmental policies to curb the spread of the virus (35–37). Finally, the pandemic has led to a range of economic consequences that may also increase one's level of stress, such as financial loss (33), scarcity of essential products (32) and personal protective equipment (PPE).

Third, how one copes with the occupational difficulties associated with the pandemic is also of crucial importance to maintain an acceptable level of well-being (32, 38–40). Examples of coping strategies that have been demonstrated to protect against the negative effects of lockdown are: resilience (41), positive thinking, and seeking social support (42, 43).

Previous research has also investigated whether different subgroups were associated with various effects on mental well-being depending on the temporal course of lockdowns (44–50). These effects may reflect growing fear of catching the virus and/or increased impact of having to maintain lockdown measures. These temporal changes are important to consider as they may disproportionately affect specific population subgroups that need to be identified and supported in order to anticipate and prevent further deterioration of mental health as well as later psychiatric or physical disorders (51, 52). A deterioration of well-being over time may also contribute to increased hopelessness and de-motivation to follow recommended protective behaviors (53).

Studies mentioned above have identified such factors as female gender, young age, past mental issues, social disadvantage, and certain psychological traits, to be related to increased deterioration of mental well-being with time spent in lockdown. Yet, to our knowledge, none of these studies has investigated the temporal effects of a broad variety of predictors in the same model, which would enable the estimation of the importance of each predictor above and beyond all the others.

In the current study, we aimed to determine how the above mentioned factors (background characteristics, COVID-related factors, coping strategies) influenced well-being over the 2 months period of the first COVID-19 lockdown in an adult population in France. Our rationale for this study was twofold. First, we wished to

confirm or infirm previous findings with a large sample of French individuals. Second, none of these studies has investigated the temporal effects of a broad variety of predictors in the same model, which would enable the estimation of the importance of each predictor above and beyond all the others.

We used responses to an anonymous repeated cross-sectional online survey from March 25 to May 10 2020. Previous reports have been published using this survey (6, 8) but focused on the initial lockdown period. Here, our analytical strategy enabled us to disentangle overall main effects aggregated over the study period from those that linearly vary with time spent in lockdown. We hypothesized that factors that have been found as significant predictors of mental health outcomes in previous studies would be associated with decreased well-being during COVID-19 lockdown (e.g., female gender, young age/being a student, not being in a relationship, having mental issues, worrying about financial precarity or not having access to essential products, lack of coping strategies).

2. Materials and methods

2.1. Data

2.1.1. Data source

A nationwide online survey (LockUwell) was launched during the second week of the first lockdown period in France and continued until the end of this period, i.e., till the end of the 8th week of lockdown. The data were collected from 25 March 2020 to 10 May 2020. No cohort was involved: different participants responded at different time points. The methodology and reporting of the results are based on the Checklist for Reporting Results of Internet E-Surveys (CHERRIES) (54).

The survey was specially developed for this study and it has already been described by Haesebaert et al. (8). Briefly, participants were recruited via online announcements on social networks, the websites of national newspapers, and mailing lists using a convenience non-sampling method, with no incentives. The questions aimed to collect a range of items relating to mental well-being and to embrace a large range of socio-demographic and environmental data relating to the lockdown situation. The questionnaire was divided into six sections: socio-demographic data (section 1), assessment of well-being over the week preceding the response date (French version of the Warwick-Edinburgh Mental Well-being Scale, WEMWBS) (13, 55) (section 2), Visual Numerical Scales for stress (section 3), history (section 4), personal situation regarding COVID-19 (i.e., whether respondents had or knew someone who had COVID-19 and personal feelings regarding COVID-19) (section 5), as well as personal and environmental conditions during lockdown (section 6). We extracted data from all the above-mentioned sections except section 3, as only well-being (and not stress) was the focus of this study.

2.1.2. Outcome variable

The WEMWBS is a 14-item measure of mental well-being (13). It covers both the hedonic and eudaimonic aspects of mental health, including positive affects (feelings of optimism, cheerfulness, and relaxation), satisfying interpersonal relationships and positive functioning (energy, clear thinking, self-acceptance, personal development, competence, and autonomy). It has good content validity and high test–retest reliability. An overall higher score indicates more positive well-being. The WEMWBS has been shown to detect subtle change in populations with both good and poor mental health (56) and has already been widely used to study the COVID-19 outbreak (57, 58). For more details, see Supplementary methods.

2.1.3. Predictors

We extracted the following variables:

2.1.3.1. Background characteristics

- Socio-demographic factors: age; sex (male vs. female); being in a relationship (no vs. yes); educational attainment (up to 12 years of education (reference) vs. 12 to 14 years of education vs. 14 years of education to Bachelor level vs. Bachelor to Master's level vs. Master's to PhD level or above); working category (employee (reference) vs. self-employed vs. student vs. retiree); having undergone a lockdown period in the past (e.g., jail, long period of hospital admission: no vs. yes); having access to an outdoor space (e.g., balcony, private garden: no vs. yes); living area (living in an urban area (reference) vs. semi-urban area vs. rural area); having a pet (no vs. yes); social contacts, which we determined by frequency of casual face to face contacts, telephone calls, text messages and contacts from social networks (measured on Likert scales; Supplementary methods); living place [French districts ("*départements*"): 69 (Rhône) vs. 75 (Paris) vs. other (ref)].
- Health-related factors: having a chronic medical illness (no vs. yes); having a psychiatric history (no history (ref) vs. past history only vs. current issues). The latter was evaluated through the following question: "Have you ever been followed for a psychiatric and/or addiction problem (by a psychologist/psychiatrist/addiction specialist)?" Possible answers: yes currently, yes in the past, no never.

2.1.3.2. COVID-related factors

- COVID-19 status and risk of contamination: COVID-19 negative and no contact with people (reference) vs. COVID-19 negative and in contact with people who are not contaminated vs. COVID-19 positive or COVID-19 negative and in contact with people who are contaminated or suspected to be contaminated;
- Lockdown policies and official information: agreement with lockdown measures; satisfaction with COVID-related information; satisfaction with the clarity of information provided by the government;
- Worries about negative consequences of lockdown: worries about having access to PPE; worries about having access to essential products; worries about financial consequences; worries about being in a precarious situation.

Lockdown policies and official information, as well as worries about negative consequences of lockdown, were measured on Likert scales (Supplementary methods).

2.1.3.3. Coping strategies

- Support from … (no vs. yes): people living under the same roof; family (other than those living under the same roof); friends (other than those living under the same roof); colleagues; neighbors/acquaintances;
- Coping with … (no vs. yes): words from people around; beliefs in a favorable outcome; advances in knowledge and scientific progress; religious faith; resilience and past experiences; collective actions; beliefs in beneficial impact that lockdown can have on the planet; beliefs in positive impacts of lockdown on the individual; none of these.

Continuous predictors were variables with a numerical outcome (age) and variables measured on a Likert scale (e.g., frequency of contact). Other predictors were categorical.

Note that from the original sample (N = 19,205), we excluded participants who did not live in France, who were younger than 16 years-old or older than 75 years-old, and those who did not define themselves as male or female. Our final dataset included N = 18,957 observations.

The research board of the Vinatier Hospital (Bron, France) stated that no ethics committee approval was needed and that the project was conducted in accordance with survey ethics. Indeed, as the survey was conducted anonymously with no personal data the EU General Data Protection Regulation (GDPR) of May 25, 2018 did not apply.

2.2. Analysis

To predict well-being over the two-months lockdown period based on our large set of predictors, we ran a regression model, including main terms as well as their first order interaction with days since the survey was launched. Main effects identify overall effects of predictors (i.e., aggregated over the study period). Interaction effects identify whether the positive or negative effect of a given predictor significantly increases with time since the survey was launched.

We were facing two methodological constraints. First, we had a very large set of predictors, incurring the risk of multi-collinearity and unreliable coefficient estimates due to high variance. We addressed this challenge by running ridge regularization regression instead of standard (OLS) linear regression (59). Ridge regression, or L2 regularization, is a method of choice when analyzing data that contain a high number of predictors and/or that potentially suffer from multi-collinearity. Ridge regression adds a penalty to the coefficient estimates, shrinking less important estimates and making the variables less correlated, overall differentiating "important" from "less-important" predictors. Of note, ridge regression does not eliminate coefficients, as is the case in LASSO regression (L1 regularization).

Mathematically, ridge regression is adding a penalty parameter to the objective function of a standard linear model. Ridge regression aims to minimize ($\|X\beta - y\|^2 + \lambda\|\beta\|^2$), X being the matrix of independent variables, β being a vector of their parameter estimates, y being the vector of the dependent variable, and λ (lambda) being the penalization parameter. While coefficients estimated by the ridge estimator have lower variance compared to the OLS estimator, they may also suffer from a higher bias. The usual practice is to minimize the bias-variance trade-off by choosing an optimal penalty parameter using a cross-validation procedure (see below).

A second methodological constraint was the imbalance in the distribution of survey responses over the duration of lockdown (11,194 respondents in week 2; 5,008 in week 3; 629 respondents in week 4; 1,259 respondents in week 5; 394 respondents in week 6; 337 respondents in week 7; and 136 respondents in week 8). To address this caveat, we used a bootstrap down-sampling strategy. We ran the ridge algorithm 1,000 times after having down-sampled the data (with replacement) so that each lockdown week presented an equal number of observations, equal to the size of the minority class data (data from week 8). Random sampling with replacement was used to down-sample for the majority classes. Data from week 8 were also sampled with replacement but kept their original size. Each sample included N = 952 observations.

Using the R package *glmnet* (60), we trained each of the 1,000 samples using a k = 20 folds cross-validation procedure. Briefly, for each of the 20 folds, the procedure ran the ridge algorithm 100 times (each time with a different lambda value) on a training set including 95% of the data, and tested the predictive accuracy on an independent testing set including 5% of the data. The model with the best lambda value (i.e., where the R^2 was maximized) was then selected and ran on the entire sample.

Overall, we obtained 1,000 best penalty parameters lambdas that each time maximized an R^2, as well as 1,000 random cases of parameter estimates for each predictor. For each parameter, we therefore obtained a distribution of these randomly generated coefficients, from which we extracted our average estimate B (defined as the median of the distribution) and 95% confidence interval (2.5 and 97.5 percentiles). Parameter estimates whose 95% confidence intervals did not include zero were deemed as significant.

Pre-processing involved the exclusion of "near zero-variance" predictors, and of highly correlated predictors. Specifically, if two variables had a correlation greater than 0.9, we removed the variable with the largest mean absolute correlation. Note that no methods such as weighting or propensity scores were used to adjust for the non-representativeness of the sample to the French population.

Analyses were conducted with R 4.0.1, and packages *glmnet* (60) and *caret* (61).

3. Results

3.1. Data description

A total of 18,957 participants had a complete questionnaire (Table 1). 76.7% were women. 26% were aged 16–29 years, 47.5% were aged 30–49 years, 26.4% were aged 50 years and older. The majority of respondents were employed (66.3%), in a relationship (63.9%), had at least 14 years of education (80.4%), and were living in an urban area (54.1%). 74.8% of participants had no past or current psychiatric history.

The overall mean WEMWBS total score was 49.2 (sd 8.2). There were variations depending on the week of lockdown, starting at 49.4 (sd 8.1) in week 2, then 49.7 (sd 7.9) in week 3, followed by a gradual decrease to 45.7 (sd 10.3) in week 8 (Table 1). Please refer to Table 1 for a description of other socio-demographic and health-related characteristics of the participants throughout the study period. Please

TABLE 1 Socio-demographic and health-related characteristics of the participants.

Variables	Week 2 (*N* = 11,194)	Week 3 (*N* = 5,008)	Week 4 (*N* = 629)	Week 5 (*N* = 1,259)	Week 6 (*N* = 394)	Week 7 (*N* = 337)	Week 8 (*N* = 136)	Total (*N* = 18,957)
WEMWBS total score: mean (SD)	49.4 (8.1)	49.7 (7.9)	48.6 (8.8)	47.8 (8.7)	47.7 (9.7)	47.4 (8.9)	45.7 (10.3)	49.2 (8.2)
Sex								
Male	2,518 (22.5%)	1,238 (24.7%)	160 (25.4%)	297 (23.6%)	96 (24.4%)	68 (20.2%)	36 (26.5%)	4,413 (23.3%)
Female	8,676 (77.5%)	3,770 (75.3%)	469 (74.6%)	962 (76.4%)	298 (75.6%)	269 (79.8%)	100 (73.5%)	14,544 (76.7%)
Age								
16–29 y/o	3,350 (29.9%)	944 (18.8%)	123 (19.6%)	292 (23.2%)	117 (29.7%)	80 (23.7%)	30 (22.1%)	4,936 (26.0%)
30–49 y/o	5,274 (47.1%)	2,487 (49.7%)	294 (46.7%)	562 (44.6%)	171 (43.4%)	161 (47.8%)	64 (47.1%)	9,013 (47.5%)
50–74 y/o	2,570 (23.0%)	1,577 (31.5%)	212 (33.7%)	405 (32.2%)	106 (26.9%)	96 (28.5%)	42 (30.9%)	5,008 (26.4%)
In a relationship								
No	3,940 (35.2%)	1810 (36.1%)	238 (37.8%)	523 (41.5%)	140 (35.5%)	133 (39.5%)	62 (45.6%)	6,846 (36.1%)
Yes	7,254 (64.8%)	3,198 (63.9%)	391 (62.2%)	736 (58.5%)	254 (64.5%)	204 (60.5%)	74 (54.4%)	12,111 (63.9%)
Education								
Up to 12 years of education	1988 (17.8%)	736 (14.7%)	111 (17.6%)	171 (13.6%)	60 (15.2%)	51 (15.1%)	27 (19.9%)	3,144 (16.6%)
12 to 14 years of education	1,498 (13.4%)	667 (13.3%)	93 (14.8%)	167 (13.3%)	59 (15.0%)	44 (13.1%)	19 (14.0%)	2,547 (13.4%)
14 years to Bachelor level	2,435 (21.8%)	1,020 (20.4%)	132 (21.0%)	249 (19.8%)	76 (19.3%)	53 (15.7%)	27 (19.9%)	3,992 (21.1%)
Bachelor to Masters	4,157 (37.1%)	1972 (39.4%)	241 (38.3%)	555 (44.1%)	153 (38.8%)	163 (48.4%)	53 (39.0%)	7,294 (38.5%)
Masters to PhD or above	1,116 (10.0%)	613 (12.2%)	52 (8.3%)	117 (9.3%)	46 (11.7%)	26 (7.7%)	10 (7.4%)	1980 (10.4%)
Access to outdoor space								
No	2001 (17.9%)	787 (15.7%)	89 (14.1%)	226 (18.0%)	65 (16.5%)	52 (15.4%)	19 (14.0%)	3,239 (17.1%)
Yes	9,193 (82.1%)	4,221 (84.3%)	540 (85.9%)	1,033 (82.0%)	329 (83.5%)	285 (84.6%)	117 (86.0%)	15,718 (82.9%)
Work situation								
Employee	7,388 (66.0%)	3,415 (68.2%)	384 (61.0%)	840 (66.7%)	260 (66.0%)	212 (62.9%)	76 (55.9%)	12,575 (66.3%)
Self-employed	1,165 (10.4%)	536 (10.7%)	65 (10.3%)	117 (9.3%)	25 (6.3%)	29 (8.6%)	16 (11.8%)	1953 (10.3%)
Student	1,390 (12.4%)	441 (8.8%)	70 (11.1%)	156 (12.4%)	65 (16.5%)	40 (11.9%)	21 (15.4%)	2,183 (11.5%)
Retired	763 (6.8%)	446 (8.9%)	74 (11.8%)	94 (7.5%)	21 (5.3%)	26 (7.7%)	11 (8.1%)	1,435 (7.6%)
Other	488 (4.3%)	170 (3.4%)	36 (5.7%)	52 (4.1%)	23 (5.8%)	30 (8.9%)	12 (8.8%)	811 (4.3%)
Ever been locked								
No	8,922 (79.7%)	4,044 (80.8%)	489 (77.7%)	966 (76.7%)	311 (78.9%)	269 (79.8%)	109 (80.1%)	15,110 (79.7%)
Yes	2,272 (20.3%)	964 (19.2%)	140 (22.3%)	293 (23.3%)	83 (21.1%)	68 (20.2%)	27 (19.9%)	3,847 (20.3%)
Chronic medical pb								
No	9,446 (84.4%)	4,199 (83.8%)	523 (83.1%)	1,033 (82.0%)	318 (80.7%)	275 (81.6%)	105 (77.2%)	15,899 (83.9%)
Yes	1748 (15.6%)	809 (16.2%)	106 (16.9%)	226 (18.0%)	76 (19.3%)	62 (18.4%)	31 (22.8%)	3,058 (16.1%)
Psychiatric history								
No	8,386 (74.9%)	3,850 (76.9%)	448 (71.2%)	898 (71.3%)	289 (73.4%)	216 (64.1%)	86 (63.2%)	14,173 (74.8%)
Past psychiatric history	1,602 (14.3%)	658 (13.1%)	101 (16.1%)	199 (15.8%)	49 (12.4%)	48 (14.2%)	21 (15.4%)	2,678 (14.1%)
Current psychiatric issues	1,206 (10.8%)	500 (10.0%)	80 (12.7%)	162 (12.9%)	56 (14.2%)	73 (21.7%)	29 (21.3%)	2,106 (11.1%)

(Continued)

TABLE 1 (Continued)

Variables	Week 2 (*N* = 11,194)	Week 3 (*N* = 5,008)	Week 4 (*N* = 629)	Week 5 (*N* = 1,259)	Week 6 (*N* = 394)	Week 7 (*N* = 337)	Week 8 (*N* = 136)	Total (*N* = 18,957)
Area of living								
Urban area	6,192 (55.3%)	2,616 (52.2%)	317 (50.4%)	681 (54.1%)	203 (51.5%)	173 (51.3%)	71 (52.2%)	10,253 (54.1%)
Semi-rural area	2,373 (21.2%)	1,101 (22.0%)	158 (25.1%)	286 (22.7%)	98 (24.9%)	76 (22.6%)	34 (25.0%)	4,126 (21.8%)
Rural area	2,629 (23.5%)	1,291 (25.8%)	154 (24.5%)	292 (23.2%)	93 (23.6%)	88 (26.1%)	31 (22.8%)	4,578 (24.1%)
Having a pet								
No	5,845 (52.2%)	2,793 (55.8%)	351 (55.8%)	711 (56.5%)	215 (54.6%)	192 (57.0%)	84 (61.8%)	10,191 (53.8%)
Yes	5,349 (47.8%)	2,215 (44.2%)	278 (44.2%)	548 (43.5%)	179 (45.4%)	145 (43.0%)	52 (38.2%)	8,766 (46.2%)

refer to Supplementary Table 1 for a description of the remaining predictors.

3.2. Adjusted analysis

We then randomly down-sampled the data 1,000 times to have a balanced representation of each of the 7 lockdown weeks. We subsequently ran a ridge regression of the above-mentioned predictors on the WEMWBS total score in each of the 1,000 sampled data. Over the 1,000 samples, the range of the penalty parameter lambda was [0.32, 6.05], and the range of R^2 was [0.29, 0.46]. Mean R^2 was of 0.37. Below, we report significant main effects (overall effects over the study period) as well as significant temporal effects (positive and negative effects that increase with time spent in lockdown) for background characteristics, COVID-related factors and support/coping strategies.

3.2.1. Main effects

- Background socio-demographic and health-related characteristics that were significantly associated with decreased well-being over the study period were: having current psychiatric issues (B = −2.26; 95% CI: −3.82, −1.39); having past psychiatric problems (B = −1.27; 95% CI: −2.75, −0.38) (Figure 1, left panel and Supplementary Table 2). Background characteristics that were significantly associated with increased well-being were age (B = 0.71 for each additional 10 years of age; 95% CI: 0.47, 1.14); and social contacts (as measured by phone contacts: B = 0.36; 95% CI: 0.04, 0.69) (Figure 1, right panel and Supplementary Table 2).
- COVID-related factors that were significantly associated with decreased well-being over the study period were: worries about being in a precarious situation (B = −0.57; 95% CI: −1.22, −0.16); worries about having access to essential products (B = −0.37; 95% CI: −0.89, −0.04; Figure 2, left panel and Supplementary Table 3). COVID-related factors that were significantly associated with increased well-being were: satisfaction with COVID-related information (B = 0.60; 95%CI: 0.31, 0.97); agreement with lockdown measures (B = 0.60; 95%CI: 0.25, 1.04; Figure 2, right panel and Supplementary Table 3).
- Coping strategies associated with increased well-being over the study period were: resilience (B = 1.35; 95%CI: 0.75, 2.34); beliefs in a favorable outcome (B = 1.14; 95%CI: 0.48, 1.83); beliefs that lockdown has positive impacts on the individual (B = 0.78; 95%CI: 0.16, 1.65; Figure 3, right panel and Supplementary Table 4). There were no coping strategies that had a significantly negative effect on well-being (Figure 3, left panel and Supplementary Table 4).

3.2.2. Temporal effects

Days in lockdown was a significant predictor of negative well-being (for 10 additional days since the survey was launched: B = −0.30, 95%CI: −0.62, −0.15). In addition:

- Background socio-demographic and health-related characteristics that showed significantly negative effects on well-being as time in lockdown progressed were: having current psychiatric issues (B = −0.37; 95%CI: −0.63, −0.04; Figure 4, left panel and Supplementary Table 5). There was no background characteristics that showed significantly positive effects on well-being as time in lockdown progressed (Figure 4, right panel and Supplementary Table 5).
- COVID-related factors that showed significantly negative effects on well-being as time in lockdown progressed were: worries about having access to PPE (B = −0.09; 95%CI: −0.18, −0.01) (Figure 5, left panel and Supplementary Table 6). There were no COVID-related factors that showed significantly positive effects on well-being as time in lockdown progressed (Figure 5, right panel and Supplementary Table 6).
- Coping strategies that showed significantly negative effects on well-being as time in lockdown progressed were: beliefs in a favorable outcome (B = 0.29; 95%CI: 0.04, 0.62); support by neighbors (B = 0.24; 95%CI: 0.04, 0.44); and collective actions (B = 0.23; 95%CI: 0.04, 0.46) (Figure 6, right panel and Supplementary Table 7). There were no significantly coping strategies that showed negative effects on well-being as time in lockdown progressed (Figure 6, left panel and Supplementary Table 7).

4. Discussion

Although social distancing did help to contain the spread of COVID-19, this strategy had a major impact on the population's mental health. This study aimed to investigate the effects of a large

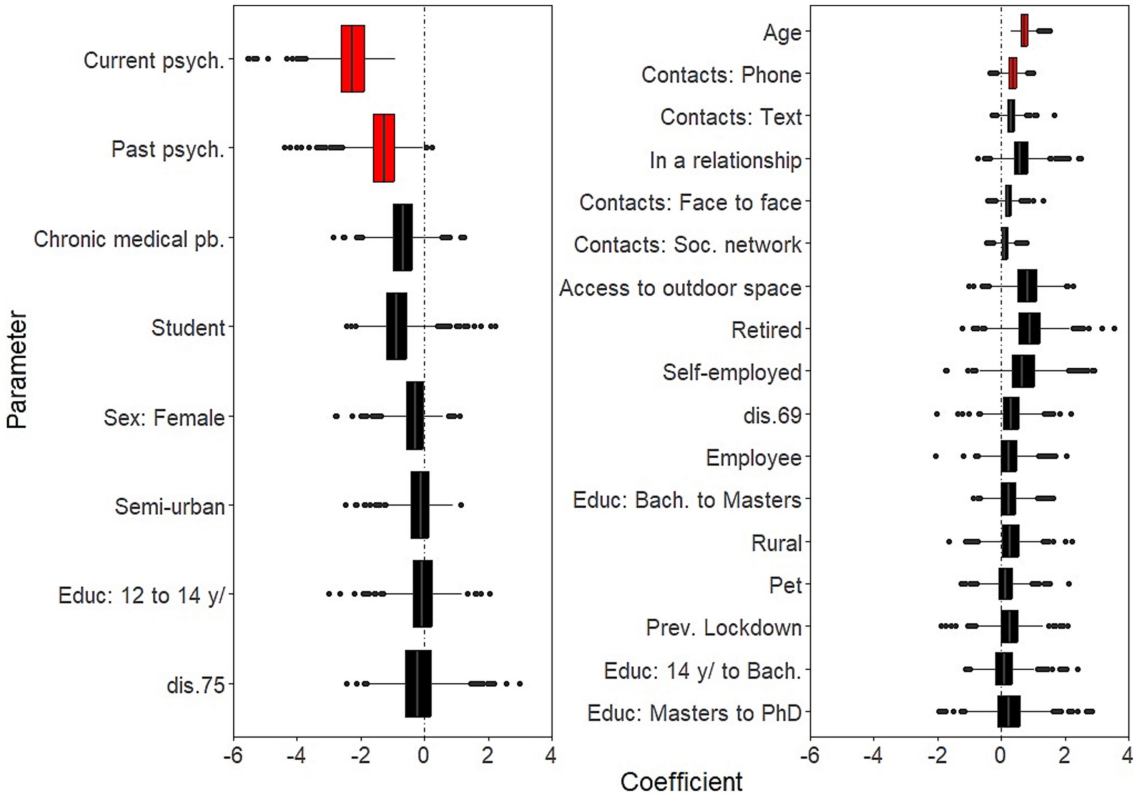

FIGURE 1
Effects of background characteristics on mental well-being. Boxplots of the bootstrap estimates are displayed for all parameters. Boxplots visualize five summary statistics: the median, two hinges and two whiskers. The lower and upper hinges correspond to the first and third quartiles (the 25th and 75th percentiles). The upper whisker extends from the hinge to the largest value no further than 1.5 * IQR from the hinge (where IQR is the inter-quartile range, or distance between the first and third quartiles). The lower whisker extends from the hinge to the smallest value at most 1.5 * IQR of the hinge. Data beyond the end of the whiskers are plotted individually. Each estimate represents the effect of each predictor over the entire study period (7 weeks of lockdown). Average estimates (median of the bootstrap distribution) that are negative are on the left and those that are positive are on the right. Significant estimates (whose 95% confidence interval do not include zero) are in red. Legend. Bach., Bachelor level; dis., district; psych., psychiatric issues; pb., problem; Educ, Education; Soc., Social; Prev., Previous.

number of background characteristics, COVID-related factors, and coping strategies on mental well-being in a sample of the French population during seven of the 8 weeks of the first lockdown due to the COVID-19 pandemic.

We found that factors that were significantly associated with decreased well-being over the study period were: having current and past psychiatric issues, having worries about being in a precarious situation and about having access to essential products. Factors that were significantly associated with increased well-being were: age, social contacts pre-pandemic period, satisfaction with COVID-related information, agreement with lockdown measures, resilience, beliefs in a favorable outcome and in positive impacts of lockdown on the individual.

Moreover, time in lockdown was associated with a decrease in well-being. Having current psychiatric issues and having worries about having access to personal protective equipment showed significantly negative effects on well-being as time in lockdown progressed. In contrast, coping by having positive beliefs about the future of the pandemic, being supported by neighbors, and being involved in collective actions showed significantly positive effects on well-being as time in lockdown progressed.

Below, we discuss significant effects from these three categories of predictors (background characteristics, COVID-related factors, and coping strategies). We then discuss temporal effects, that is, positive and negative effects on well-being as time in lockdown progressed.

4.1. Background characteristics

We found that having less regular contacts with people before lockdown were associated with lower well-being whilst in lockdown. Loneliness has long been shown to be related to poor mental health outcomes (62), an increased risk of depression (63), but also increased physical health problems and mortality (64). Yet, while social distancing may have affected loneliness (29, 65), others have suggested that the effects of loneliness on mental well-being were for the most part precedent to lockdown (66, 67). This may explain why having less regular contact with people *whilst in lockdown* was not retrieved as a significant factor in our study.

Those with a current or past psychiatric illness may also be particularly sensitive to social distancing, as shown in previous reports (47). This may be due to excessive fear of the virus or to

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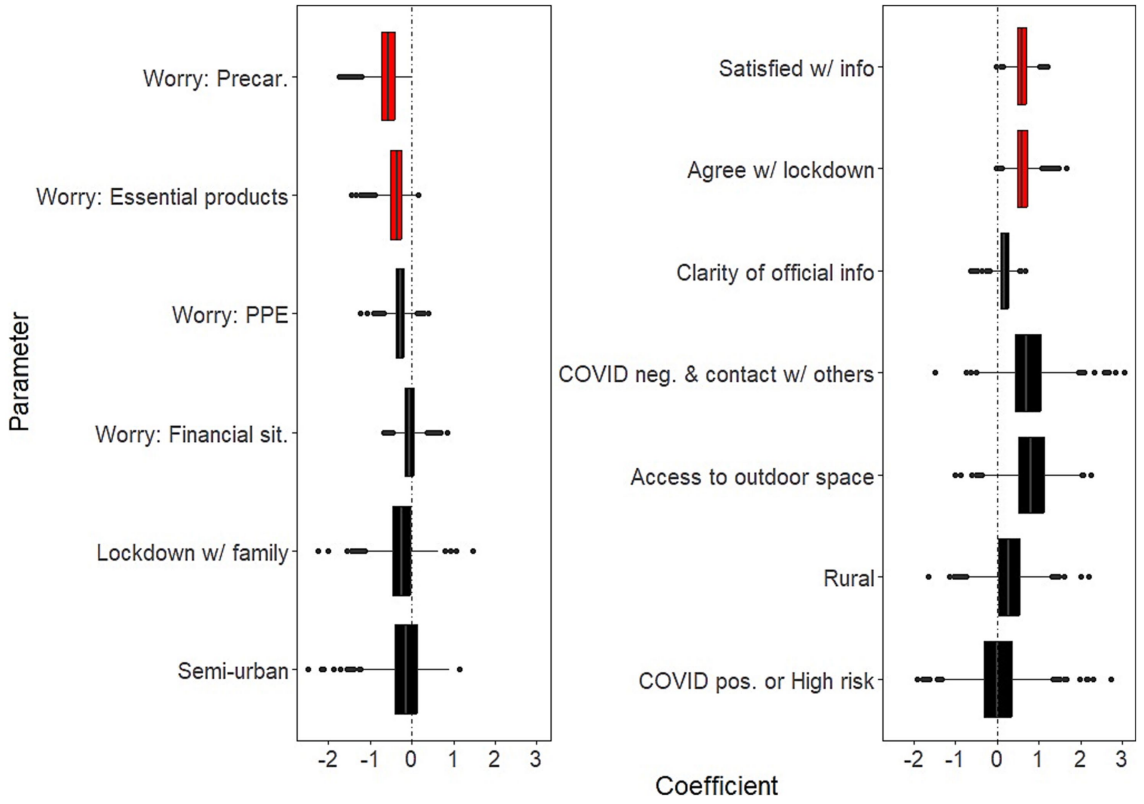

FIGURE 2
Effects of COVID-related factors on mental well-being. Boxplots of the bootstrap estimates are displayed for all parameters. Boxplots visualize five summary statistics: the median, two hinges and two whiskers. The lower and upper hinges correspond to the first and third quartiles (the 25th and 75th percentiles). The upper whisker extends from the hinge to the largest value no further than 1.5 * IQR from the hinge (where IQR is the inter-quartile range, or distance between the first and third quartiles). The lower whisker extends from the hinge to the smallest value at most 1.5 * IQR of the hinge. Data beyond the end of the whiskers are plotted individually. Each estimate represents the effect of each predictor over the entire study period (7 weeks of lockdown). Average estimates (median of the bootstrap distribution) that are negative are on the left and those that are positive are on the right. Significant estimates (whose 95% confidence interval do not include zero) are in red. Legend. PPE, Personal Protective Equipment; Precar., Precariousness; sit., situation; info, COVID-related information; neg., negative; pos., positive.

increased difficulties to deploy diverting strategies to cope with life. This population may also be particularly exposed to the negative consequences of social distancing with their mental health teams.

Being of a young age also showed a negative effect on well-being. Time in lockdown may have negatively impacted young persons more than older adults as the former may have felt more constrained and less autonomous due to social and movement restrictions during the pandemic (68). Connecting with others is critical to psychological development (69–72), and any restrictions in social connectedness (e.g., due to social distancing) might alter well-being (73). Young persons may also be particularly affected by the pandemic, due to higher risks of economic difficulties (27). In addition, it has been shown that while older individuals were more concerned by COVID-19 at the very beginning of the pandemic, they were less worried about the virus during lockdown and changed their behavior to a lesser extent (74).

As mentioned in the Introduction, others have shown that female gender was associated with decreased well-being (15–17), yet this relationship did not turn out to be significant in our study. Differences in sample selection may explain these discrepancies, given that individuals from our sample have voluntarily chosen to be involved in the study. Another potential explanation is that we investigated a large number of predictors that may be linked to gender (e.g., having psychiatric issues, worrying about being in a precarious situation or about having access to essential products). These in turn may have masked the effect of gender on well-being.

4.2. COVID-related factors

COVID-related policies resulted in citizens having to face the deterioration of economic conditions. Similarly to others, we showed that worries about the breakdown of supply chains of essential products or PPE, and worries about being in a precarious situation (e.g., due to work restrictions), were significantly associated with lower levels of well-being (35, 75). As obvious as they may seem, these findings underline the absolute necessity for policymakers to provide all efforts to ensure the supply of basic goods that are critical to one's survival and protection.

Disagreement with lockdown policies and dissatisfaction with information provided about the pandemic were also associated with lower well-being. At their most extreme, citizens with lower levels of well-being may demonstrate resentment and mistrust for

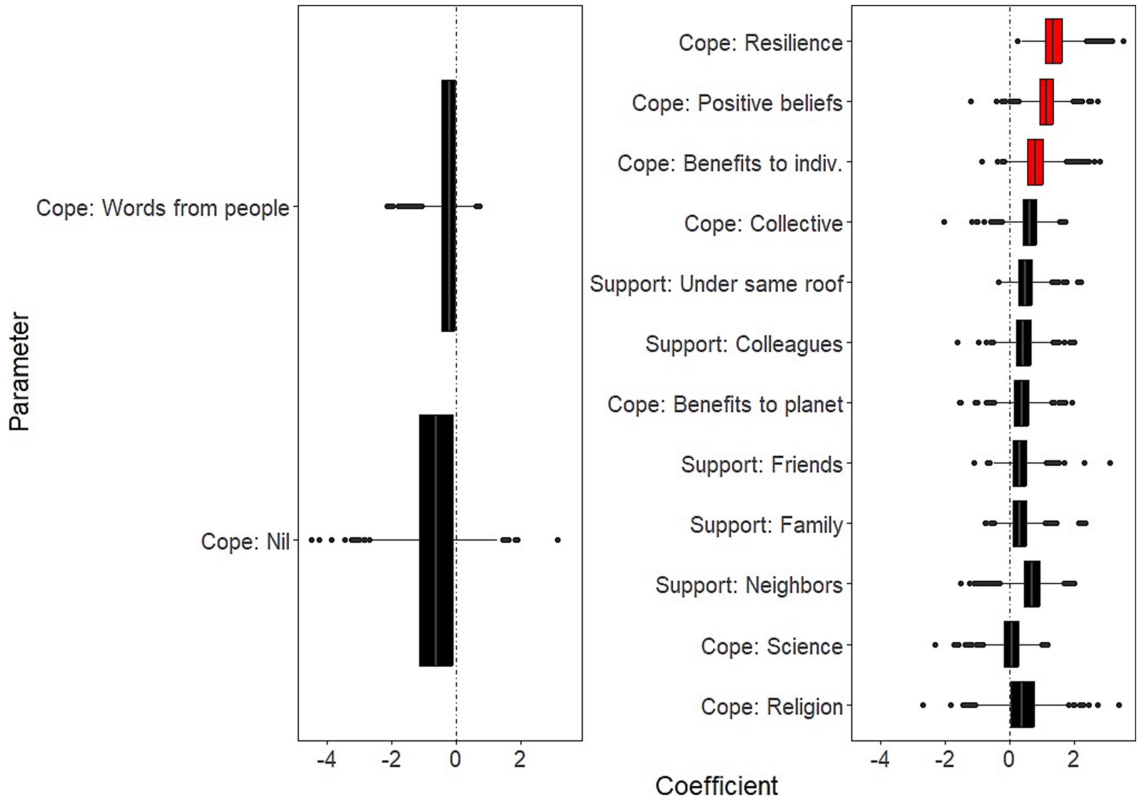

FIGURE 3
Effects of coping strategies on mental well-being. Boxplots of the bootstrap estimates are displayed for all parameters. Boxplots visualize five summary statistics: the median, two hinges and two whiskers. The lower and upper hinges correspond to the first and third quartiles (the 25th and 75th percentiles). The upper whisker extends from the hinge to the largest value no further than 1.5 * IQR from the hinge (where IQR is the inter-quartile range, or distance between the first and third quartiles). The lower whisker extends from the hinge to the smallest value at most 1.5 * IQR of the hinge. Data beyond the end of the whiskers are plotted individually. Each estimate represents the effect of each predictor over the entire study period (7 weeks of lockdown). Average estimates (median of the bootstrap distribution) that are negative are on the left and those that are positive are on the right. Significant estimates (whose 95% confidence interval do not include zero) are in red. Legend. indiv., the individual.

governments and policy makers (37, 75), that themselves are correlated with COVID-19 and generic conspiracy and pseudo-scientific beliefs (37, 76).

Interestingly, effects of COVID-related stressors may be moderated by personality traits such as extroversion or emotional reactivity, which themselves have been found to predict well-being during the COVID-19 pandemic (68, 75, 77). For instance, it was demonstrated that lifestyle disruptions due to COVID-lockdown was less detrimental to introverts than extroverts (68, 77), perhaps because the former were more adapted to lockdown life circumstances than the latter. Further investigation is needed to disentangle the effect of personality traits vs. contextual factors (e.g., economic risk, supply chains and agreement with policies) on overall levels of well-being.

4.3. Coping strategies

In line with others, we found that coping strategies that specifically demonstrated an effect on well-being during lockdown involved collective actions (78) and having positive beliefs about the future (34). Research in Wuhan, China has shown that neighborhoods' social infrastructure (e.g., services provided by urban residents' committees and volunteer groups) provided social cohesion (78). In turn, such an increased sense of community and connectedness may mitigate the decreased level of well-being observed during lockdown (78, 79) in promoting eudaimonic living (80).

Likewise, we showed that optimistic beliefs about the future of the pandemic improved well-being and quality of life. We also found virtuous effects of beliefs in positive impacts of lockdown on the individual: spending less on fuel, working from home, or staying home with their loved ones. In line with our findings, some have shown that hope, optimism and acceptance, along with other psychological resources such as gratitude of being, gratitude towards the world, and personal wisdom, increased the level of well-being during COVID (48). Of note, others have pointed that at their extremes, such psychological traits may also be somehow unrealistic and at the cost of underestimation of health risk (75, 81, 82).

Finally, those having skills to adapt to difficult situations (a.k.a. resilience) showed an obvious advantage in terms of well-being during lockdown. Resilience however is closely linked to the concept of agency, "the capacity to make choices and the power to act on those choices" (83), which by definition is seriously compromised during lockdown periods. Key domains in relation to successful coping whilst in lockdown were suggested to depend on actively and intentionally being involved in physical health, spiritual health, and social connection (29). In contrast, avoidant coping strategies, such as

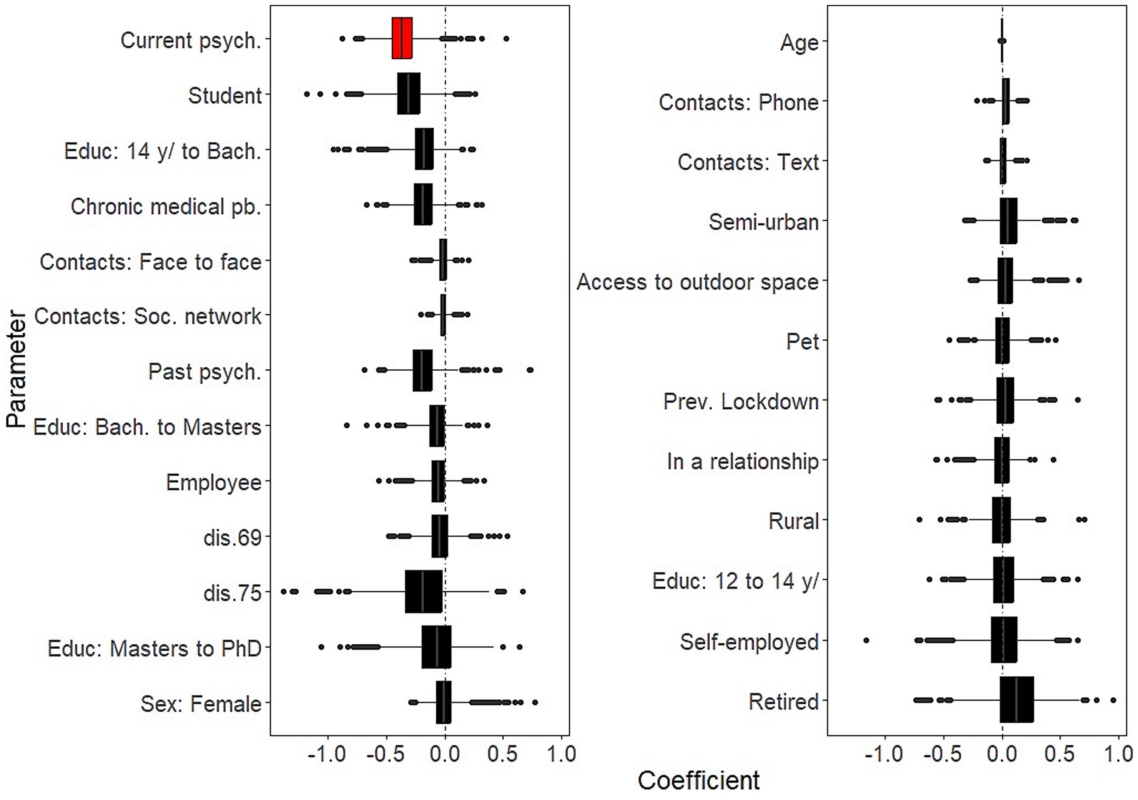

FIGURE 4
Temporal effects of background characteristics on mental well-being. Boxplots of the bootstrap estimates are displayed for all parameters. Boxplots visualize five summary statistics: the median, two hinges and two whiskers. The lower and upper hinges correspond to the first and third quartiles (the 25th and 75th percentiles). The upper whisker extends from the hinge to the largest value no further than 1.5 * IQR from the hinge (where IQR is the inter-quartile range, or distance between the first and third quartiles). The lower whisker extends from the hinge to the smallest value at most 1.5 * IQR of the hinge. Data beyond the end of the whiskers are plotted individually. Each estimate represents the effect of each predictor for 10 days of lockdown. Average estimates (median of the bootstrap distribution) that are negative are on the left and those that are positive are on the right. Significant estimates (whose 95% confidence interval do not include zero) are in red. Legend. Bach., Bachelor level; dis., district; psych., psychiatric issues; pb., problem; Educ, Education; Soc., Social; Prev., Previous.

self-distraction, venting, denial, and emotional disengagement, were shown to be associated with negative health outcomes, such as increased loneliness (84).

4.4. Temporal effects

Our analytical framework allowed to disentangle overall main effects from those that linearly changed with time spent in lockdown. We reasoned that the latter effects may be associated with the so-called "pandemic fatigue." According to the WHO, "pandemic fatigue is an expected and natural response to […] the implementation of invasive measures" to curb the spread of the virus (53). Pandemic fatigue is "defined as de-motivation to follow recommended protective behaviors, emerging gradually over time and affected by a number of emotions, experiences and perceptions" (53). As suggested, lockdown may be both psychologically demanding and "cost accumulating," with gradual increase in psychological fatigue associated with physical distancing (85). In other words, one of the major contributors of pandemic fatigue may be the gradual deterioration of well-being as a result of lockdown policies (86). In our study, overall well-being deteriorated as time in lockdown progressed, and even more so after the seventh week of lockdown. Those factors that showed negative effects on well-being as time in lockdown progressed may therefore predispose or precipitate to pandemic fatigue: having current psychiatric issues and worrying about having access to PPE. By contrast, factors that showed positive effects on well-being as time in lockdown progressed may be protective of pandemic fatigue: having support from neighbors, coping by having positive beliefs about the future, coping by being involved in collective actions. We wish to encourage policymakers to better consider these factors to prevent any de-motivation to follow policies, in case more social distancing becomes necessary in the future.

4.5. Limitations and strengths

Our study has several limitations. First, individuals from our sample have voluntarily chosen to be involved in the study, therefore we cannot generalize our results to the French population. For instance, our sample is likely to under-estimate the mental health effects of lockdown, as those who are digitally excluded may be under-represented.

Second, participation dropped significantly after the second week of lockdown, and even more so after the third week. While we used a down-sample strategy to address this caveat, in an ideal situation we would not have observed such a dramatic drop of the number of observations.

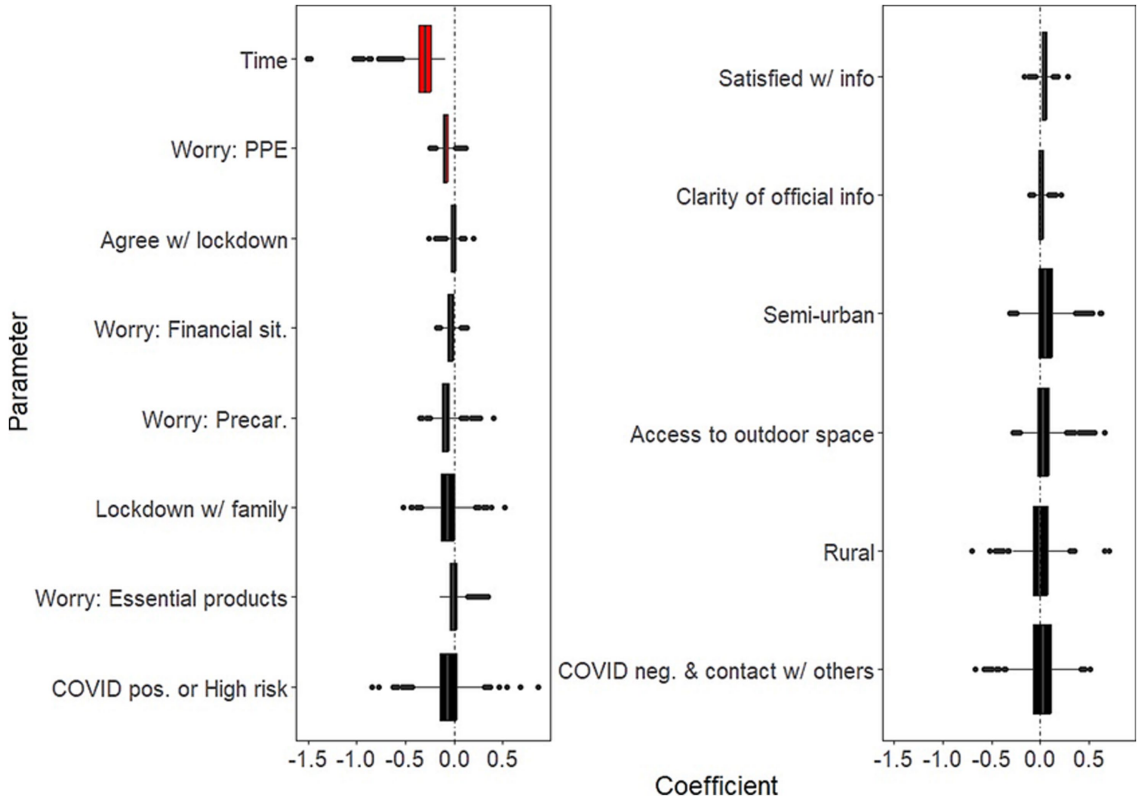

FIGURE 5
Temporal effects of COVID-related factors on mental well-being. Boxplots of the bootstrap estimates are displayed for all parameters. Boxplots visualize five summary statistics: the median, two hinges and two whiskers. The lower and upper hinges correspond to the first and third quartiles (the 25th and 75th percentiles). The upper whisker extends from the hinge to the largest value no further than 1.5 * IQR from the hinge (where IQR is the inter-quartile range, or distance between the first and third quartiles). The lower whisker extends from the hinge to the smallest value at most 1.5 * IQR of the hinge. Data beyond the end of the whiskers are plotted individually. Each estimate represents the effect of each predictor for 10 days of lockdown. Average estimates (median of the bootstrap distribution) that are negative are on the left and those that are positive are on the right. Significant estimates (whose 95% confidence interval do not include zero) are in red. Legend. PPE, Personal Protective Equipment; Precar., Precariousness; sit., situation; info, COVID-related information; neg., negative; pos., positive.

Third, a longitudinal design investigating well-being pre- and post-lockdown would have been more appropriate than a repeated cross-sectional design investigating well-being during lockdown. While we cannot ascertain causality, our study still provides an interesting description of predictive factors of well-being during lockdown, and may be used as background knowledge for further research.

Fourth, our results may not be generalizable to other periods of COVID lockdowns. Indeed, passed the first wave, individuals may have gotten used to the pandemic and may have reacted differently to government restrictions. Therefore, our results need to be interpreted with respect to the *initial* lockdown period.

Fifth, our model only included main effects and first order interactions with time in lockdown. We were therefore unable to discuss potential interactions between predictors and non-linear temporal effects. For instance, the first announcement by the French government on 16 March set the duration of lockdown at 2 weeks. This was then extended on 27 March for another 2 weeks, before a final 4-week extension was announced on 13 April. This series of official announcements may have had an impact on mental well-being, which may have translated into non-linear temporal effects.

Sixth, psychological well-being was the only mental health-related construct assessed in this study. Therefore, our results should not be interpreted with respect to other dimensions of well-being (e.g., physical or social well-being). Likewise, other psychopathological domains, such as the emergence of affective symptoms, were shown to be significantly impacted by the COVID-19 pandemic (5). It would have been interesting to perform our analysis on other psychopathological constructs to investigate whether background characteristics, COVID-related factors, and coping strategies, were differentially associated with well-being vs. other measures of mental health.

Our study also has a number of strengths. First, the number of observations was high. Second, we investigated a large number of predictors of various nature (background characteristics, COVID-related factors, coping strategies). Third, we reduced the risk of multi-collinearity by running ridge regularization regression instead of standard (OLS) linear regression. Fourth, we palliated for the imbalance in the distribution of survey responses over the duration of lockdown using a bootstrap down-sampling strategy.

4.6. Conclusion

Despite those limitations, our data suggest that a substantial number of factors predicted deterioration of mental well-being over

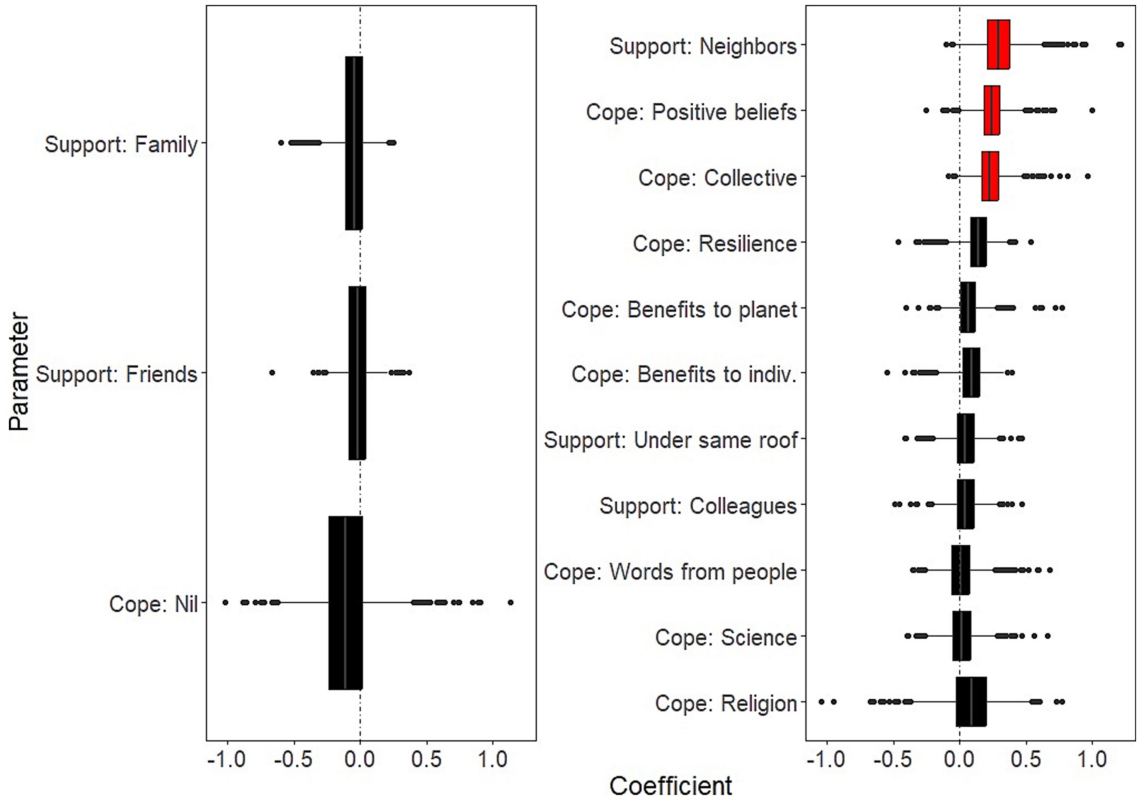

FIGURE 6
Temporal effects of coping strategies on mental well-being. Boxplots of the bootstrap estimates are displayed for all parameters. Boxplots visualize five summary statistics: the median, two hinges and two whiskers. The lower and upper hinges correspond to the first and third quartiles (the 25th and 75th percentiles). The upper whisker extends from the hinge to the largest value no further than 1.5 * IQR from the hinge (where IQR is the inter-quartile range, or distance between the first and third quartiles). The lower whisker extends from the hinge to the smallest value at most 1.5 * IQR of the hinge. Data beyond the end of the whiskers are plotted individually. Each estimate represents the effect of each predictor for 10 days of lockdown. Average estimates (median of the bootstrap distribution) that are negative are on the left and those that are positive are on the right. Significant estimates (whose 95% confidence interval do not include zero) are in red. Legend. indiv., the individual.

the first lockdown period due to the COVID-19 pandemic in France. Vulnerable populations were identified as young persons, people with less social contacts, and those having psychiatric issues. Unfortunately, there are risks of other pandemics like COVID-19 in the near future (87), with potential disastrous consequences on mental health. Our findings suggest that, in case of future lockdowns, financial and economic measures should protect those who are the most at risk of financial precariousness and at risk of not accessing basic goods. In addition, policy-makers should think of promoting other interventions, such as collective actions and local support (e.g., from neighbors). Not only would such interventions increase mental well-being during lockdown periods, and have positive spillover effects on related mental and physical health in the long-term. These interventions may also decrease the likelihood of pandemic fatigue and in turn, increase compliance to lockdown measures.

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 requirement of ethical approval was waived by the research board of the Vinatier Hospital (Bron, France) for the studies involving humans. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

FH, EZ, and NF conceived and designed the study. AT ran the first set of analyses and wrote the first draft. GB performed a second set of analyses and wrote the second draft in response to the major comments made by the reviewers. All authors provided an interpretation of the data and critical revisions to the manuscript. All authors read and approved the submitted manuscript. All authors had full access to the data (including statistical reports and tables) in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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.2023.1234023/full#supplementary-material

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The prevalence and factors associated with posttraumatic growth after 3-years outbreak of COVID-19 among resident physicians in China: a cross-sectional study

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Introduction: The Coronavirus disease 2019 (COVID-19) pandemic is a global traumatic event that has profoundly struck individuals' mental health. However, this might potentially promote positive transformation such as posttraumatic growth (PTG). Studies have indicated that the COVID-19 pandemic negatively affected the well-being of resident physicians, but little is known about PTG among this vulnerable population in China. Therefore, this study investigated the prevalence and associated factors of PTG among Chinese resident physicians after 3-years outbreak of COVID-19.

Methods: An online survey was conducted from 9 March to 20 March in 2023. PTG was assessed using the 10-item Posttraumatic Growth Inventory-Short Form (PTGI-SF). Scores ≥30 implied moderate-to-high PTG. We also collected possible associated factors for PTG, including socio-demographic and psychological variables. Data was analyzed by applying descriptive statistics, univariable and multivariable logistic regression models.

Results: In total, 2267 Chinese resident physicians provided validated data. 38.7% of them reported moderate-to-high PTG. In the multivariable logistic regression models, age (odds ratio, OR = 1.039; 95% confidence interval, 95%CI = 1.008–1.070), female (OR = 1.383, 95%CI = 1.151–1.662), satisfied or neutral with annual income (OR = 2.078, 95%CI = 1.524–2.832; OR = 1.416, 95%CI = 1.157–1.732), sufficient support at work (OR = 1.432, 95%CI = 1.171–1.751) and resilience (OR = 1.171, 95%CI = 1.096–1.252) were significantly positively associated with moderate-to-high PTG. On the contrary, burnout (OR = 0.653, 95%CI = 0.525–0.812), depression symptoms (OR = 0.700, 95%CI = 0.552–0.889), and stress (OR = 0.757, 95%CI = 0.604–0.949) were significantly negatively associated with moderate-to-high PTG.

Discussion: Overall, resident physicians in China experienced relatively high prevalence of PTG that could be associated with several psychosocial factors. Findings may provide evidence to develop interventions for resident physicians to systematically and constructively process traumatic events related to the pandemic and foster their PTG.

KEYWORDS

China, COVID-19 pandemic, physicians, posttraumatic growth, standardized residency training program

Introduction

The Coronavirus disease 2019 (COVID-19) pandemic is an unforeseen and unprecedented global public health emergency that has had severe and far-reaching repercussions for health systems, economies, and societies worldwide. It is a shared global traumatic event that has profoundly threatened people's mental health through disruptive societal changes and neuropsychiatric consequences following the infection (1, 2). Healthcare workers (HCW) experienced more adverse psychological outcomes due to the increased workload and heightened risk of infection, with prevalence rates ranging from 27.0 to 49.0% for anxiety, depression, sleep problems and post-traumatic stress disorder (3, 4).

Resident physicians constituted a crucial workforce in the healthcare system during the pandemic. In China, all medical graduates are required to undergo 3 years of systematic training, known as standardized residency training program (SRTP). As the healthcare system was strained during the COVID-19 epidemic, resident physicians inevitably assumed additional responsibilities and burdens, and had to rapidly adapt to changing pandemic management regulations (5, 6). Besides, physicians at this stage may generally experience higher levels of stress due to factors such as insufficient clinical training, financial constraints, heavy academic workload, family responsibilities and job competitions (7). Consequently, they were more susceptible to burnout, sleep disturbances and psychological distress during this challenging period (8–10). Their impaired mental health would not only interfere with their personal and professional growth but also negatively influence the quality of patient care (11).

As a global traumatic event, COVID-19 pandemic has not only caused widespread chaos and suffering, but also presented opportunities for positive transformation, a phenomenon known as posttraumatic growth (PTG). PTG is manifested in five aspects: more meaningful interpersonal relationships, new possibilities, increased sense of personal strength, deeper appreciation for life, and richer understanding of spiritual matters (12). Previously, numerous studies have demonstrated that individuals who have experienced life-threatening events such as cancer (13), natural disasters (14) and major life changes such as divorce (15) and bereavement (16) would experience PTG. And PTG encompasses extensive benefits, varying from making meaning of the adversity (17) and turning wounds into wisdom (18) to reducing the risk of psychiatric disorders and suicide intention (19, 20) and increasing personal development and life satisfaction (21).

In recent years, there has been a growing interest in PTG in the general public (22), university students (23) and HCW (24–26) during the COVID-19 pandemic. However, the existing psychological research on resident physicians during the pandemic predominantly focused on the negative impacts. Little has documented the PTG of them amidst this special stage. To fill this gap, this study aimed to evaluate the PTG and its associated factors among Chinese resident physicians after 3 years of the COVID-19 outbreak.

A recent systematic review of 27 studies on HCW demonstrated that PTG could enhance HCWs' coping abilities in dealing with trauma, and it can be influenced by socio-demographic and psychological factors (27). Socio-demographics, such as age, gender, marital status and educational background, are assumed to be associated with PTG across diverse cohorts (27, 28). Working situations, including region, prior experience and work hours, are associated with the PTG of resident physicians during the COVID-19 pandemic (27). Psychological factors are important to the cognitive reconstruction, a necessary process in the formation of PTG (29). Income satisfaction, perceived support at work, burnout, stress, depression, anxiety, and resilience stand as pivotal variables that may influence PTG (27). Income satisfaction, as a measure of financial well-being, might influence the psychological adjustment of resident physicians (27). Support at work is anticipated to play a significant role in shaping their psychological responses (30). However, burnout, a prevalent issue among medical professionals, could hinder PTG by diminishing psychological resources and adaptive capacities (31, 32). Stress, depression, and anxiety are previously shown to be associated with PTG; however, consensus on whether these relationships are positive or negative has not been reached (33, 34). Conversely, resilience, characterized by tenacity, strength and optimism, could potentially facilitate PTG by enabling individuals to navigate the challenges on pandemic (35). To our knowledge, there is limited research on the relationship between PTG and the variables above among Chinese resident physicians.

Current study

This study is cross-sectional and was approved by the Tongji Hospital of Tongji University Institutional Review Board (Registration Number K-W-2023-002). The study was registered with the Chinese Clinical Trial Registry (Registration Number ChiCTR2300074782). An online survey was conducted from 9 March to 20 March in 2023. The aim of this study are two folds: firstly, to provide an overview of the current status of PTG among Chinese resident physicians after 3 years outbreak of COVID-19; secondly, to explore the association between PTG and socio-demographic (e.g., age, gender) or other psychological variables (e.g., income satisfaction, support at work, burnout, depression, anxiety, stress and resilience). We hope to provide evidence to develop interventions for resident physicians to systematically and constructively process traumatic events related to the pandemic and foster their PTG.

Materials and methods

Participants and procedure

Convenience sampling was adopted to collect data. The questionnaire was designed based on literature review and group discussion. A pilot study was conducted to improve the questionnaire's

quality. It involved 20 resident physicians from our team who completed the questionnaire. Their feedback and suggestions were carefully considered, leading to revisions aimed at enhancing the clarity and comprehensibility of the questions. Then an online questionnaire was created via www.wjx.cn, an extensively utilized online-survey platform in China. Thereafter, we distributed the questionnaire link to managers of SRTP from all Chinese provinces and municipalities via WeChat group (a widely used social media in China). SRTP managers volunteered to distribute the questionnaire link to resident physicians within their own units. The inclusion criteria of the study population were: (1) registered resident physician in China, and (2) voluntarily signed the informed consent form. There was no missing data as all questions were mandatory before submission. During the completion process, participants were free to terminate any time, and all previous responses would not be saved. A total of 2,364 residents completed the questionnaire. For the sake of data quality, 97 questionnaires with a completing time of less than 3 min were excluded. The remaining 2,267 were retained in the analyses, with a validity rate of 95.9%.

Sample size

Sample size was calculated based on a recent PTG survey of Chinese nurses during the COVID-19 pandemic, which reported a moderate-to-high PTG prevalence of 39.3% (36). A desired level of precision, with an allowable error of 0.03 and a significance level (α) of 0.05, was used to calculate the required sample size, resulting in a minimum of 1,018 resident physician. The actual sample size 2,267 exceeded this requirement, thus enabling the study to be conducted with sufficient statistical power.

Materials

Outcome—post-traumatic growth

The Posttraumatic Growth Inventory-Short Form (PTGI-SF) (37) was used to assess resident physicians' positive psychological changes following COVID-19. The PTGI-SF consisted of 10 items measuring five domains of PTG: relating to others, personal strength, appreciation of life, spiritual change, and new possibilities (e.g., "I changed my priorities about what is important in life"). It was scored using a 6-point scale (0 as *I did not experience this change*, 5 as *I experienced this change to a very great degree*), with higher scores indicating greater levels of PTG. Scores ≥ 30 imply moderate-to-high PTG (38). The PTGI-SF has been applied among Chinese nurses over the pandemic and exhibited good reliability (25). The Cronbach's α for this sample was 0.88.

Influential factors—socio-demographic and psychological factors

Socio-demographics include age, gender (male or female), marital status (unmarried/divorced or married/cohabitation), region of work (eastern, central or western China), residential status (living in dormitory, living with family, shared housing or living alone), educational background (Bachelor's, Master's or Doctoral degree), years in SRTP (1st, 2nd, or 3rd year), work experience before SRTP (yes or no), training specialty and weekly working hours.

Psychological factors include annual income satisfaction, being supported at work, sleep hours per day, burnout, stress, depression and anxiety symptoms and resilience. Annual income satisfaction was classified into satisfied, neutral and unsatisfied. Being supported at work was assessed by a 5-point Likert scale and subsequently categorized as either "insufficiently (very bad/bad)" or "sufficiently (average/good/very good)." Daily sleep hours was measured as a continuous variable and was cut off by 7 h.

Burnout was measured by the 2-item Maslach Burnout Inventory (MBI-2) (39) (e.g., "I feel burned out from my work"). Responses were rated on a 7-point scale ranging from 0 (*never*) to 6 (*every day*). Answering less than once a week (scores < 4) on both questions meant low burnout, otherwise the results stood for high burnout (40). The MBI-2 has been found to be reliable among Chinese physicians (41).

Stress was measured by the "stress subscale" of Depression Anxiety Stress Scales-21 (DASS-21) (42) which comprised of 7 items (e.g., "I found it difficult to relax.") and was scored using a 4-point scale (0 as *not apply to me at all*, 3 as *apply to me very much*). Scores of 0–7 were considered normal, while scores of ≥8 represented mild or higher levels of stress (42). Evidence of reliability of the DASS-Stress was found among healthcare workers in China during the COVID-19 pandemic (43). For the present sample, the Cronbach's α was 0.91.

Depression symptoms was measured by the Patient Health Questionnaire-2 (PHQ-2) (44). It consists of 2 items (e.g., Feeling down, depressed or hopeless.) and was rated on a 4-point scale ranging from 0 (*not at all*) to 3 (*nearly every day*). Scores of ≥3 indicating a positive screen for depression. PHQ-2 has been validated among Chinese population and the Cronbach's α was 0.85 in this study (45).

Anxiety symptoms was measured by the Generalized Anxiety Disorder-2 (GAD-2) (46). It consists of 2 items (e.g., Feeling nervous, anxious or on edge). Participants used a 4-point scale ranging from 0 (*not at all*) to 3 (*nearly every day*). Scores of ≥3 indicating a positive screen for anxiety. Application of GAD-2 among Chinese people showed robust validation (47). The Cronbach's α was 0.90 in this study.

Resilience was measured by Connor Davidson Resilience Scale-2 (CD-RISC-2), which contains 2 items (e.g., "Able to adapt to change") (48). On a five-point scale from 0 (*not true at all*) to 4 (*true nearly all the time*), a higher score suggests more resilience. The reliability is good among Chinese people (49). The Cronbach's α was 0.82 in the current sample.

Statistical analysis

Descriptive statistics were computed using frequencies and percentages for categorical variables, means and standard deviations (SD) for continuous variables. Univariable and multivariable binary logistic regression analyses were performed. In the multivariable binary logistic regression analysis, the input variables with $p < 0.05$ in the univariable analysis were selected using the forward stepwise method based on the likelihood ratio (LR). Odds ratios (ORs) and their 95% confidence intervals (CIs) were calculated to estimate the magnitude and direction of the relationship between each independent variable and PTG. The variance inflation factor (VIF) was used to assess multicollinearity among independent variables, with a VIF higher than 5 to 10 presenting significant multicollinearity (50). The goodness-of-fit of the logistic regression model determined using the

Hosmer-Lemeshow test. Statistical significance was defined at $p < 0.05$. All statistical analyses were conducted using SPSS version 25.0 (IBM Corporation, Armonk, NY, United States).

Results

Participant characteristics

Our investigation covered 24 provinces and municipalities in China, such as Shanghai, Jiangsu, Zhejiang in eastern China, Hebei, Hunan, Anhui in central China; and Guangxi, Shaanxi, Sichuan in western China. The average age of the respondents was 26.68 years (range = 20–39; SD = 2.97). The majority of participants were female (1,241, 54.7%), single (1,801, 79.4%), working in central China (1,097, 48.4%), living in dormitory (781, 34.5%) and bachelors (2,066, 91.1%). 557 (23.6%) respondents were from internal medicine, 390 (16.5%) were from surgery, 359 (15.2%) were from family medicine, 158 (6.7%) were from anesthesiology, 155 (6.6%) were from medical imaging and nuclear medicine, 153 (6.5%) were from pediatrics, 122 (5.2%) were from obstetrics and gynecology, and the remaining respondents were from Dentistry (106, 4.7%), emergency medicine (64, 2.8%), neurology (59, 2.6%), psychiatry (36, 1.6%), dermatology (28, 1.2%), Otolaryngology (25, 1.1%), medical laboratory (22, 1.0%), ophthalmology (21, 0.9%), rehabilitation (9, 0.4%) and intensive care unit (3, 0.1%). Approximately half of the resident physicians had work experience before SRTP (52.7%), worked over 48 h per week (51.3%) and slept less than 7 h per day (50.2%). Three fifths thought they got sufficient support at work while merely one tenth were satisfied with their annual income. The proportion of high burnout, positively screened depression, positively screened anxiety, mild or higher stress were 37.3%, 34.5%, 30.3%, and 37.7%, respectively. The average score of resilience was 4.72 ± 1.61. Other details of participant characteristics were shown in Table 1.

A total of 878 (38.7%) participants met the criteria of moderate-to-high level of PTG (scores ≥30). Shown in Table 2, the Mean ± SD scores of PTG total score, appreciation of life, personal strength, relating to others, spiritual change, and new possibilities were 25.19 ± 9.48, 6.29 ± 2.23, 5.63 ± 2.23, 5.04 ± 2.46, 4.45 ± 2.53, and 3.76 ± 2.43, respectively.

Logistic regression models

Table 3 demonstrates the univariable and multivariable binary logistic regression analyses of PTG. The VIFs among independent variables were between 1.027 and 2.197. According to the univariable regression model, age, gender, marital status, work experience before SRT, satisfaction with annual income, being supported at work, burnout, sleeping hours, depression and anxiety symptoms, stress and resilience were significant correlates of moderate-to-high PTG ($p < 0.050$). Multivariable binary logistic regression showed that age (OR = 1.039, 95%CI = 1.008–1.070, $p = 0.014$), female (OR = 1.383, 95%CI = 1.151–1.662, $p = 0.001$), satisfied with annual income (OR = 2.078, 95%CI = 1.524–2.832, $p < 0.001$), neutral in annual income (OR = 1.416, 95%CI = 1.157–1.732, $p = 0.001$), sufficient support at work (OR = 1.432, 95%CI = 1.171–1.751, $p < 0.001$) and resilience (OR = 1.171, 95%CI = 1.096–1.252, $p < 0.001$) were significant positive correlates of moderate-to-high PTG. On the contrary, burnout (OR = 0.653, 95%CI = 0.525–0.812, $p < 0.001$), depression symptoms (OR = 0.700, 95%CI = 0.552–0.889, $p = 0.003$), and stress (OR = 0.757, 95%CI = 0.604–0.949, $p = 0.016$) were significant negative correlates of moderate-to-high PTG. The Hosmer-Lemeshow goodness of fit test was $\chi^2 = 7.313$, df = 8, $p = 0.503$.

Discussion

The present study shows that, among Chinese resident physicians after 3 years outbreak of COVID-19, the prevalence of moderate-to-high PTG in this population was 38.7%. We report a similar prevalence and mean score among Chinese nurses in response to COVID-19 pandemic (36). The average score in our sample is higher than those reported in Hong Kong (25) and Australian (51) nurses, mental and community healthcare workers in the UK (52) and psychotherapists in the US (53). One possible explanation for the observed discrepancies in PTG scores could be the timing of investigation. As Zhou and Wu (54) showed, increased time elapsed after trauma allowed individuals more opportunity for deliberate rumination, which led to higher PTG. Our investigation was conducted 3 years after the outbreak of COVID-19, during which time resident physicians were faced with less challenging clinical work situations, providing them with more opportunities to restore inner harmony and facilitate positive changes. Additionally, disparities in PTG scores might also be linked to differences in the management of the pandemic across countries and variations in the responsibilities of healthcare workers.

Interestingly, appreciation of life is the highest scoring PTG domain, followed by personal strength, which suggested that the focus of resident physicians' PTG is more internal and self-centered. In contrast, more experienced healthcare professionals might have a broader perspective on the pandemic, leading to a greater emphasis on relationships and new opportunities for personal and professional development, as evidenced by highest scores in domains of new possibilities and relating to others in a previous study of senior physicians and nurses (55).

Female resident physicians report greater PTG than males, which is in line with previous research findings (56). It is conceivable that females were more likely to seek out social resources and use emotion-focused coping strategies than males, which may facilitate PTG (57). However, it should be noted that the gender differences in PTG were not consistent across studies that varied in populations, types of trauma, and PTG measurement tools (58, 59). Age is weakly positively associated with PTG, implying that older resident physicians with more life experiences and coping skills might have a slightly greater capacity for positive adjustment in response to the pandemic.

Being supported at work and having high income satisfaction are two significant positive correlates of moderate-to-high PTG in resident physicians. PTG theoretical model by Tedeschi RG and Calhoun LG asserted that social support was instrumental in the development of PTG (29). Support at work and income are regarded as two forms of social support from workplace. On the one hand, being supported at work can provide resident physicians with a sense of belonging and assistance in coping with the demands and stressors of their job. When they perceived adequate support from colleagues, supervisors, or the organization as a whole, they might feel more

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TABLE 1 Socio-demographic and psychological characteristics.

Category	Subcategory	Overall (*N* = 2,267)		Moderate-to-high PTG (*N* = 878)		Low PTG (*N* = 1,389)	
		N	%	*N*	%	*N*	%
Socio-demographics							
Age (Mean ± SD)		26.68 ± 2.97		26.94 ± 3.15		26.51 ± 2.84	
Gender	Male	1,026	45.3	353	15.6	673	29.7
	Female	1,241	54.7	525	23.2	716	31.5
Marital status	Unmarried/divorced	1,801	79.4	669	29.5	1,132	49.9
	Married/cohabitation	466	20.6	209	9.2	257	11.4
Region of work	Eastern China	637	28.1	224	9.9	413	18.2
	Central China	1,097	48.4	441	19.5	656	28.9
	Western China	533	23.5	213	9.4	320	14.1
Residential status	Dormitory	781	34.4	285	12.5	496	21.9
	Living with family	567	25.0	244	10.8	323	14.2
	Shared housing	487	21.5	186	8.2	301	13.3
	Living alone	432	19.1	163	7.2	269	11.9
Education	Bachelor's degree	2,066	91.1	790	34.8	1,276	56.3
	Master's degree	161	7.1	70	3.1	91	4.0
	Doctoral degree	40	1.8	18	0.8	22	1.0
Year in SRTP	1st year	784	34.6	313	13.8	471	20.8
	2nd year	711	31.4	270	11.9	441	19.5
	3rd year	772	34.0	295	13.0	477	21.0
Work experience before SRTP	No	1,073	47.3	389	17.1	684	30.2
	Yes	1,194	52.7	489	21.6	705	31.1
Working hour (weekly)	<48	1,103	48.7	437	19.3	666	29.4
	≥48	1,164	51.3	441	19.4	723	31.9
Psychological factors							
Satisfaction with annual income	Unsatisfied	1,267	55.9	374	16.5	893	39.4
	Neutral	759	33.5	354	15.6	405	17.9
	Satisfied	241	10.6	150	6.6	91	4.0
Being supported at work	Insufficiently	904	39.9	245	10.8	659	29.1
	Sufficiently	1,363	60.1	633	27.9	730	32.2
Burnout	Low	1,422	62.7	673	29.7	749	33.0
	High	845	37.3	205	9.0	640	28.3
Sleep hour (daily)	<7	1,137	50.2	409	18.0	728	32.2
	≥7	1,130	49.8	468	20.6	662	29.2
Depression	Screened negatively	1,486	65.5	694	30.6	792	34.9
	Screened positively	781	34.5	184	8.1	597	26.4
Anxiety	Screened negatively	1,581	69.7	710	31.3	871	38.4
	Screened positively	686	30.3	168	7.4	518	22.9
Stress	No	1,412	62.3	659	29.1	753	33.2
	Yes	855	37.7	219	9.7	636	28.0
Resilience (Mean ± SD)		4.72 ± 1.61		5.20 ± 1.39		4.43 ± 1.68	

SD, Standard deviations.

TABLE 2 Results of PTGI-SF scale.

PTG (Mean ± SD)	Overall (*N* = 2,267)	Moderate-to-high PTG (*N* = 878)	Low PTG (*N* = 1,389)
Total score	25.19 ± 9.48	33.84 ± 4.29	19.72 ± 7.61
Appreciation of life	6.29 ± 2.23	7.25 ± 1.51	5.69 ± 2.39
Personal strength	5.63 ± 2.23	7.23 ± 1.33	4.63 ± 2.27
Relating to others	5.04 ± 2.46	6.99 ± 1.29	3.81 ± 2.22
New possibilities	4.45 ± 2.53	6.59 ± 1.35	3.10 ± 2.13
Spiritual change	3.76 ± 2.43	5.79 ± 1.65	2.48 ± 1.92

SD, Standard deviations.

valued and validated, thereby promoting cognition processing and contributing to PTG (60). On the other hand, high income satisfaction could mitigate financial stress and provide a sense of security and stability (61), which might enable resident physicians to adopt more positive coping strategies, such as seeking psychotherapy or participating in leisure activities. Notwithstanding, it is worth noting that a majority of resident physicians in our study reported low satisfaction with their annual income, in accordance with our earlier investigation of Shanghai resident physicians (62). Therefore, hospitals can implement interventions aimed at fostering and maintaining a supportive workplace environment and improving the work compensation for resident physicians to promote PTG.

Burnout is negatively associated with resident physicians' PTG. This is congruent with a study conducted among Chinese nurses showing higher level of burnout were negatively associated with PTG (36). According to the effort-reward imbalance model by Johannes and colleagues (63), the additional workload, health risks, and relatively low income during the pandemic might increase the risk of burnout among resident physicians. Notably, burnout can trigger a range of detrimental consequences, including psychological issues such as depression and suicidal ideation, physical manifestations such as pain and fatigue, alongside challenges within the healthcare system such as strained doctor-patient relationships and medical errors (64–66), all of which might impede the experience of PTG. Although ours is one of the earliest studies to provide evidence on the relationship between burnout and PTG, further research is needed to fully understand the underlying mechanisms of this relationship.

Depression symptoms and stress are negatively associated with PTG, whereas resilience may catalyze it. The findings concur with former studies showing significant negative relationships between depression and PTG, stress and PTG (30) and a positive association between resilience and PTG (67). The negative effects of depression symptoms and stress on PTG may be attributed to the impact on cognitive processing, such as negative automatic thoughts and intrusive rumination, which can impede the meaning-construction process necessary for PTG (29). In contrast, resilience may ignite positive coping strategies and adaptive problem-solving skills in the face of trauma, leading to a more positive outlook and greater capacity for PTG (35). However, affective-cognitive processing model of PTG proposed by Joseph et al. (57) posited that high distress would challenge individuals' understanding of the world, leading them to reflect extensively on their core beliefs and create new schemas and meanings, thus spurring the process of PTG. Although this theoretical framework is substantiated by prior research conducted with cancer patients (68) and earthquake survivors (69), our findings appear to contradict it. A possible account for this may be our study was cross-sectional designed and the depression and stress screening measurements only evaluated the current distress. At the time of assessment, the negative automatic thoughts and intrusive rumination caused by depression and stress had a more intense influence on PTG.

To our knowledge, this study represents the first attempt to adopt a positive perspective to investigate the favorable factors of PTG among resident physicians in China following the 3-years outbreak of COVID-19. The study also sheds light on psychological factors that may influence resident physicians' PTG, addressing several under-researched questions, such as the relationship between burnout and PTG. Another notable strength of this study is the large sample size and coverage of the majority of the provinces and municipalities in China.

This study has some limitations. Firstly, the cross-sectional design of the study limits our ability to establish causality between the examined factors and outcome. Secondly, the use of online convenience sampling as a recruitment method may introduce response biases and affect the generalization of the results. Finally, the use of brief screening measurements to assess burnout, depression and anxiety may have limited the ability to explore complex relationships between variables, highlighting the need for more in-depth measurement tools in future research.

Based on the perspective of positive psychology, this study examined the associated factors of PTG among resident physicians in the wake of the COVID-19 pandemic. Practically, findings of this study implied that fostering a supportive workplace environment and improving the work compensation for resident physicians might be important to promote PTG among resident physicians. For those experiencing burnout, depression and stress, interventions based on positive psychology principles, such as emotional regulation training and narrative therapy, may potentially facilitate PTG (70). Future research should conduct a longitudinal design to investigate the trajectories of PTG over time and to explore the temporal relationships between PTG and other psychological characteristics among resident physicians.

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 humans were approved by Tongji Hospital of Tongji University Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

ZZ was responsible for study design, recruitment of respondents, and manuscript writing. YZ, RC, and XZ collected data and

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TABLE 3 Univariable and multivariable logistic regression analyses.

Variables		Moderate-to-high PTG			
		Univariable analysis		Multivariable analysis	
		OR(95% CI)	*p*	OR(95% CI)	*p*
Socio-demographics					
Age		1.049(1.020,1.079)	0.001	1.039(1.008,1.070)	0.014
Gender	Female	1.398(1.178,1.659)	<0.001	1.383(1.151,1.662)	0.001
	Male	Ref.		Ref.	
Marital status	Unmarried	0.727(0.591,0.893)	0.002		
	Married	Ref.			
Region of work	Eastern China	0.815(0.642,1.033)	0.091		
	Central China	1.010(0.818,1.247)	0.927		
	Western China	Ref.			
Residential status	Dormitory	0.948(0.744,1.209)	0.668		
	Living with family	1.247(0.965,1.610)	0.091		
	Shared housing	1.020(0.781,1.332)	0.886		
	Living alone	Ref.			
Education	Bachelor's degree	0.757(0.403,1.420)	0.385		
	Master's degree	0.940(0.469,1.887)	0.862		
	Doctoral degree	Ref.			
Year in SRTP	1st year	1.075(0.876,1.317)	0.489		
	2nd year	0.990(0.803,1.221)	0.925		
	3rd year	Ref.			
Work experience before SRTP	No	0.820(0.692,0.972)	0.022		
	Yes	Ref.			
Working hour (weekly)	≥48	0.930(0.785,1.101)	0.397		
	<48	Ref.			
Psychological factors					
Satisfaction with annual income	Satisfied	3.936(2.965,5.244)	<0.001	2.078(1.524,2.832)	<0.001
	Neutral	2.087(1.731,2.516)	<0.001	1.416(1.157,1.732)	0.001
	Unsatisfied	Ref.		Ref.	
Being supported at work	Sufficiently	2.332(1.946,2.796)	<0.001	1.432(1.171,1.751)	<0.001
	Insufficiently	Ref.		Ref.	
Burnout	High	0.356(0.295,0.430)	<0.001	0.653(0.525,0.812)	<0.001
	Low	Ref.		Ref.	
Sleep hour (daily)	<7	0.788(0.665,0.934)	0.006		
	≥7	Ref.			
Depression	Screened positively	0.352(0.290,0.427)	<0.001	0.700(0.552,0.889)	0.003
	Screened negatively	Ref.		Ref.	
Anxiety	Screened positively	0.398(0.326,0.486)	<0.001		
	Screened negatively	Ref.			
Stress	Yes	0.393(0.327,0.474)	<0.001	0.757(0.604,0.949)	0.016
	No	Ref.		Ref.	
Resilience		1.374(1.297,1.456)	<0.001	1.171(1.096,1.252)	<0.001

PTG, posttraumatic growth; OR, odds ratio; CI, confidence interval.

performed the data analyses. HW, ZL, and YL provided critical revisions. LH contributed to manuscript revision and research supervision. 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/fpsyt.2023.1228259/full#supplementary-material

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The impact of exercise on mental health during the COVID-19 pandemic: a systematic review and meta-analysis

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Introduction: Amidst the COVID-19 pandemic, there has been a global surge in mental health challenges. This study (PROSPERO CRD42023443860) aimed to investigate the impact of exercise on individuals' mental health through systematic evaluation and meta-analysis to develop a scientific exercise program.

Methods: We systematically searched the literature up to August 2023 using PubMed, Web of Science, and SCOPUS. The Cochrane Risk Assessment Tool gaged the methodological quality of the included literature.

Results: Among the initially identified 10,343 search records, 12 studies were deemed to meet the criteria for systematic review and meta-analysis. Exercise significantly improved anxiety (SMD -0.81, 95% CI -1.10 to −0.52, $p < 0.00001$), depression (−1.02, 95% CI -1.42 to −0.62, $p = 0.0001$), stress (−1.05, 95% CI -1.33 to −0.78, $p < 0.00001$), and quality of life (1.11, 95% CI 0.81 to 1.41, $p < 0.00001$). Subgroup analyzes indicated that a single exercise session lasting 30–40 min had the most pronounced effect on reducing anxiety (−1.29, 95% CI -1.12 to −0.86, $p < 0.00001$) and depression (−1.76, 95% CI -2.24 to −1.28, $p < 0.00001$). Similarly, an exercise frequency of 3–5 times per week yielded the greatest benefits for anxiety (−1.31, 95% CI -2.15 to −0.46, $p < 0.00001$) and depression (−1.27, 95% CI -2.11 to −0.41, $p = 0.0003$). Notably, exercise exhibited its most significant impact on depression improvement in the 40–64 age group (−1.32, 95% CI -1.78 to −0.86, $p < 0.00001$). Moreover, exercise notably enhanced anxiety levels among individuals in middle and upper-income brackets (−0.99, 95% CI -1.11 to −0.87, $p < 0.00001$).

Conclusion: Exercise alleviated anxiety disorders, depression, stress levels, and quality of life during the COVID-19 pandemic. The most significant impact on anxiety and depression improvement is achieved by engaging in 30–40 min of exercise sessions, 3–5 times per week.

KEYWORDS

COVID-19, exercise, physical activity, mental health, psychological health

1. Introduction

The COVID-19 pandemic, caused by the novel coronavirus, has rapidly spread on a global scale, prompting widespread public health crises (1). In the face of such public health crises, numerous countries have advocated for minimizing direct social interactions and implementing lockdown measures to curb the virus's transmission. However, these stringent measures, combined with the inherent fear surrounding the virus, can induce significant psychological strain and distress. These may encompass concerns about physical well-being, heightened apprehension regarding economic stability, and even the emergence of anxiety and depression due to the enforced restrictions (2). Statistical analysis reveals that the prevalence of depression

and anxiety disorders on a global scale throughout the COVID-19 pandemic stands at 24.0 and 21.3%, respectively (3). These psychological challenges transcend age demographics and profoundly affect individuals' mental well-being.

Psychological issues are typically treated through either medication or psychological intervention. Medication serves as a prevalent approach for managing anxiety disorders, involving the utilization of GABA receptor agonists and benzodiazepines (4, 5), as well as depression, employing medications such as selective serotonin reuptake inhibitors (SSRIs) and norepinephrine reuptake inhibitors (SNRIs) (6, 7). However, it is essential to note that the effectiveness of these medications varies due to the diverse nature of psychological conditions. Moreover, it is worth acknowledging that medications can potentially compromise neuronal function, resulting in an array of somatic symptoms and adverse impacts on bone metabolism (8). Furthermore, a range of psychotherapies, encompassing positive thinking therapy, hypnotherapy, music therapy, and Morita therapy, are integrated into the treatment paradigm. These psychotherapeutic approaches complement traditional treatments and play a crucial role in ameliorating psychological problems. Nonetheless, it is important to consider that the duration of psychotherapeutic interventions is often limited that outcomes exhibit variability among individuals (9). In conclusion, these governance strategies have not yet achieved optimal outcomes.

An increasing number of trials and studies are concentrating on exercise. Several studies have demonstrated a substantial influence of exercise on mental health (10–13). Furthermore, it has been established as both an effective and cost-efficient intervention for a wide spectrum of psychological issues, encompassing anxiety disorders and depression (14, 15). Scholarly research has deduced a notable correlation between physical activity and reduced occurrences of mental ailments (such as depression, stress, negative emotions, and overall psychological distress) and heightened psychological well-being (including self-image, life satisfaction, well-being, and mental health) (16–18). Moreover, the COVID-19 pandemic has triggered extensive psychological challenges. Over this specific period, numerous studies have indicated that exercise can ameliorate COVID-19-related negative psychology. For instance, one study demonstrated that practicing tai chi during the pandemic effectively intervened to enhance psychological and physical functioning among older adults (19). Similarly, interventions involving yoga and mindfulness interventions have exhibited a significant impact on alleviating anxiety and depression symptoms in adolescents in middle schools (20). Nevertheless, these studies were limited in sample size, and the effects of exercise on mental health displayed variability. Further incorporation of additional studies is imperative to achieve comprehensive representation. In the first place, we posit that physical exercise exerts a positive influence on psychological well-being, implying a significant positive correlation between engaging in physical activities and mental health. Secondly, we hypothesize that exercise can diminish the severity of symptoms related to anxiety, depression, and stress while also enhancing the overall quality of life, thus mitigating the adverse impacts of mental disorders. Thirdly, considering the unique psychological stresses during the COVID-19 pandemic, we postulate that exercise may have a more pronounced impact on mental health during this period, as it can serve as an effective psychological intervention. Fourthly, we also propose that different forms of exercise, such as Tai Chi, yoga, and mindfulness interventions, may yield varying effects on mental health, necessitating further comparisons of their outcomes. Therefore, a comprehensive systematic review and meta-analysis are required to obtain more precise conclusions. These hypotheses are expected to guide the design and analysis of research, enabling a deeper understanding of the impact of exercise on mental health during the COVID-19 pandemic.

2. Methods

This systematic review was registered with PROSPERO, the International Prospective Registry of Systematic Reviews (registration number: CRD42023443860). The review was conducted following the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement (21).

2.1. Literature search strategy

Two independent researchers systematically conducted an extensive search of randomized controlled trials (RCTs) across the PubMed, Web of Science, and Scopus databases. RCTs published in English before August 1, 2023, that investigated the impact of exercise on mental health during the COVID-19 pandemic were eligible for inclusion. Additionally, reference tracking of published trials and meta-analytic reviews in the field was performed to ensure the comprehensive inclusion of all relevant studies. The search employed specific terms as follows: "CoV-19" OR "SARS-CoV-2" OR "2019 nCoV," "Physical Activity (PA)," "Exercise" OR "Physical Activity," and "Mental Health" OR "Mental Hygiene." Detailed information on the search strategy can be found in Supplementary material.

2.2. Eligibility criteria

The inclusion criteria were established following the PICOS method (population, intervention, comparison, outcome, and study design). Studies were eligible for inclusion if they met the following criteria: (1) Population: all groups during the COVID-19 epidemic, encompassing specific cohorts of COVID-19-infected individuals, convalescents, and healthcare workers. And the search was not limited to any particular population to ensure comprehensive meta-analyzes. (2) Interventions: we considered various types of exercises, such as aerobic workouts, strength training, yoga, and more. No specific requirements were set for intervention frequency, intensity, or duration. Interventions were categorized as single- or multiple-group interventions. (3) Control: the control group either did not receive interventions, received non-exercise interventions, or received routine care without medical treatment. (4) Outcome: based on the Isabel Dore classification (22), mental health components encompass emotional health, quality of life, and psychological and social well-being. This systematic review focused on depression, anxiety, perceived stress, and quality of life. (5) Study Design: Only English-language, peer-reviewed RCTs were included. Reviews, single-case studies, dissertations, conference papers, and abstracts were excluded.

Exclusion criteria were as follows (1): Reviews, letters, editorial comments, case reports, conference abstracts, unpublished articles,

and non-English articles were excluded. (2) Studies without quantified results or lacking corresponding outcome indicators were excluded. (3) Literature inaccessible in full text through various channels and methods was excluded. (4) Articles of poor research quality or lacking obtainable qualitative information were excluded. (5) Literature lacking a control group was excluded.

2.3. Study selection and data extraction

All retrieved literature was imported into the EndNote software for de-duplication. Subsequently, two researchers (CCW and QYL) independently screened the titles, abstracts, and full texts of the literature. In cases of disagreement, a consensus was reached with the assistance of a third researcher to determine the final results. Following the literature screening, the two researchers utilized a Microsoft Excel spreadsheet for information extraction and coding from the trials. Information extracted for each trial encompassed the first author, country, publication year, study population, intervention details, intervention protocol (including duration of single intervention, intensity, and duration of intervention), measurement tools, and outcome indicators.

2.4. Quality appraisal

The Cochrane Risk of Bias tool was employed to evaluate the quality of eligible trials, with a focus on seven aspects: (i) randomized sequence generation; (ii) allocation concealment; (iii) blinding of participants and personnel; (iv) blinding of outcome assessment; (v) completeness of outcome data; (vi) selective reporting of study results; and (vii) other sources of bias. Each study was assessed holistically based on a 6-item criteria set, then categorized into three levels: low risk of bias, moderate risk of bias, and high risk of bias. Risk of bias diagrams were generated using Review Manager 5.3 software. The quality assessment was conducted independently by two researchers (CCW and QYL), and any discrepancies were resolved through discussions with a third individual (ZGT).

2.5. Data synthesis and analysis

The evidence synthesis was conducted using Review Manager version 5.3, provided by the Cochrane Collaboration Network, located in Oxford, United Kingdom. The variables under investigation included anxiety, depression, perceived stress, and quality of life, all of which were analyzed as continuous variables. The results for all indicators are presented as 95% confidence intervals (CIs). Heterogeneity within the studies was evaluated utilizing both the chi-square (X^2) test (Cochran's Q) and the inconsistency index (I^2) (23). Significant heterogeneity was determined by X^2 p-values <0.05 or $I^2 > 50\%$. In cases of significant heterogeneity, a random effects model was employed; otherwise, a fixed effects model was used. Funnel plots were generated using Review Manager version 5.3 from the Cochrane Collaboration in Oxford, United Kingdom. These plots were analyzed in a minimum of two of the included randomized controlled trials (RCTs). Subgroup analysis was undertaken for analyzes exhibiting high heterogeneity, focusing on diverse study characteristics to identify potential sources of heterogeneity. To ensure the reliability of the findings, sensitivity analyzes were performed, wherein each article was individually removed to assess its impact on the combined effect. If the trial group encompassed 10 or more trials, the potential for publication bias was assessed through the Begg and Egger tests using STATA 12.0, developed by Stata Corp in College Station, TX, United States. A significance level of $p < 0.05$ was considered indicative of statistically significant publication bias.

3. Results

3.1. Study selection

Initially, 10,343 studies were identified through searches conducted in the three databases. Following the elimination of 3,486 duplicates, the screening of titles and abstracts yielded 135 full-text manuscripts for assessment. After a thorough evaluation of these full texts, 123 articles were subsequently excluded. Ultimately, 12 articles fulfilled the stipulated criteria and were incorporated into our systematic review and meta-analysis of the collected studies (see Figure 1).

3.2. Study characteristics

Table 1 displays the primary characteristics of the participants and interventions. The included studies span the years 2020 to 2023, comprising a total of 12 randomized controlled trials (RCTs) (Table 1). Within these 12 studies, the participant pool consisted of 1,689 individuals, with 919 (54.4%) being male. The study encompassed participants from nine different countries. Among these studies, three studies (25%) were conducted in China (24–26), one study (8.3%) in Lithuania (19), one study (8.3%) in the United Kingdom (27), two studies (16.7%) in Turkey (28, 33), one study (8.3%) in Iran (29), one study (8.3%) in Tunisia (29), one study (8.3%) in the United States (20), one study (8.3%) in South Korea (31), and one study (8.3%) in Saudi Arabia (32).

Regarding exercise interventions, the chosen approaches varied. One study (8.3%) implemented home exercise (24), three studies (25%) incorporated progressive muscle relaxation exercises (25, 28, 29), another study (8.3%) adopted Tai chi (19), and a separate one (8.3%) utilized broadcast exercise programs (26). Additionally, four studies (33.3%) integrated yoga (20, 27, 30, 33), Additionally, four studies (33.3%) integrated yoga (31), and one study (8.3%) implemented aerobic training (32). Within our review, only a single study reported the intensity of the intervention, with intervention frequency showing substantial variation. Exercise intervention durations ranged from 1 to 10 weeks, with the majority lasting 6 weeks (25%) or 8 weeks (25%).

Regarding the intervention outcomes, anxiety was addressed in 11 studies (91.7%) (19, 20, 24–30, 32, 33), depression in 8 studies (66.7%) (19, 20, 24, 27, 30–33), perceived stress in 4 studies (33.3%) (19, 27, 30, 31), and quality of life in three studies (25%) (24, 27, 32). Although various validated scales were employed across trials for outcome assessment, the data collection process was consistently overseen by experienced staff. For assessing anxiety, instruments included the Self-Rated Anxiety Scale (24, 26), Spielberger State–Trait Anxiety Scale (25, 28, 33), DASS-21 (27, 30), Corona disease anxiety

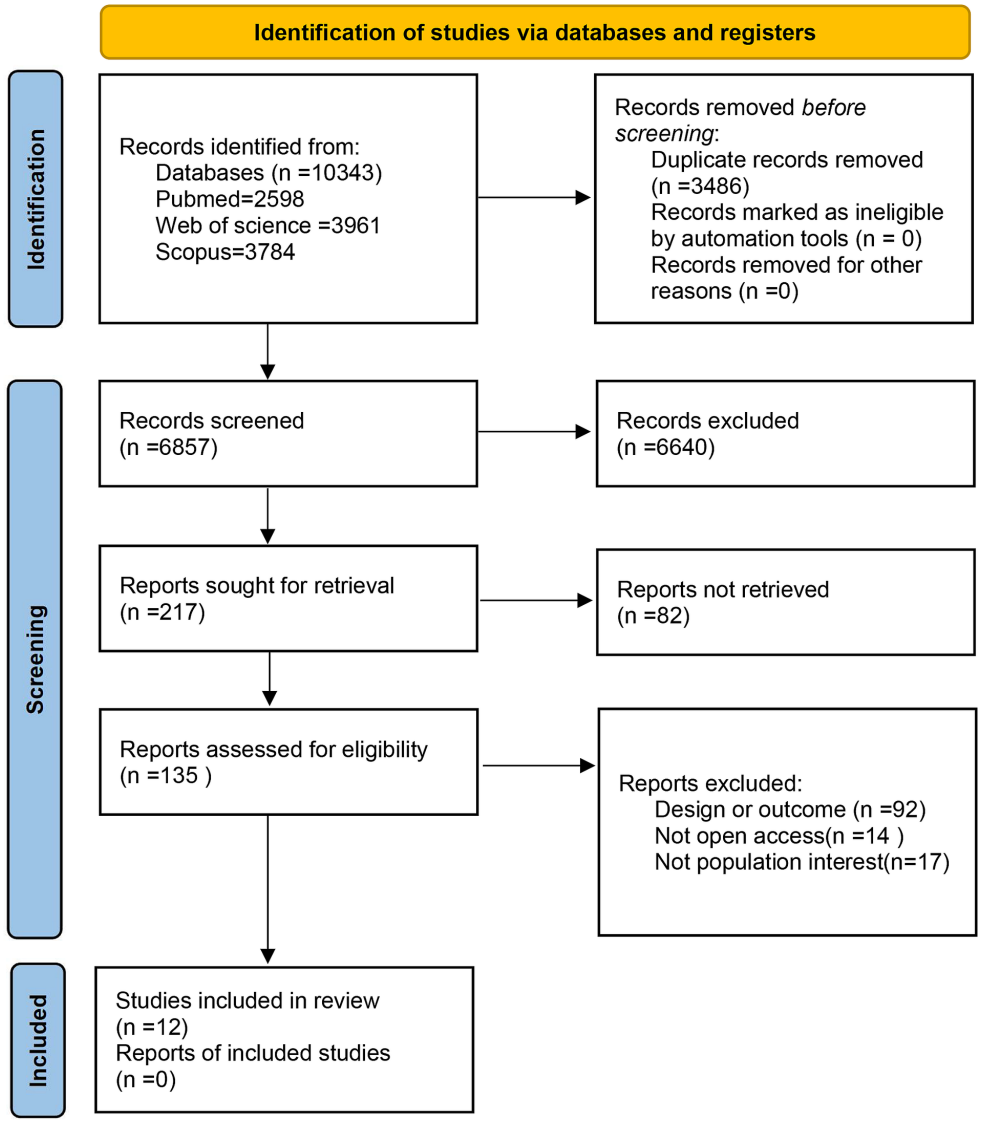

FIGURE 1
PRISMA 2020 flow diagram.

scale (29), HADS (19, 32), and SCARED (20). The assessment of depression employed instruments such as SDS (24), PSS-10 (19, 26), DASS-12 (30), PHQA (20), EPDS (31), HADS (32), and BDS (33). The evaluation of perceived stress utilized the PSS-10 (19, 27, 31), and DASS-21 (30), while the quality of life was assessed using the SF-36 (24), WEMWBS (27), and SF-36 (32).

3.3. Risk-of-bias assessment

(Figure 2) summarizes the risk of bias. Overall, the risk of bias in the 12 trials included in the review was within acceptable limits. Random sequence was adequately determined in 8 trials (66.7%), and allocation concealment was adequately recognized in 5 trials (41.7%). Ten trials (83.3%) blinded participants and staff. Nine trials (75%) were blinded to the outcome assessor, and the risk of detection bias for these trials was judged to be low. In 12 trials, no dropouts or selectivity were reported. Among the other risks of bias, only one mentioned interference by other factors. Therefore, the risk of reporting bias for these trials was rated as low.

3.4. Results of the meta-analysis

In the trials included, various instruments were utilized to assess mental health outcomes during the COVID-19 pandemic. Our review primarily focused on conducting meta-analyzes for anxiety, depression, perceived stress, and quality of life. The efficacy analysis was based on the change from baseline to final value scores. The outcomes of our analysis for each of these aspects are presented below.

3.4.1. Anxiety

Eleven trials (19, 20, 24–30, 32, 33) reported anxiety, involving a total of 1,673 subjects. In one study (32), the intervention group was subdivided into two segments, each with varying intensities. Another study (33) presented two distinct anxiety outcomes (STAI-I and

TABLE 1 Characteristics of studies included in this meta-analysis.

Study	Country	Sample size	Sex (Male, n, %)	Age (M ± SD)	Intervention	Intensity	Duration of a single intervention	Outcome measures	Duration of Intervention (week)	Outcome
Liu et al. (24) RCT	China	IG: 36 CG: 36	IG: 24(66.7%) CG: 25(69.4%)	IG:69.4 (8.0) CG: 68.9 (7.6)	IG: Home exercise CG: No exercise intervention	N/A	10 min per day	Self-rating depression scale self-rating anxiety scale the Short Form-36	6	Depression* Anxiety* Quality of life* (IG)
Liu et al. (25) RCT	China	IG: 25 CG:26	IG: 14(56.00%) CG: 14(53.85%)	50.41 ± 13.04	IG: Progressive muscle relaxation exercises CG: No exercise intervention	N/A	30 min per day	The Spielberger State–Trait Anxiety Scale	1	Anxiety* (IG)
Solianik et al. (19) RCT	Lithuania	IG:15 CG:15	4(13.33%)	67.0 ± 5.9	IG: Tai chi CG: No exercise intervention	N/A	a biweekly 60-min	Perceived Stress Scale Hospital Anxiety and Depression Scale	10	Depression*(I) Perceived Stress* (IG&CG)
Zheng et al. (26) RCT	China	IG:485CG:469	IG:248 (51.1%) CG:251 (53.5%)	IG:13.5 ± 0.50 CG:13.5 ± 0.50	IG: health education + broadcast exercise programs CG: only health education	N/A	15 min each time; 4 times per day	Spence Children's Anxiety Scale	2	Anxiety* (IG)
Wadhen et al. (27) RCT	UK	IG:17 CG:17	IG:0(0%) CG:3(17.65%)	IG:42.7 ± 10.94 CG:42.2 ± 10.20	IG: yoga CG: No exercise intervention	N/A	a minimum of two and a maximum of three 50-min classes each week for six weeks	Perceived stress Depression, Anxiety & Stress scale; DASS-21 WEMWBS	6	Depression* Perceived Stress* Anxiety* Quality of life* (IG)
Ozlu et al. (28) RCT	Turkey	IG:33 CG:34	IG:21(63.64%) CG:16(47.06%)	IG:36.48 ± 11.63 CG:33.15 ± 11.90	IG: progressive muscle relaxation exercises CG: No exercise intervention	N/A	twice a day for 5 days 20–30 min	The State–Trait Anxiety Inventory	1	Anxiety* (IG)

(Continued)

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TABLE 1 (Continued)

Study	Country	Sample size	Sex (Male, n, %)	Age (M ± SD)	Intervention	Intensity	Duration of a single intervention	Outcome measures	Duration of Intervention (week)	Outcome
Zendehdel et al. (29) RCT	Iran	IG:57 CG:58	IG:57(100%) CG:58(100%)	IG:22.93 ± 1.72 CG:28.12 ± 1.71	IG: Progressive muscle relaxation exercises CG: No exercise intervention	N/A	Three times a week; 30 min each time	Corona disease anxiety scale	4	Anxiety* (IG)
Baklouti et al. (30) RCT	Tunisia	IG:65 CG:95	IG:42(42.86%) CG:56(57.14%)	65–85 (Range)	IG: yoga CG: No exercise intervention	N/A	80 twice a week	Depression, Anxiety, and Stress Scales	8	Depression* Perceived Stress* Anxiety* (IG)
Bazzano et al. (20) RCT	USA	IG:42 CG:44	IG:23(57.5%) CG:21(50.0%)	11–14 (Range)	IG: yoga CG: No exercise intervention	N/A	45 once a week	the Screen for Child Anxiety-Related Disorders the Patient Health Questionnaire revised for adolescents	8	Depression* (IG)
Kim et al. (31) RCT	Korea	IG:8 CG:8	IG:8(100%) CG:8(100%)	IG:38.14 ± 1.39 CG:39.71 ± 2.01	IG: Online Pilates Exercise CG: No exercise intervention	50–60% of the maximum heart rate,	twice a week, 50 min a day.	Edinburgh Postnatal Depression Scale Perceived Stress Scale	8	Depression* Perceived Stress* (IG)
Ibrahim et al. (32) RCT	Saudi Arabia	MIG:24 LIG:24 CG:24	MIG:11(45.83%) LIG:12(50%) CG:8(33.33%)	MIG:62.6 ± 5.01 LIG:62.5 ± 4.67 CG:62.7 ± 4.3	IG: Aerobic training CG: No exercise intervention	moderate-intensity low-intensity	40 min four times a week	Hamilton Anxiety and Depression Scale SF-36	10	Depression* Anxiety* Quality of life* (IG)
Gunebakan et al. (33) RCT	Turkey	IG:16 CG:16	IG:16(100%) CG:16(100%)	IG:25.56 ± 4.55 CG:29.81 ± 7.00	IG: yoga CG: No exercise intervention	N/A	Twice a week for 45 min	Beck Depression Scale The State and Trait Anxiety Inventory	6	Depression* Anxiety* (IG)

EG experimental group. IG control group. MIG Moderate intensity group. LIG Low-intensity group. *significant improvement.

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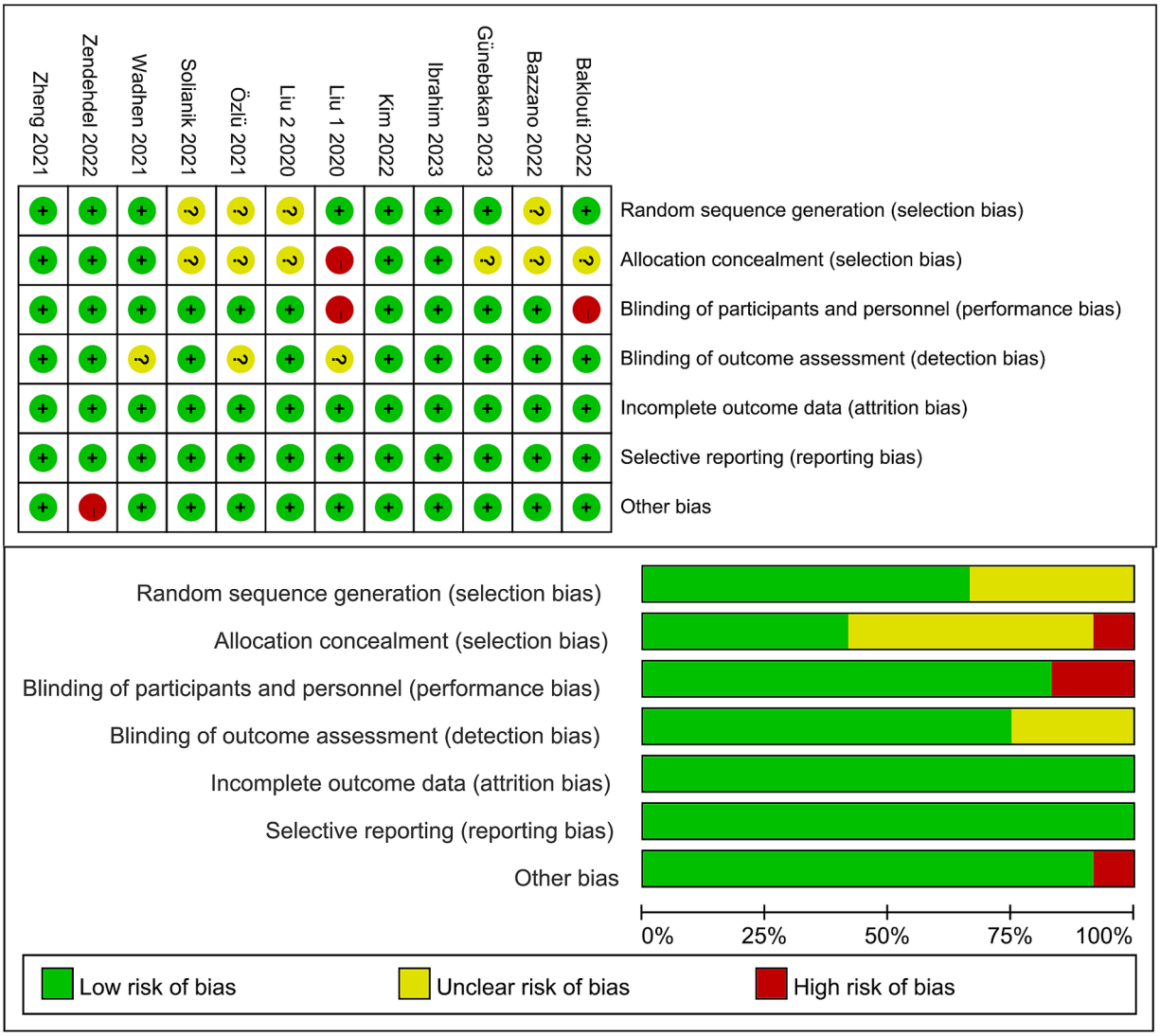

FIGURE 2
Risk-of-bias summary. Above: Risk of bias summary: review authors' judgments about each risk of bias item for each included study. Below: Risk of bias graph: review authors' judgments about each risk of bias item presented as percentages across all included studies.

STAI-II). Consequently, the meta-analysis encompassed 13 items. Given the observed heterogeneity in this review ($I^2 = 82\%$, $p < 0.00001$), a random effects model was adopted. The findings revealed an aggregated sample size of 1729, accompanied by substantial evidence indicating significant levels of anxiety due to exercise intervention in comparison to the control group [SMD = −0.81, 95% CI = (−1.10, −0.52), $p < 0.00001$; see Figure 3].

3.4.2. Depression

Eight studies (19, 20, 24, 27, 30–33) reported depression, involving a total of 502 subjects. One study (32) subdivided the intervention group into two segments with differing intensities. Nine studies were included in the meta-analysis. Owing to the heterogeneity in this review ($I^2 = 75\%$, $p = 0.0001$), a random effects model was employed. There was substantial evidence indicating a significant distinction in depression levels between the exercise intervention and control groups [SMD = −1.02, 95% CI = (−1.42, −0.62), $p < 0.00001$; see Figure 4].

3.4.3. Stress

Stress was documented in four trials (19, 27, 30, 31), involving 240 subjects. As no heterogeneity was observed in these findings ($I^2 = 0\%$), we employed a fixed effects model to combine the results. The overall outcome indicated a notable disparity in perceived stress between the exercise intervention and control groups, with significant statistical significance [SMD = −1.05, 95% CI = (−1.33, −0.78), $p < 0.00001$; see Figure 5].

3.4.4. Quality of life

The impact of exercise on quality of life was assessed in three trials (24, 27, 32), encompassing 202 subjects. Due to the absence of heterogeneity in this analysis ($I^2 = 36\%$), a fixed-effects model was selected. The study outcomes demonstrated a substantial effect of exercise on the quality of life in comparison to the control group [SMD = 1.11, 95% CI = (0.81, 1.41), $p < 0.00001$; see Figure 6].

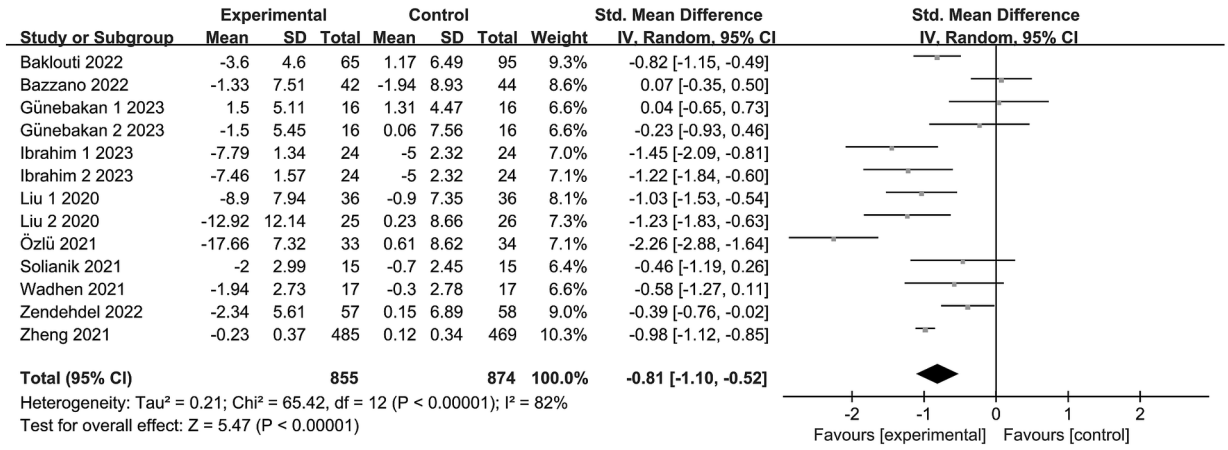

FIGURE 3
Forest plot for Exercise on Anxiety. CI, confidence interval.

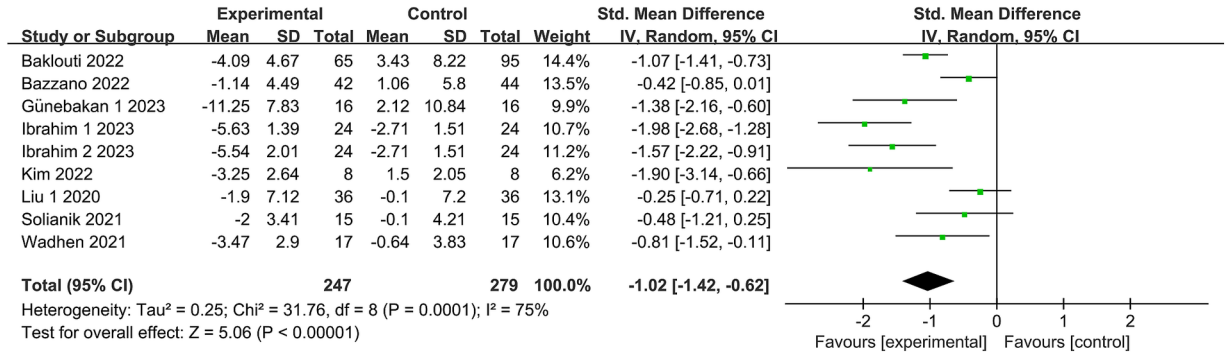

FIGURE 4
Forest plot for Exercise on Depression. CI, confidence interval.

3.5. Sensitivity analysis

We conducted sensitivity analyzes to evaluate the impact of each study on exercise intervention, anxiety, and depression by systematically removing studies on a case-by-case basis (see Figure 7A). The results of the meta-analysis concerning exercise intervention for anxiety yielded a statistically significant outcome with an odds ratio (OR) of −0.82 (95% CI: −1.11, −0.53; see Figure 7B). Similarly, the meta-analysis on exercise interventions for depression also demonstrated statistically significant results, with an OR of −1.05 (95% CI: −1.45, −0.64). Our sensitivity analyzes exhibited the robustness of the findings regarding exercise interventions for anxiety disorders and depression, even after excluding individual studies.

3.6. Publication risk of bias detection

The funnel plot depicting the impact of exercise on anxiety, depression, stress, and quality of life (see Figure 8) illustrates a symmetrical distribution on both its left and right sides, indicating minimal publication bias in the results.

More than ten studies have examined indicators of both anxiety and depression. To assess publication bias, we employed the Egger and Begg linear regression tests (refer to Table 2). Anxiety ($t = 0.52$, $p = 0.615$; Figure 9A) and depression ($t = -1.27$, $p = 0.244$; Figure 9B) were evaluated using Egger's linear regression, demonstrating no significant difference between the two conditions ($p > 0.05$). The Egger linear regression analysis indicated the absence of publication bias. Begg's linear regression yielded anxiety ($z = 0.55$, Pr = 0.583; Figure 9C) and depression ($z = 0.73$, Pr = 0.466; Figure 9D) values. Similarly, no significant difference ($p > 0.05$) between anxiety and depression was observed. The Begg linear regression also confirmed the absence of publication bias in these measures.

3.7. Subgroup analysis

The results indicated no significant heterogeneity for stress ($I^2 = 0\%$) and low heterogeneity for quality of life ($I^2 = 36\%$), implying consistent findings across the included studies and a limited study pool. As a result, subgroup analyzes were not conducted for stress and quality of life outcomes. Conversely, our findings demonstrated significant heterogeneity for anxiety disorders ($I^2 = 82\%$) and

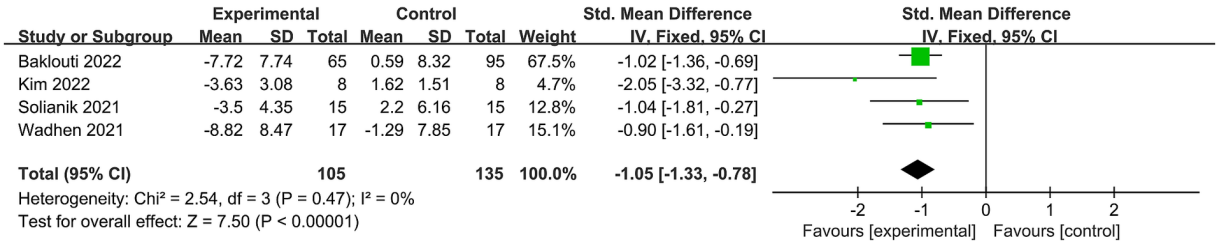

FIGURE 5
Forest plot for Exercise on Perceived Stress. CI, confidence interval.

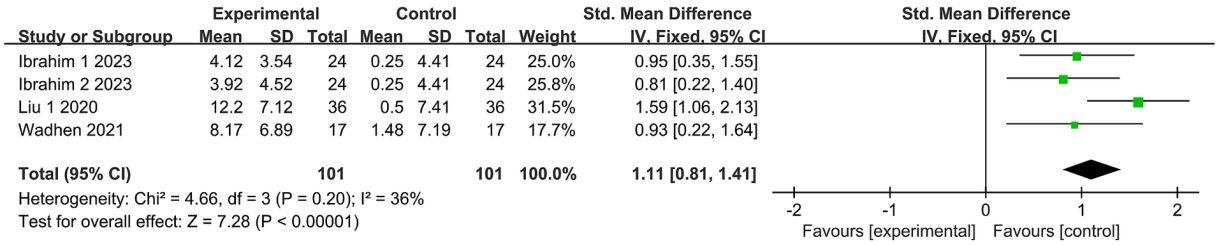

FIGURE 6
Forest plot for Exercise on Quality of Life. CI, confidence interval.

depression ($I^2 = 75\%$), prompting subgroup analyzes for both conditions. Subgroup analyzes were employed for the five components of the exercise intervention program in the meta-analysis: intervention duration, frequency, period, participant age, and regional income. Among these elements, intervention duration, frequency, participant age, and regional income displayed varying levels of heterogeneity, signifying differential impacts on the exercise intervention's effect on mental health. In contrast, the cycle subgroup exhibited lower heterogeneity, suggesting that the exercise cycle did not influence the mental health effect.

Regarding the duration of single interventions—less than 20 min, 30–40 min, 40–60 min, and more than 60 min—significant heterogeneity in intervention effects was observed among the four groups ($I^2 = 90.5\%$, $p < 0.000001$), implying the vital role of intervention duration in influencing exercise's impact on anxiety disorder interventions. The intervention effects on anxiety disorders followed this pattern: less than 20 min (SMD = −0.99), 30–40 min (SMD = −1.29), 40–60 min (SMD = −0.10), and more than 60 min (SMD = −0.76). Statistically significant differences were found in the less than 20 min, 30–40 min, and more than 60 min groups ($p < 0.05$), whereas the 40–60 min group exhibited no statistical significance ($p = 0.49$). Notably, intervention effects for the 30–40 min group surpassed those of the other groups (see Figure 10A).

Examining exercise frequency—less than 2 times per week, 2–3 times per week, 3–5 times per week, and more than 5 times per week—revealed heterogeneous intervention effects among these groups ($I^2 = 82.4\%$, $p = 0.0007$), indicating that intervention frequency influences exercise's impact on anxiety disorder interventions. The intervention effect sizes for anxiety were as follows: less than 2 sessions per week (SMD = −0.11), 2–3 sessions per week (SMD = −0.47), 3–5 sessions per week (SMD = −1.31), and more than 5 sessions per week (SMD = −1.00). No statistical significance was observed in the less than 2 times per week group ($p = 0.67$), whereas statistical significance emerged in the 2–3 times per week ($p = 0.02$), 3–5 times per week ($p = 0.002$), and more than 5 times per week ($p < 0.00001$) groups. Overall, an intervention frequency of 3–5 sessions per week yielded the most significant improvement in anxiety disorders (refer to Figure 10B).

Analyzing the intervention period—less than 6 weeks, 6 weeks, 8 weeks, and 10 weeks—revealed slight heterogeneity in intervention effect sizes among these groups ($I^2 = 37.8\%$, $p = 0.19$), indicating that the intervention period did not exert a significant influence on the effect of exercise on anxiety disorders (refer to Figure 10C).

Exploring participants' ages—less than 20 years, 20–39 years, 40–64 years, and more than 65 years—revealed no significant heterogeneity in intervention effect sizes across these groups ($I^2 = 0\%$, $p = 0.41$). This suggests that participants' age did not exert a significant influence on the impact of exercise and movement interventions for anxiety disorders (refer to Figure 10D).

Examining income levels—low-middle income, high-middle income, and high income—revealed significant heterogeneity in intervention effect sizes across the three groups ($I^2 = 82.4\%$, $p = 0.002$). This underscores income level as a vital determinant affecting the efficacy of exercise interventions for anxiety disorders. The intervention effect sizes for income levels on anxiety disorders were statistically significant ($p < 0.05$) for low-middle income (SMD = −0.63), high-middle income (SMD = −0.99), and high income (SMD = −0.57). Notably, the middle and upper-income groups exhibited notably superior intervention effects (refer to Figure 10E).

Regarding single intervention duration—less than 20 min, 30–40 min, 40–60 min, and more than 60 min—significant heterogeneity in intervention effect sizes was observed among the four groups ($I^2 = 84.9\%$, $p = 0.0002$). This underscores the pivotal role of intervention duration in influencing the impact of exercise and sports

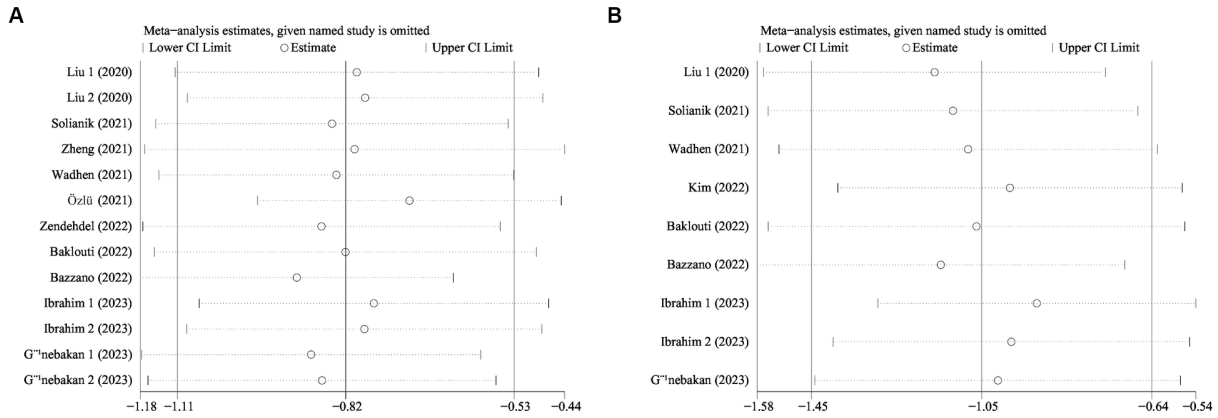

FIGURE 7
Sensitivity analysis of **(A)** Anxiety **(B)** Depression.

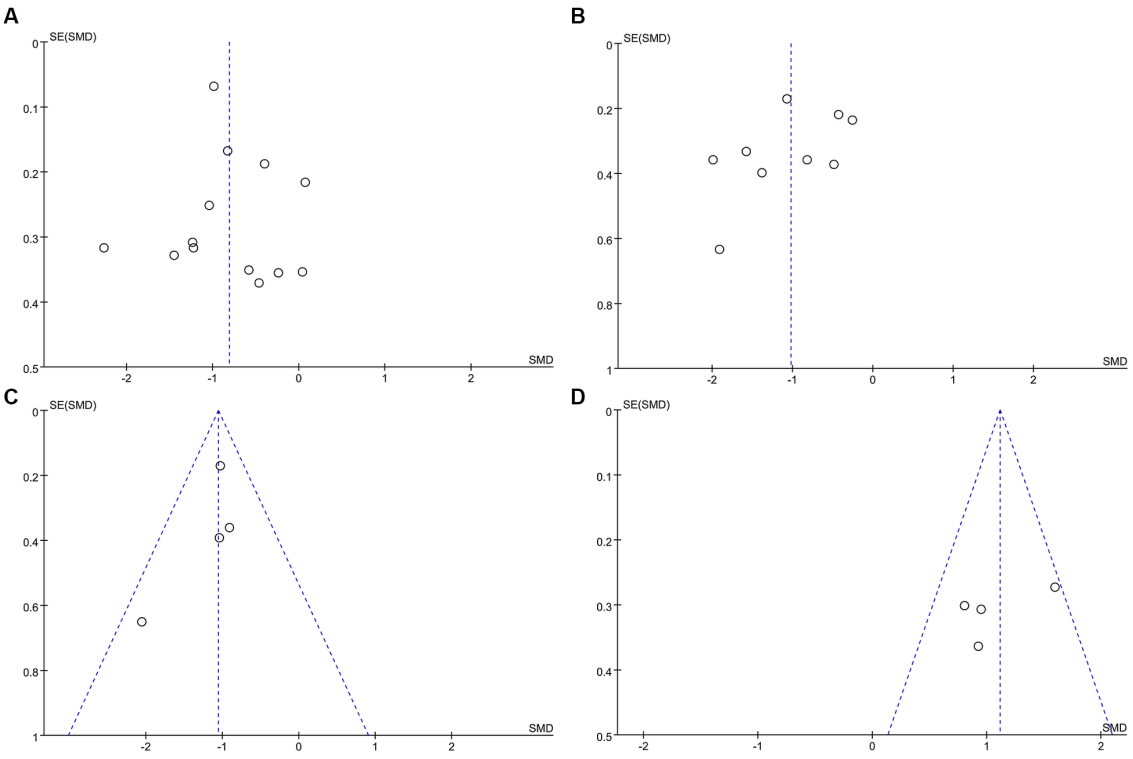

FIGURE 8
Funnel plot. **(A)** Funnel plot for Anxiety. **(B)**Funnel plot for Depression. **(C)** Funnel plot for Stresses. **(D)** Funnel plot for Quality of life.

activities on depression interventions. The intervention effect on depression in each group followed this sequence: less than 20 min group (SMD = −0.25), 30–40 min group (SMD = −1.76), 40–60 min group (SMD = −0.98), and more than 60 min group (SMD = −0.87). Statistically significant differences were found in the 30–40 min, 40–60 min, and more than 60 min groups ($p < 0.05$), while no statistical significance emerged in the less than 20 min group ($p = 0.29$). Notably, the 30–40 min group demonstrated notably superior intervention effects compared to the other groups (refer to Figure 11A).

Regarding exercise frequency—less than 2 times per week, 2–3 times per week, and 3–5 times per week—variance in intervention effect sizes was observed among the three groups ($I^2 = 72.8\%$, $p = 0.03$), implying that intervention frequency impacts the efficacy of exercise workouts as a depression intervention. The intervention effect sizes for

TABLE 2 analysis of bias.

Outcomes	Egger		Begg	
	t	*P*	*z*	Pr
Anxiety	0.52	0.615	0.55	0.583
Depression	−1.27	0.244	0.73	0.466

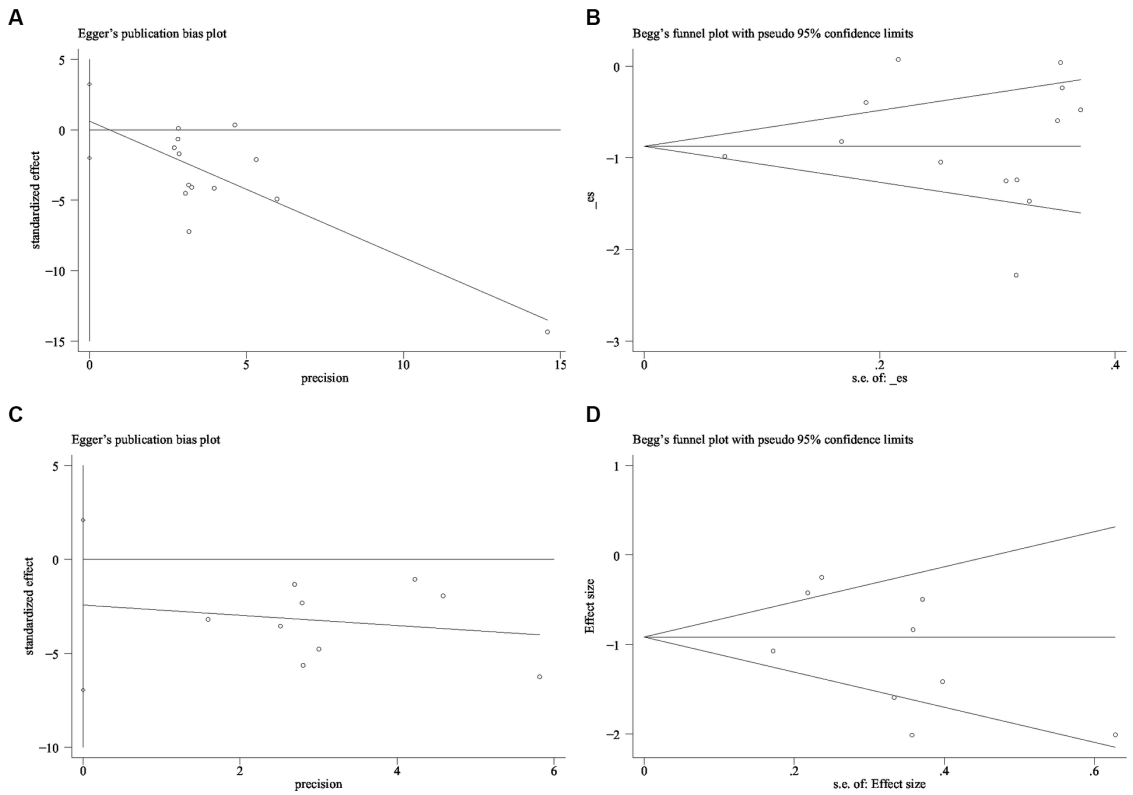

FIGURE 9
Publication bias detection **(A)** Anxiety Egger test **(B)** Anxiety Begg test **(C)** Depression Egger test **(D)** Depression Begg test.

depression were as follows: less than 2 sessions per week (SMD = −0.44), 2–3 sessions per week (SMD = −1.08), and 3–5 sessions per week (SMD = −1.27), all of which were statistically significant ($p < 0.05$). Notably, the subgroup effect sizes were greater for 2–3 sessions per week and 3–5 sessions per week, with the frequency of 3–5 sessions per week yielding the most substantial intervention effect size for exercise in improving depression (refer to Figure 11B).

Regarding the intervention period—6 weeks, 8 weeks, and 10 weeks—no heterogeneity in intervention effect sizes was observed among the three groups ($I^2 = 0\%$, $p = 0.55$). This indicates that the intervention period does not significantly impact the efficacy of motor exercise interventions for depression (refer to Figure 11C).

Regarding participants' age—less than 39 years, 40–64 years, and more than 65 years—significant heterogeneity in intervention effect sizes was observed among the three groups ($I^2 = 82.2\%$, $p = 0.004$). This indicates that participants' age is an influential factor affecting the impact of exercise interventions on depression. The intervention effect sizes were as follows: SMD = −1.11 for the less than 39 years group, SMD = −1.32 for the 40-64-year-old group, and SMD = −0.32 for the more than 65 years group. Statistically significant differences were found in the less than 39-year-old and 40-64-year-old groups ($p < 0.05$), while no statistical significance emerged in the more than 65-year-old group ($p = 0.11$). Notably, the most substantial intervention effect size for exercise in improving depression was observed in the 40-64-year-old group (refer to Figure 11D).

Income level: middle-income and high-income. No heterogeneity in intervention effect sizes was observed between the two groups ($I^2 = 0\%$, $p = 0.54$), implying that income level does not significantly influence the impact of exercise interventions on depression (refer to Figure 11E).

4. Discussion

4.1. Summarize the main results of the article

The COVID-19 pandemic precipitated a surge in mental health issues. Yet, there is a lack of a systematic assessment and meta-analysis of exercise's impact on mental health amid the pandemic. This meta-analysis furnishes evidence that exercise during the pandemic ameliorated anxiety disorders, depression, stress levels, and quality of life compared to controls. We assessed 12 eligible studies exploring exercise effects on anxiety, depression, perceived stress, and quality of life during COVID-19. We systematically evaluated these studies, extracting data on sample characteristics, study design, methodological aspects, and mental health outcomes. However, as the included studies were RCTs of exercise interventions, full blinding was unattainable. Previous research suggests potential bias risks even with optimal methods in trials. Nonetheless, deeming trials of low quality solely due to the lack of blinding is not warranted. Consequently, nine studies were deemed of high quality in the assessment process, bolstering our study's credibility and validity and thereby enhancing the validity and accuracy of our results and conclusions. Even when grouping anxiety and depression outcomes by participant age, intervention frequency,

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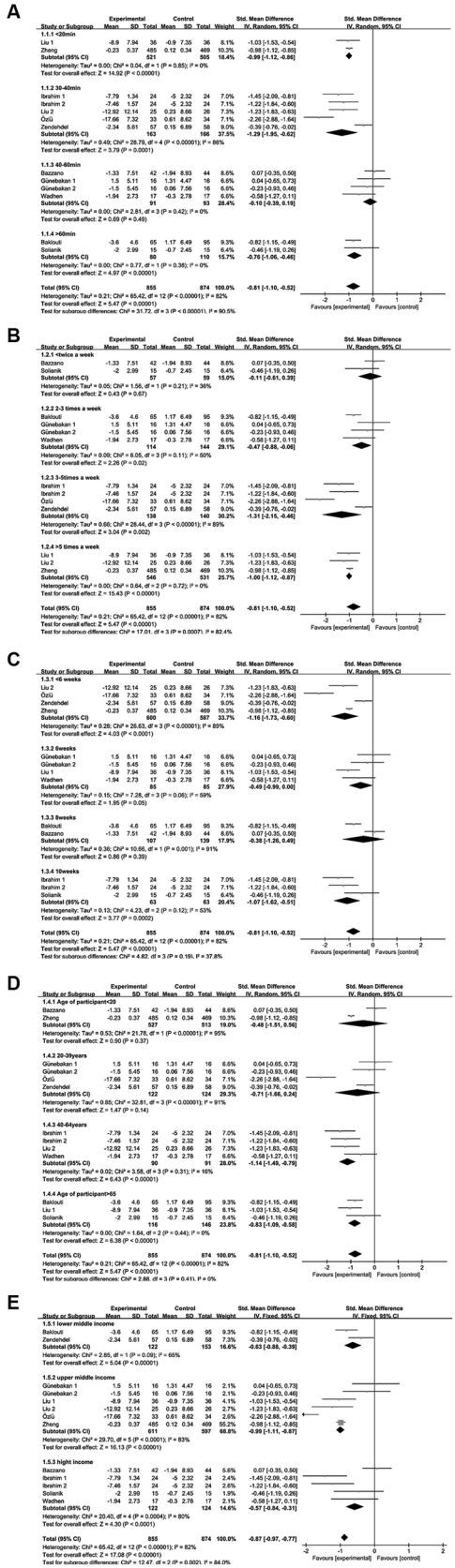

FIGURE 10
Anxiety subgroup analysis of **(A)** single intervention duration, **(B)** exercise frequency, **(C)** intervention period, **(D)** participant age, and **(E)** income level.

duration, and period, complete heterogeneity elimination wasn't achieved. Given the diverse interventions and measurement instruments across trials, substantial heterogeneity is unsurprising in this context.

4.2. Analysis of the effects of exercise program interventions

We observed significant variations in exercise interventions, encompassing diverse exercise intensities, single exercise durations, exercise frequencies, intervention cycles, and exercise patterns. Initially, by focusing on exercise intensity, its role as an effective treatment method for individuals becomes evident. This aspect holds crucial significance in understanding the direct therapeutic impacts of exercise on mental well-being. However, this pivotal matter remains underexplored in the existing literature. For instance, Gordon BR conducted a meta-analysis of resistance exercise interventions for anxiety disorders (34), scrutinizing the distinction between moderate and high-intensity exercise, thereby critically assessing the optimal resistance exercise dose necessary for anxiety improvement. Nevertheless, this study exclusively centered on resistance exercise, with stricter control over movement patterns. In another investigation, Broman-Fulks JJ demonstrated (35) that low-intensity exercise reduces sensitivity to mental health concerns, while high-intensity exercise amplifies this sensitivity. Our included studies span the COVID-19 pandemic period, and most of them omit reporting exercise intensity. Only two studies provided insight into exercise intensity effects: one study (31) set the intensity at 50–60% of maximal heart rate, while another study (32) compared moderate and low intensity, highlighting the superiority of moderate-intensity aerobic exercise in enhancing exercise capacity, quality of life, and psychological well-being. Merely two studies addressed the influence of exercise intensity on mental health, underscoring the need for further research to ascertain optimal exercise dosages.

Another notable factor is the varying duration of single exercises. The study's findings highlight that the 30-40-min single exercise duration group exhibited the most pronounced impact on alleviating anxiety and depression, markedly surpassing the groups with durations of less than 20 min, 40–60 min, and more than 60 min. Notably, intervention effect sizes declined with extended exercise durations. This trend aligns with the World Health Organization's recommendation of 30–60 min of moderate-intensity aerobic exercise per session. In the context of the COVID-19 pandemic, Peijie's investigation (36) revealed that excessively long exercise sessions induced additional fatigue and stress among participants.

An additional variable to consider is exercise frequency, which exhibits varying impacts on mental health. The findings indicated that an exercise frequency of 3–5 times per week yielded the most significant improvements in anxiety and depression, aligning with the World Health Organization's recommendation of 3 times per week. Notably, as the intervention frequency increased or decreased, the corresponding intervention effects diminished. Chekroud (37) conducted a substantial cross-sectional study on the correlation between physical activity and mental health, involving around 1 to 2 million individuals in the United States. This research identified (38) the efficacy of three to five exercise sessions per week in alleviating psychological burdens. Moreover, Chekroud's study (37) underscored

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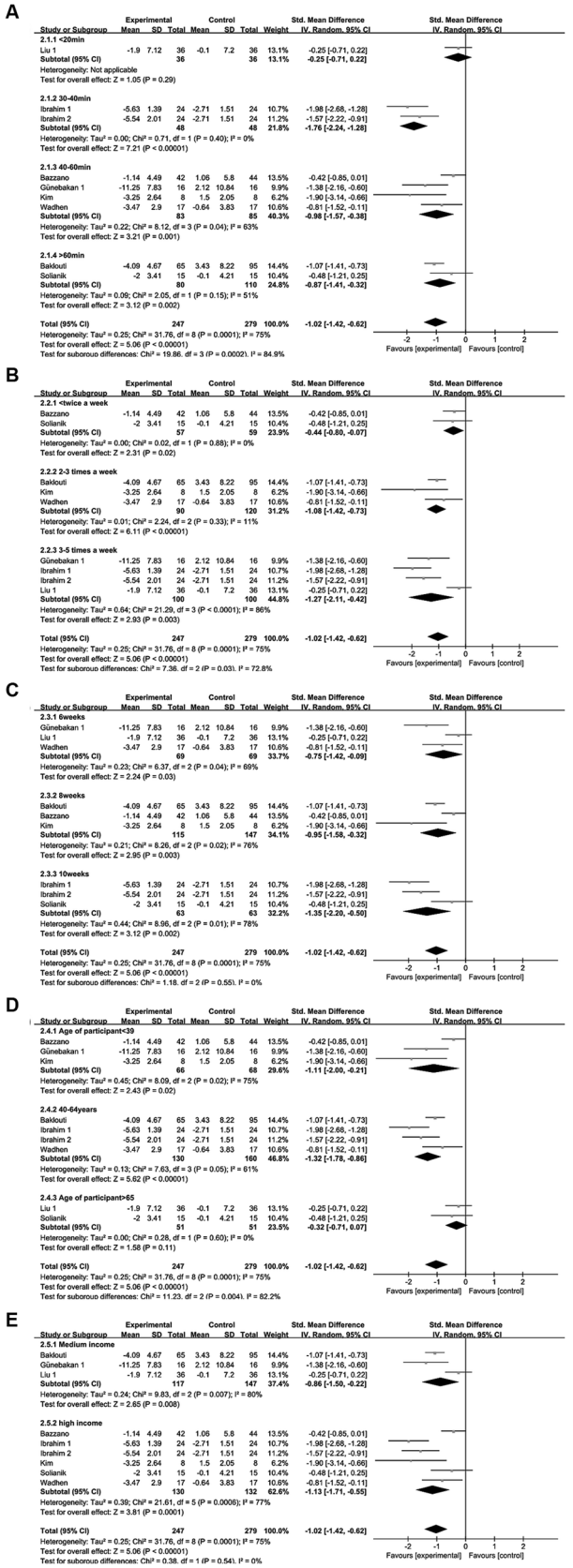

FIGURE 11
Depression subgroup analysis of **(A)** single intervention duration, **(B)** exercise frequency, **(C)** intervention period, **(D)** participant age, **(E)** income level.

that a frequency surpassing 5 interventions per week might hinder full muscle recovery, potentially leading to exercise load accumulation and subsequent immune system, psychological, and sleep disorders. Conversely, exercise frequencies below 2 times per week demonstrated relatively lower effectiveness in addressing anxiety, depression, and related mental health issues (39).

The impact of distinct intervention cycles represents the fourth variable under scrutiny. Our findings reveal significant effects across short and long cycles, yet no substantial disparities emerged. Consequently, the intervention period's influence on the effectiveness of exercise interventions for anxiety and depression appears minimal. This outcome could be attributed to potential counteracting factors inherent to the diverse study designs, methodologies, and participant characteristics. Among these factors, individual physiological adaptations and psychological responses to exercise exhibit variations due to inherent differences (40). Certain individuals might favor short-term, high-intensity exercise, while others could benefit more from extended periods of low-intensity activity. These individual variances tend to balance out to some degree, mitigating potential differences on a broader scale. Thus, the comparable effects of diverse exercise cycles on anxiety and depression interventions yielded no significant overall discrepancies.

The fifth aspect under examination is exercise patterns. Notably, amidst the COVID-19 pandemic, no studies were identified that directly compared the impacts of varied exercise patterns or types on mental health. Nevertheless, it is important to highlight that all exercise modalities exhibited a reduction in mental health burden. Among the studies encompassed in this review, three (25, 28, 29) incorporated progressive muscle relaxation exercises, while four (20, 27, 30, 33) focused on yoga–both of which are categorized as aerobic exercises. It is worth noting that no investigations about the effects of resistance exercise on mental health during the COVID-19 pandemic were found, thus precluding a conclusive assessment of diverse exercise patterns.

4.3. Analysis of the effect of age and income level

Besides variations in exercise intervention programs, disparities in age and income level were observed to impact the distinct outcomes of exercise interventions on mental health. Initially, the influence of age on exercise intervention efficacy for mental health was explored. The findings from this investigation indicated that participants' age did not significantly affect the effectiveness of exercise interventions for anxiety disorders. However, in the context of depression, participant age emerged as a pivotal factor influencing the potency of sport and exercise interventions. Particularly, exercise exhibited its most pronounced impact on alleviating depression within the 40–64 years age group, a phase categorized as midlife according to the International Health Organization's age classification. Midlife, spanning 40 to 64 years, represents a phase of heightened vulnerability to mental health challenges. Kessler's research (41) illuminated that during midlife, individuals often encounter a confluence of stressors encompassing occupational pressures, familial responsibilities, and life transitions, amplifying their susceptibility to mental health issues. The intrinsic stresses and shifts characteristic of middle adulthood render individuals more predisposed to depressive symptoms, thereby

augmenting the incidence of depression within this age bracket. Notably, a systematic evaluation (42) and a meta-analysis (43) have corroborated the pivotal role of exercise in effectively intervening against depression among middle-aged adults by enhancing physiological well-being, facilitating social engagements, and augmenting psychological states.

Next, the impact of income level on exercise intervention's influence on mental health is examined. The study outcomes suggest that income level does not significantly affect the efficacy of exercise interventions for depression. However, noteworthy improvements in anxiety were observed within the upper-middle-income group. Amid the COVID-19 pandemic, numerous coping barriers surfaced, encompassing food insecurity, mental health challenges, isolation, economic strain, restricted healthcare access, and virtual schooling, further exacerbated by limited Internet access. Enhanced social support and networking resources often characterize middle- and high-income regions, offering online and offline avenues for health promotion and exercise (44). This expanded resource spectrum provides individuals with diverse options, rendering exercise a feasible approach to alleviating anxiety symptoms. Additionally, middle- and upper-income neighborhoods host a greater number of profit-driven establishments that facilitate physical activity opportunities (45), contributing to a reduced prevalence of physical inactivity (46). The heightened physical activity levels in upper-middle-income regions hold the potential to enhance mental health, avert chronic ailments, and elevate overall quality of life.

4.4. Mechanisms of the effect of exercise on mental health during the COVID-19 pandemic

The COVID-19 pandemic triggers a systemic and chronic inflammatory response, with inflammatory molecules potentially entering the brain and disrupting neurotransmitter equilibrium, subsequently affecting mood and cognitive functions (47, 48). The pandemic-induced tension and uncertainty may further disturb neurotransmitter balance (49, 50). Factors like chronic health concerns, social instability, and economic stress can exacerbate persistent stress responses (51, 52). Although limited, research has begun exploring the mechanisms underlying the relationship between exercise and mental health, identifying several potential pathways. First, there's a physiological perspective. Exercise can alleviate anxiety, depression, and stress by releasing endogenous hormones (e.g., endorphins, dopamine, and serotonin) with analgesic and pleasurable effects. Physical activity aids in neurotransmitter regulation (e.g., 24-hydroxytryptophan, norepinephrine), fostering neuroplasticity and proper brain region functioning, thereby enhancing positive moods (53–55). Additionally, exercise assists in modulating the hypothalamic–pituitary–adrenal (HPA) axis function, curbing excessive stress responses, and mitigating anxiety and depression symptoms (43, 56). Moreover, exercise stimulates the immune system to release beneficial cytokines, particularly anti-inflammatory ones, fostering immune balance and curbing excessive inflammation–a crucial component for mental well-being (57, 58). Second, a social-behavioral explanation exists. Exercise can elevate an individual's self-esteem and self-efficacy, enabling more constructive coping with mental health issues (59). The attainment of physical activity goals brings forth a sense of achievement, positively impacting emotional states. Furthermore, exercise serves as a platform for social interaction, diminishing social isolation and augmenting mental health (60).

4.5. Limitations and advantages

This systematic evaluation and meta-analysis have limitations. Firstly, the included studies were randomized controlled trials of exercise interventions, precluding complete blinding. Thus, subjective factors might introduce bias into the quality assessment process. Secondly, non-uniform scales employed to evaluate mental health indicators led to considerable heterogeneity. Thirdly, due to the limited follow-up data reported in the included studies, the long-term effects of exercise on COVID-19 pandemic-related mental health were not analyzed. Lastly, despite encompassing multiple countries, the meta-analysis lacked representation from low-income areas.

This study holds numerous strengths. Firstly, it pioneers in systematically evaluating and meta-analyzing the impact of exercise on mental health during the COVID-19 pandemic, introducing an innovative dimension. Secondly, adhering to PRISMA guidelines, our review employed a rigorous systematic methodology, ensuring meticulous identification and assessment of pertinent literature with optimal scientific rigor. Thirdly, our review was *a priori* registered in the Prospero database, predefining research inquiries and inclusion criteria and enhancing methodological transparency. Fourthly, an extensive search across three electronic sources was conducted, documented in our comprehensive search strategy detailed in the electronic Supplementary Table S1. Additionally, the quality of the included studies was scrupulously examined, fortifying the conclusions drawn *via* quality assessment tools. Fifthly, we explored the influence of exercise on COVID-19 pandemic-linked mental health from diverse standpoints, encompassing exercise regimes, age, and regional income levels. Our findings offer valuable insights for the real-time enhancement of mental health services and the elevation of initiatives to foster positive mental health outcomes.

5. Conclusion

Our analysis demonstrated the efficacy of exercise in alleviating anxiety disorders, depression, and stress levels and enhancing quality of life among individuals during the COVID-19 pandemic. Notably, a physical activity regimen with a single exercise duration of 30–40 min and an exercise frequency of 3–5 times per week yielded the most pronounced effects in ameliorating anxiety and depression. Particularly, individuals aged 40–64 years experienced the most significant improvements in depression through exercise interventions. Moreover, exercise was most impactful in reducing anxiety among individuals from middle- and high-income backgrounds. For future research, it is imperative to address certain aspects. Firstly, expanding the study sample size, standardizing tools for assessing mental health indicators, and extending exercise cycles will enhance the comprehensiveness of meta-analysis outcomes. Secondly, employing more rigorous and scientifically robust methods to elevate the quality of randomized controlled trials (RCTs) will enable the derivation of more conclusive results. This, in turn, will offer enhanced references for medical practitioners and serve as a

valuable scientific foundation for individuals engaging in physical exercise.

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

CW: Data curation, Methodology, Software, Writing – original draft, Writing – review & editing. ZT: Supervision, Writing – review & editing. QL: Data curation, Methodology, Writing – original draft.

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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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The association between emotion malleability beliefs and severe psychological distress stratified by sex, age, and presence of any psychiatric disorders

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Background: Recent studies have shown an association between psychological distress and emotion malleability beliefs, meaning mindsets about whether one's emotions are fixed or changeable. However, most studies have not examined the association between these beliefs and sociodemographic factors.

Methods: A nationwide cross-sectional Internet survey of residents of Japan aged 15–79 years was conducted using sampling weights for national estimates to investigate the association between emotion malleability beliefs and sociodemographic factors and between fixed beliefs and severe psychological distress (SPD). SPD was defined as a Kessler 6 Scale score of ≥13. Adjusted odds ratios for SPD were calculated considering potential confounders. Further analyses were stratified by sex, age and presence of any psychiatric disorder.

Results: The analysis included 23,142 participants (female, 48.64%). Fixed beliefs were associated with female sex, age < 45 years, and presence of psychiatric disorders. These beliefs were associated with SPD, and additional analysis showed stronger associations with SPD among female respondents, respondents aged 45–59 years, and those aged ≥60 years.

Conclusion: Results indicate that female sex, age < 45 years, and current mental disorders were associated with fixed emotion malleability beliefs. Associations between fixed emotion malleability beliefs and SPD were particularly strong among female respondents and people aged ≥45 years compared with the general population. Our study extends the association between emotion malleability beliefs and psychological health to the general population. Future studies should explore mechanisms underlying individual differences in emotion beliefs.

KEYWORDS

emotion regulation, emotion malleability beliefs, mindset, psychological distress, emotion belief

1. Introduction

Individuals' belief systems, also known as implicit theories or mindsets (Dweck and Leggett, 1988), have been widely examined with respect to mental health. Specifically, there is growing interest in research on emotion malleability beliefs in relation to emotional problems (Kneeland et al., 2016; Burnette et al., 2020; Reffi et al., 2020; Schroder, 2021). People with more malleable beliefs about emotion show a positive correlation with positive emotions and well-being and a negative correlation with negative emotions and depressive symptoms (Tamir et al., 2007; King and dela Rosa, 2019). A recent meta-analysis demonstrated a negative association between fixed (less malleable) emotion beliefs and mental health. Moreover, previous studies suggest that individuals holding these beliefs frequently use maladaptive emotion regulation strategies (King and dela Rosa, 2019; Ortner and Pennekamp, 2020; Schell et al., 2023), which are associated with the development, persistence, and exacerbation of emotional disorders (Kneeland et al., 2016; Schroder, 2021).

Emotion dysregulation is at the core of trans-diagnostic mechanisms of emotional disorders (Gross, 2013; Sloan et al., 2017). Whether individuals believe emotions to be malleable or fixed affects their emotion regulation strategies and their experience of emotions, which is associated with psychopathologies such as depression and anxiety (for reviews, see Kneeland et al., 2016; Schroder, 2021). People who believe that emotions can be changed are more likely to engage in adaptive emotion regulation, such as cognitive reappraisal, in which they think of alternative interpretations of a situation (Tamir et al., 2007). On the other hand, people believe that emotions are fixed are more likely to be disengaged from regulation of their own emotions, and consequently to use maladaptive emotion regulation strategies such as avoidance and rumination (De Castella et al., 2018; Kneeland and Dovidio, 2020). These associations between fixed beliefs and psychological health have been observed in clinical research. In patients with social anxiety disorder, fixed beliefs independently explain variance in stress, trait anxiety, negative affect, and self-esteem, even after adjusting for the severity of social anxiety symptoms (De Castella et al., 2014). In patients with depression, fixed beliefs indirectly influence depressive symptoms via experiential avoidance (Sung et al., 2020). Thus, emotion malleability beliefs have been shown to have the potential to advance our understanding of the psychopathology of emotional disorders.

Although studies of emotion malleability beliefs should account for factors such as sex, age, and socioeconomic status, most have not. Some studies indicate that females are less likely to believe that they can regulate their own emotions (Nolen-Hoeksema and Jackson, 2001), whereas others found no gender differences (Tamir et al., 2007; De Castella et al., 2013, 2018). Such inconsistencies might be due to small sample sizes and lack of diversity among study participants. Most studies to date have included fewer than 1,000 participants, and have been conducted with young, Caucasian populations (Burnette et al., 2020). In addition, people who believe emotions are malleable tend to become stronger from early adulthood (18–25 years) to post-25 years old, although the difference was not statistically significant in comparison with adolescents aged 12–17 years (Burnette et al., 2020). Moreover, older people utilize maladaptive emotion regulation strategies less frequently than younger people (Schirda et al., 2016). These age differences in emotion regulation strategies might mean that older people have malleable beliefs about emotions than younger people. Similarly, differences in associations by race and the presence of psychiatric disorders have been examined, but no significant differences were found. Furthermore, the relationship between these beliefs and psychological health in people who have physical illnesses has not been clarified. The prevalence of depression is higher in people with physical illnesses such as hypertension, diabetes, and chronic pain compared with the general population (Gavard et al., 1993; Miller and Cano, 2009; Roy and Lloyd, 2012; Michal et al., 2013; Rayner et al., 2016). Thus, people with these illnesses may have some unique relationship between emotion malleability beliefs and psychological health. To our knowledge, no study has yet examined differences in these beliefs with respect to these factors in the general population.

Our study aimed to examine how emotion malleability beliefs vary by sex, age, health conditions and other socioeconomic factors and how these effect modifiers vary the strength of the association between these beliefs and psychological distress in a general population sample. This study is expected to provide some important findings. First, this study would reveal the relationship between emotion malleability beliefs and these factors. Empirical studies have shown that people who believe emotion is less malleable seek less support from their peers (Tamir et al., 2007) and they prefer medication to psychotherapy (Schroder et al., 2015). Thus, clarifying these associations would enable the dissemination of persuasive messages for improved mental health tailored to each group. Second, identifying a population with fixed beliefs in this study is expected to provide important data to advance the literature on emotion malleability beliefs. We expected that people with fixed beliefs would have higher rates of severe psychological distress than people with malleable beliefs. Therefore, we conducted an exploratory analysis without a specific hypothesis to examine the following research question: Do the associations between these beliefs and psychological distress differ according to the presence of various factors such as health status?

2. Methods

2.1. Study design and participants

This study was a secondary analysis of data from the second wave of the Japan "COVID-19 and Society" Internet Survey (JACSIS; Yoshioka et al., 2021). The JACSIS study complied with ethical standards of the relevant national and institutional committees on human experimentation and the 1975 Declaration of Helsinki (as revised in 2008). The protocol was approved by the Research Ethics Committee of the Osaka International Cancer Research Institute (June 19, 2020; approval number 20084), and the survey allows for secondary use of the data. The protocol for the present study was reviewed and approved by the Research Ethics Committee of the [Anonymised for review] (June 11, 2022; approval number 2021-31-02).

In September 2020, the JACSIS study conducted a nationwide baseline survey of 28,000 male and female respondents aged 15–79 years who were selected randomly from 224,389 panelists registered with a large Internet survey company (Rakuten Insight, Inc.,

Tokyo, Japan).[1] In February 2021, a follow-up survey was conducted in which 24,059 of the 28,000 baseline survey participants took part. In addition, 1,941 participants aged 15–79 years were newly recruited, without stratification by age, sex, or prefecture of residence, giving a total of 26,000 participants. "E-points" (points used for Internet shopping or cash exchange) were offered to encourage participation. Although the survey agency declined to disclose the exact value of the e-points, one E-point is considered equivalent to approximately 100 yen (approximately US$1 at the time of the survey). The study was a cross-sectional study that used data obtained from this follow-up survey, in which participants responded to a scale to measure their beliefs about emotion malleability.

2.2. Measures

2.2.1. Emotion malleability beliefs

The Japanese version of the Personal Implicit Beliefs About Emotions scale (De Castella et al., 2013) assessed emotion malleability beliefs. This questionnaire consists of four items, two of which employ reversed items ("I can learn to control my emotions," "If I want to, I can change the emotions that I have"). Each item is rated on a 5-point scale (1 = strongly disagree, 5 = strongly agree). A higher total score means that they strongly believe in a lack of control over their emotions.

We developed the Japanese version of this scale based on a report by a working group of the International Society for Pharmacoeconomics and Outcomes Research (Wild et al., 2005). This scale was independently translated from English to Japanese by a psychologist and a bilingual Japanese-English psychiatrist, both of whom integrated the translations through discussion. In addition, another bilingual Japanese-English psychiatrist compared the original version with the Japanese version and made corrections to the translation. The preliminary Japanese version was then back translated into English by a bilingual individual employed at a translation company who was unfamiliar with the original version. The author of the original version reviewed the back-translation and confirmed the equivalence of its semantic content with that of the original version.

De Castella et al. (2013) did not report the factor structure of the Personal Implicit Beliefs about Emotion Scale. In our analyses below, we used the total score of this scale as in previous studies (De Castella et al., 2013, 2014). In the present study, internal reliability was demonstrated based on Cronbach's α of 0.59 and McDonald's ω of 0.66, which were slightly lower compared with the Cronbach's alpha of 0.73 reported previously (De Castella et al., 2018).

2.2.2. Severe psychological distress

The Japanese version of The Kessler Psychological Distress Scale, a widely used measure of psychological distress in the general population, was used to assess psychological distress (Furukawa et al., 2003). For this study, severe psychological distress (SPD) was defined as a total score of 13 or higher. A score of 13 was a cutoff to screen for severe mood disorder or any anxiety disorder (Furukawa et al., 2003; Kessler et al., 2003). The present study showed good internal consistency ($\alpha = 0.93$; $\omega = 0.94$).

2.2.3. Sociodemographic factors

The following sociodemographic factors were considered: sex, age (15–29, 30–44, 45–59, 60–79 years), income (low, <JPY2.5 million/US$25,000/£16,667; intermediate, JPY2.5–JPY4.3 million/US$25,000–US$43,000/£16,667–£28,667; high, <JPY4.3 million/<US$43,000/<£28,667; unknown/declined to answer), marital status (unmarried, married, and widowed/separated), education, working status (working, schooling, homemaker, not working), history of tobacco use, history of alcohol use, and presence of current illness (hypertension, diabetes mellitus, asthma or chronic obstructive pulmonary disease, cardiovascular disease, cerebrovascular disease, cancer, chronic pain, psychiatric disorders).

2.3. Statistical methods

First, an inverse probability weighting (IPW) method was used to correct for differences between Internet survey respondents and the general population. By logistic regression analysis, propensity scores (weights) were calculated using sex, age, and socioeconomic factors to correct for differences between respondents to the current Internet survey and respondents to the 2019 National Survey on Living Standards, which is representative of the Japanese population. Details of this calculation are described in our previous studies (Okubo et al., 2021a,b). Second, an individual's malleable beliefs are described on a spectrum, with malleable beliefs at one pole and fixed beliefs at the other pole (Dweck and Leggett, 1988); therefore, we trichotomized participants' beliefs as malleable (T1: total score from 4 to 10), neither (T2: total score from 11 to 12), or fixed (T3: total score from 13 to 20 scores), where high signifies a strong belief in emotion malleability. Implicit theories research explains belief effects by contrasting individuals who do believe in emotion malleability with those who do not (Dweck et al., 1995; Tamir et al., 2007). Finally, the association between emotion beliefs and SPD was clarified by calculating adjusted odds ratios (aORs) and 95% confidence intervals (CIs) for SPD by logistic regression analysis with IPW based on propensity scores. In these analyses, all variables noted above were entered into the model as independent variables. All analyses were performed using R software version 4.0.3.

3. Results

Of the 26,000 study participants, 2,858 were excluded for satisficing or straight-lining or discrepant survey responses (for example, respondents who chose inappropriate responses to the instruction "Please choose the second from the bottom of the following options." or respondents who answered "currently have this condition and receiving treatment" or "currently have this condition but not receiving treatment" (as opposed to "never in the past" or "not now, but had in the past") to all 16 questions regarding the following comorbidities). Thus, the analysis included data from 23,142 (89.0%) participants. The sociodemographic characteristics of the participants are shown in Table 1. Among 23,412 participants, the median total score for implicit beliefs about emotions was divided into tertiles,

1 https://in.m.aipsurveys.com

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TABLE 1 Participant characteristics (before and after propensity score weighting).

Variables	After weighting		Before weighting	
	n	%	*n*	%
Sex				
Male	11,766	50.8	11,766	50.8
Female	11,376	49.2	11,376	49.2
Age (years)				
15–29	3,448	14.9	3,476	15.0
30–44	5,255	22.7	5,330	23.0
45–59	6,711	29.0	6,614	28.6
≥60	7,728	33.4	7,722	33.4
Income (million JPY/year)				
Less than 1	841	3.6	898	3.9
1 to less than 6	10,699	46.2	10,310	44.6
6 to less than 12	5,433	23.5	5,938	25.7
12 or more	952	4.1	1,308	5.7
No response/unknown	5,217	22.5	4,688	20.3
Marital status				
Married	13,669	59.1	12,560	54.3
Never married	4,876	21.1	5,770	24.9
Widowed/divorced	4,596	19.9	4,812	20.8
Education				
Junior high school graduate	4,114	17.8	3,366	14.5
High school graduate	9,739	42.1	6,012	26.0
Junior college graduate	3,366	14.5	4,247	18.4
Bachelor's degree	4,315	18.7	8,576	37.1
Master's or doctoral degree	1,608	7.0	941	4.1
Living alone, yes	3,535	15.3	4,504	19.5
Working status				
Working	11,955	51.7	14,315	61.9
Schooling	2,246	9.7	1,275	5.5
Homemaker	4,358	18.8	3,800	16.4
Not working	4,334	18.7	3,752	16.2
Smoking status				
Never	11,955	51.7	12,709	54.9
Ever	9,188	39.7	8,731	37.7
Current	1999	8.6	1702	7.4
Alcohol use				
Never	4,111	17.8	3,791	16.4
Ever	7,373	31.9	7,379	31.9
Current	11,658	50.4	11,972	51.7
Current medical history				
Hypertension	4,490	19.4	4,359	18.8
Diabetes mellitus	1,628	7.0	1,467	6.3
Asthma or COPD	1,153	5.0	959	4.1
Cardiovascular disease	627	2.7	464	2.0
Cerebrovascular disease	260	1.1	222	1.0
Cancer	442	1.9	435	1.9
Chronic pain	2,330	10.1	1939	8.4
Psychiatric disorders	1,463	6.3	1,256	5.4
Severe Psychological Distress (K6 ≥ 13)	2,741	11.8	2,570	11.1

(Continued)

TABLE 1 (Continued)

COPD, chronic obstructive pulmonary disease; K6, Kessler Psychological Distress Scale.

namely, a malleable group (T1), an neither group (T2), and a fixed group (T3) with median total scores of 16, 12, and 10, respectively. The high group had 8,123 participants (35.1%), the middle group 11,465 participants (49.5%), and the fixed group 3,554 participants (15.4%).

Table 2 shows sociodemographic characteristics factors associated with emotion malleability beliefs. We found that female respondents had significantly fixed beliefs than male respondents (aOR = 1.31; 95% CI = 1.18–1.44, $p < 0.001$). Compared with people aged 45–59 years, those aged 29 years or younger (aOR = 1.24; 95% CI = 1.09–1.41, $p < 0.001$) and those aged 30–44 years (aOR = 1.16; 95% CI = 1.05–1.28, $p < 0.01$) had fixed beliefs, whereas those aged 60 years or older had malleable beliefs (aOR = 0.57; 95% CI = 0.51–0.65, $p < 0.001$). In terms of income, we found that compared with the group earning 1 million to 6 million yen, the group earning 6 million to 12 million yen had significantly fixed beliefs (aOR = 1.13; 95% CI = 1.02–1.24, $p < 0.05$), whereas the non-response group had significantly malleable beliefs (aOR = 0.85; 95% CI = 0.77–1.13, $p < 0.01$). As for marital status, never-married people had significantly fixed beliefs compared with married people (aOR = 1.13; 95% CI = 1.02–1.27, $p < 0.05$). Regarding educational background, compared with respondents with a bachelor's degree, junior high school graduates (aOR = 1.20, 95% CI = 1.04–1.39, $p < 0.05$) and high school graduates (aOR = 1.15, 95% CI = 1.04–1.28, $p < 0.01$) had significantly fixed beliefs, whereas those with a master's degree or above had significantly malleable beliefs (aOR = 0.22, 95% CI = 0.16–0.30, $p < 0.001$). Meanwhile, people living alone had significantly fixed beliefs than people living with others (aOR = 0.87, 95% CI = 0.77–0.98, $p < 0.05$). We found that emotion malleability beliefs were significantly fixed in ever-smokers (aOR = 1.20, 95% CI = 1.08–1.35, $p < 0.001$) and current smokers (aOR = 1.16, 95% CI = 1.04–1.30, $p < 0.01$) than in never-smokers. In terms of current medical history, people with hypertension (aOR = 1.19, 95% CI = 1.07–1.32, $p < 0.001$), diabetes (aOR = 1.21, 95% CI = 1.04–1.40, $p < 0.01$), chronic pain (aOR = 1.45, 95% CI = 1.29–1. 63, $p < 0.001$), or psychiatric disorders (aOR = 2.79, 95% CI = 2.46–3.16, $p < 0.001$) had significantly fixed beliefs, whereas people with cerebrovascular disease (aOR = 0.69, 95% CI = 0.48–0.98, $p < 0.05$) or cancer (aOR = 0.63, 95% CI = 0.44–1.82, $p < 0.01$) had significantly malleable beliefs.

Table 3 shows the relationship between fixed malleability beliefs and risk of SPD. The aORs for the association between these beliefs and SPD were higher in the neither group (aOR = 2.48, 95% CI = 2.18–2.83, trend $p < 0.001$) and fixed group (aOR = 7.55, 95% CI = 6.56–8.68, trend $p < 0.001$) than in the malleable group. For relationships between fixed beliefs and SPD by sociodemographic characteristic factors,

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TABLE 2 Association between sociodemographic characteristics and total scores of binarized (malleable + neither vs. ficed) emotion malleability beliefs.

Emotion malleability beliefs	Malleable + neither		Fixed			
Variables	*n*	%	*n*	%	aOR	95% CI
Sex						
Male	10,063	51.37	1,703	47.93	1.00	ref
Female	9,525	48.63	1,851	52.08	1.31***	(1.20–1.43)
Age (years)						
15–29	2,754	14.06	694	19.53	1.24***	(1.09–1.41)
30–44	4,276	21.83	980	27.56	1.16**	(1.05–1.28)
45–59	5,572	28.45	1,139	32.04	1.00	ref
≥60	6,986	35.67	742	20.87	0.57***	(0.51–0.65)
Income (million JPY/year)						
Less than 1	690	3.52	150	4.23	0.96	(0.79–1.17)
1 to less than 6	9,097	46.44	1,603	45.09	1.00	ref
6 to less than 12	4,484	22.89	950	26.73	1.13*	(1.02–1.24)
12 or more	824	4.21	128	3.59	0.82	(0.67–1.01)
No response/unknown	4,494	22.94	723	20.35	0.85**	(0.77–0.94)
Marital status						
Married	11,733	59.90	1,936	54.47	1.00	ref
Never married	3,995	20.40	881	24.79	1.13*	(1.01–1.27)
Widowed/divorced	3,859	19.70	737	20.75	0.99	(0.87–1.13)
Education						
Junior high school	3,401	17.36	713	20.08	1.20*	(1.04–1.39)
High school	8,152	41.62	1,586	44.63	1.15**	(1.04–1.28)
Junior college graduate	2,808	14.34	558	15.71	1.06	(0.93–1.21)
Bachelor's degree	3,672	18.75	642	18.08	1.00	ref
Master's or doctoral degree	1,555	7.94	54	1.51	0.22***	(0.16–0.30)
Living together (with one or more persons)	16,512	84.29	3,095	87.08	1.00	ref
Living alone	3,077	15.71	459	12.92	0.87*	(0.77–0.98)
Working status						
Working	10,139	51.76	1,816	51.11	1.02	(0.90–1.14)
Schooling	1,850	9.44	396	11.14	1.03	(0.83–1.29)
Homemaker	3,698	18.88	659	18.55	1.00	ref
Not working	3,790	19.35	544	15.31	1.16	(1.00–1.35)
Smoking status						
Never	10,139	51.76	1,816	51.11	1.00	ref
Ever	7,742	39.52	1,447	40.70	1.20***	(1.08–1.35)
Current	1,708	8.72	291	8.19	1.16**	(1.04–1.30)
Alcohol use						
Never	3,534	18.04	577	16.24	1.00	ref
Ever	6,100	31.14	1,272	35.80	1.02	(0.93–1.11)
Current	9,954	50.82	1,704	47.96	0.96	(0.83–1.11)
Current medical history						
Hypertension	3,817	19.49	674	18.95	1.19***	(1.07–1.32)
Diabetes mellitus	1,344	6.86	284	8.00	1.21**	(1.04–1.40)

(Continued)

TABLE 2 (Continued)

Emotion malleability beliefs	Malleable + neither		Fixed			
Variables	*n*	%	*n*	%	aOR	95% CI
Asthma or COPD	918	4.69	235	6.62	1.17	(0.99–1.38)
Cardiovascular disease	502	2.56	126	3.54	1.23	(0.96–1.57)
Cerebrovascular disease	212	1.08	48	1.34	0.69*	(0.48–0.98)
Cancer	372	1.90	70	1.97	0.63**	(0.46–0.84)
Chronic pain	1,835	9.37	495	13.93	1.45***	(1.29–1.63)
Psychiatric disorders	964	4.92	498	14.03	2.79***	(2.46–3.16)

COPD, chronic obstructive pulmonary disease; OR, odds ratio; CI, confidence interval.
aORs were adjusted for age, sex, income, marital status, education, living together, working status, use of combustible cigarettes or heated tobacco products, use of alcohol, current medical history. These were calculated by comparing the low emotional malleability beliefs group with the high and low groups. ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$ for each OR.

when compared with all participants, there was a strong association between fixed beliefs and SPD in the neither group (aOR = 3.69, 95% CI = 3.03–4.49, trend $p < 0.001$) and fixed group (aOR = 11.42, 95% CI = 9.27–14.08, trend $p < 0.001$) among females, the fixed group among those aged 45–59 years, and in the neither group (aOR = 8.81, 95% CI = 6.89–11.26, trend $p < 0.001$) and fixed group (aOR = 30.32, 95% CI = 14.56–64.05, trend $p < 0.001$) among those aged 60 years or older.

4. Discussion

This study aimed to examine differences in emotion malleability beliefs across sex, age, and socioeconomic factors and differences in the relative strength of the association between these beliefs and SPD across effect modifiers, such as sex and age, using a large general population sample. Logistic regression analysis revealed a significant association between fixed beliefs and female sex, younger age, lower education, unmarried status, nonemployment, smoking, and the presence of hypertension, diabetes, chronic pain, or psychiatric disorders. In addition, fixed beliefs were a risk factor for SPD, with the association stronger for female respondents and respondents aged 45 years or older than for all participants.

The proportion of respondents with high emotion malleability beliefs increased with age. This result is consistent with previous research showing that older adults exhibit more mature emotional processing and regulation strategies than younger adults (Lawton, 2001; Blanchard-Fields, 2007; Urry and Gross, 2010). Older adults are characterized by their ability to pay attention to positive aspects and to construct better evaluations when confronted with negative information (Charles and Luong, 2013). When compared with younger adults, older adults are reported to utilize more adaptive emotion regulation strategies, such as acceptance, and fewer maladaptive emotion regulation strategies during anxiety- and sadness-provoking situations (Schirda et al., 2016).

We found that female respondents had fixed beliefs than male. Although several studies have reported no sex differences in emotion malleability beliefs (Tamir et al., 2007; De Castella et al., 2013, 2018), all of these studies had small sample sizes ($n = 101–437$) and did not adjust for confounders such as educational background, income, and current illness. This is the first study to examine differences in the distribution of emotion malleability beliefs using a large sample (>10,000 people). Interestingly, the association between fixed beliefs and SPD was more than twice as strong in female respondents than in male respondents. This difference can be explained by sex differences in emotion regulation strategies that are strongly related to emotion malleability beliefs. Female tend to focus more attention on their emotions than do male and they engage in excessive rumination to understand their feelings and the causes of their emotions, resulting in emotion regulation failure (Nolen-Hoeksema, 2012). Meta-analyses found that female ruminate more frequently than male (Rood et al., 2009; Johnson and Whisman, 2013). Failure to regulate emotions reinforces the belief that emotions are uncontrollable. In addition, these differences in these beliefs between male and female may be partially explained by the influence of psychosocial development on sex differences. According to gender socialization theory, girls of a certain generation are expected to internalize negative emotions and display more empathy and sympathy than boys of a certain generation (Brody and Hall, 2008; Zahn-Waxler et al., 2008). Female may be affected by cultural pressures that promote the internalization of negative emotions and may develop the belief that controlling emotions is difficult.

Our finding that people with any psychiatric disorder have fixed beliefs than those without is consistent with previous studies showing fixed beliefs in patients with social anxiety disorder (De Castella et al., 2014) and depressive disorder (Sung et al., 2020) compared with healthy individuals. Our findings support the theory that people who believe that emotions are uncontrollable are less motivated to effectively regulate negative emotions and become increasingly symptomatic (Kneeland et al., 2016; Schroder, 2021). Studying individual differences in how people respond to their own emotions can help clarify the mechanisms underlying depression and anxiety disorders and elaborate psychological interventions (Campbell-Sills et al., 2007).

This study is the first to examine the association between physical illness and emotion malleability beliefs. Our results showed that people with hypertension, diabetes, and chronic pain had fixed beliefs. People with these illnesses have a high prevalence of depression. More specifically, the prevalence of depression is 21.3% in people with hypertension (Michal et al., 2013) and 30% in people with chronic pain (Miller and Cano, 2009; Rayner et al., 2016); and people with diabetes have a prevalence of depression 2–3 times that in the general adult population (Gavard et al., 1993; Roy and Lloyd, 2012). Emotion beliefs can partially explain the differences in the prevalence of depression between people with physical illness and healthy individuals. In addition, people with fixed emotion malleability beliefs

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TABLE 3 Odds ratio and 95% confidence intervals for severe psychological distress according to the trisect of the total score on emotion malleability beliefs (lower score = lower malleability).

	Malleable	Neither	Fixed	Trend *p*
Total score				
Median (min-max) score	8 (4–10)	12 (11–12)	14 (13–20)	
Number of cases/controls	337/7786	1299/10165	1104/2450	
Age, sex-adjusted OR (95% CI)	1.00 (ref)	2.40 (2.12–2.72)	8.12 (7.11–9.27)	***
Multivariate aOR (95% CI)	1.00 (ref)	2.48 (2.18–2.83)	7.55 (6.56–8.68)	***
Male				
Median (min-max) score	8 (4–10)	13 (12–11)	12 (13–20)	
Number of cases/controls	194/3593	611/5664	448/1256	
Age-adjusted OR (95% CI)	1.00 (ref)	1.72 (1.45–2.04)	5.74 (4.77–6.90)	***
Multivariate aOR (95% CI)	1.00 (ref)	1.66 (1.39–1.99)	5.23 (4.30–6.34)	***
Female				
Median (min-max) score	8 (4–10)	11 (12–12)	14 (13–20)	
Number of cases/controls	143/4192	689/4501	657/1194	
Age-adjusted OR (95% CI)	1.00 (ref)	3.55 (2.94–4.29)	12.26 (10.08–14.92)	***
Multivariate aOR (95% CI)	1.00 (ref)	3.69 (3.03–4.49)	11.42 (9.27–14.08)	***
Age				
Age 15–29 years				
Median (min-max) score	9 (4–11)	12 (12–12)	14 (13–20)	
Number of cases/controls	122/711	91/231	563/1729	
Sex-adjusted OR (95% CI)	1.00 (ref)	0.80 (0.66–0.98)	3.71 (3.00–4.58)	***
Multivariate aOR (95% CI)	1.00 (ref)	0.91 (0.73–1.13)	3.55 (2.83–4.46)	***
Age 30–44 years				
Median (min-max) score	9 (4–11)	12 (12–12)	14 (13–20)	
Number of cases/controls	89/1280	74/376	709/2728	
Adjusted OR (95% CI)	1.00 (ref)	1.68 (1.38–2.04)	5.87 (4.77–7.22)	***
Multivariate aOR (95% CI)	1.00 (ref)	1.74 (1.41–2.14)	5.16 (4.14–6.43)	***
Age 45–59 years				
Median (min-max) score	8 (4–10)	12 (11–12)	14 (13–20)	
Number of cases/controls	98/2071	368/3035	361/778	
Adjusted OR (95% CI)	1.00 (ref)	2.56 (2.04–3.22)	9.72 (7.67–12.33)	***
Multivariate aOR (95% CI)	1.00 (ref)	2.33 (1.84–2.95)	8.81 (6.89–11.26)	***
Age ≥ 60 years				
Median (min-max) score	7 (4–9)	12 (10–12)	14 (13–20)	
Number of cases/controls	9/2246	107/2215	149/3001	
Adjusted OR (95% CI)	1.00 (ref)	12.59 (6.92–22.90)	28.68 (15.20–54.10)	***
Multivariate aOR (95% CI)	1.00 (ref)	13.08 (6.58–26.02)	30.32 (14.36–64.05)	***
Education				
Junior high school				
Median (min-max) score	8 (4–10)	12 (11–12)	14 (13–20)	
Number of cases/controls	52/1186	253/1910	252/461	
Age, −adjusted OR (95% CI)	1.00 (ref)	2.69 (1.97–3.66)	10.25 (7.42–14.16)	***
Multivariate aOR (95% CI)	1.00 (ref)	2.16 (1.54–3.03)	7.75 (5.41–11.11)	***
High school				
Median (min-max) score	8 (4–10)	12 (11–12)	14 (13–20)	

(Continued)

TABLE 3 (Continued)

	Malleable	Neither	Fixed	Trend *p*
Number of cases/controls	139/2754	463/4797	463/1123	
Age, −adjusted OR (95% CI)	1.00 (ref)	1.55 (1.27–1.89)	6.74 (5.48–8.28)	***
Multivariate aOR (95% CI)	1.00 (ref)	1.46 (1.18–1.81)	5.92 (4.73–7.42)	***
Junior college graduate				
Median (min-max) score	8 (4–10)	12 (11–12)	14 (13–20)	
Number of cases/controls	44/1072	246/1445	165/394	
Age, −adjusted OR (95% CI)	1.00 (ref)	3.60 (2.58–5.02)	8.72 (6.11–12.45)	***
Multivariate aOR (95% CI)	1.00 (ref)	3.23 (2.24–4.64)	8.08 (5.47–11.92)	***
Bachelor's degree				
Median (min-max) score	8 (4–10)	12 (11–12)	14 (13–20)	
Number of cases/controls	91/1615	239/1727	207/435	
Age, −adjusted OR (95% CI)	1.00 (ref)	2.03 (1.58–2.62)	6.96 (5.29–9.16)	***
Multivariate aOR (95% CI)	1.00 (ref)	1.91 (1.44–2.53)	5.38 (3.96–7.31)	***
Master's or doctoral degree				
Median (min-max) score	7 (4–9)	12 (10–12)	14 (13–20)	
Number of cases/controls	3/747	83/511	39/226	
Age, −adjusted OR (95% CI)	1.00 (ref)	40.60 (12.54–131.45)	26.29 (7.63–90.56)	***
Multivariate aOR (95% CI)	1.00 (ref)	1.46 (1.18–1.81)	5.92 (4.73–7.42)	***
Without psychiatric disorders				
Median (min-max) score	8 (4–10)	12 (11–12)	14 (13–20)	
Number of cases/controls	296/7528	1023/9777	766/2289	
Age, −adjusted OR (95% CI)	1.00 (ref)	2.08 (1.82–2.38)	6.46 (5.58–7.47)	***
Multivariate aOR (95% CI)	1.00 (ref)	1.93 (1.67–2.23)	6.10 (5.21–7.13)	***
With psychiatric disorders				
Median (min-max) score	12 (4–12)	13 (13–13)	15 (14–20)	
Number of cases/controls	164/305	154/341	338/160	
Age, −adjusted OR (95% CI)	1.00 (ref)	2.28 (1.58–3.29)	5.83 (4.39–7.73)	***
Multivariate aOR (95% CI)	1.00 (ref)	2.46 (1.64–3.69)	7.57 (5.47–10.46)	***

OR, odds ratio; CI, confidence interval. aORs were adjusted for age, sex, income, marital status, education, living together, working status, use of combustible cigarettes or heated tobacco products, use of alcohol, current medical history. These were calculated by comparing the low emotional malleability beliefs group with the high and low groups. ***$p < 0.001$.

tend to prefer medication over psychotherapy (Schroder et al., 2015). Psychotherapy is reported to be effective in improving comorbid depression (Li et al., 2017, 2021; Ólason et al., 2018). Therefore, clinicians might first need to motivate their patients to believe in the malleability of their emotions to enhance their motivation for treatment before providing psychological intervention.

Interestingly, our results showed that cancer patients have high emotion malleability beliefs. Some researchers have proposed that more than two-thirds of adults cancer patients do not experience clinical anxiety or mood disorders (Mitchell et al., 2011Ólason et al., 2018 Linden et al., 2015) because most people can effectively regulate their emotions throughout the disease course (Kangas and Gross, 2020). Future research should investigate changes in emotion malleability beliefs throughout the course of cancer to gain a more detailed understanding of emotion regulation processes.

The association between fixed beliefs and SPD was stronger in older adults than in younger adults. One explanation is that mediators of the association between fixed beliefs and SPD differ between younger and older adults. For example, people with fixed beliefs are less likely to receive support from new friends (Tamir et al., 2007). Fifty-five percent of older adults experience moderate or greater loneliness and social isolation, which significantly reduces their mental health (Musich et al., 2015; Erzen and Çikrikci, 2018). Future research should examine factors such as loneliness that can specifically mediate these beliefs and SPD in older adults. Development of an education or intervention program that focuses on these mediators might be needed as well.

This study has several limitations that should be considered. First, the sample was collected through an Internet survey, which does not fully reflect the demographic distribution of the general population. Although we conducted weighted sampling utilizing nationally representative data to adjust for potential bias, it is possible that only people with a high affinity for Internet use participated in the survey. Second, this cross-sectional study cannot deny the reverse causation. For example, severe depression or anxiety might cause people to believe that their emotions are fixed. Finally, recent studies have

shown that beliefs about emotions are not only malleability but also include beliefs such as useful and unfriendly (Ford and Gross, 2019; Veilleux et al., 2021). The present study cannot exclude the possibility that other emotion beliefs may have a more important relationship with psychological distress.

In conclusion, we found that the beliefs that individuals hold about emotions are fixed was associated with female sex, younger age, lower educated, unmarried status, nonemployment, smoking, and hypertension, diabetes, chronic pain, and psychiatric disorders. Furthermore, the association between fixed beliefs and SPD was stronger in female respondents and the elderly. These results can be explained by differences in factors such as loneliness and emotion regulation strategies, which might mediate the association between emotion malleability beliefs and SPD. Future studies are needed to compare the strength of the association between emotion malleability beliefs and emotion regulation strategies, such as rumination, using simultaneous multi-population analyses to partially explain the 2–3 times higher risk of major depressive disorder in female compared with men (Van de Velde et al., 2010; Breslau et al., 2017). In addition, it would be beneficial to provide group education on emotion malleability beliefs and psychological distress in educational settings utilized by many young people with fixed beliefs. An intervention for middle school students was conducted with the aim of improving mental health by modifying these beliefs (Smith et al., 2018), and such intervention programs targeting emotion beliefs in young people should be further developed. Furthermore, people with fixed beliefs tend to be less motivated to engage in psychotherapy (Schroder et al., 2015), so it is important to measure emotion malleability beliefs when administering psychotherapy. Psychoeducation about the controllability of emotions prior to psychotherapy is a potentially beneficial clinical strategy for motivating patients with fixed beliefs to engage in evoke strong emotion techniques, such as exposure (Kneeland et al., 2016). Our research supports the possibility that the study of emotion malleability beliefs can contribute to the development of more tailored strategies and interventions to improve psychological health.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: all anonymized individual participant data reported in this paper are available for interested researchers who send a request for data sharing, along with a synopsis of the secondary analysis plan paper to the RO. Requests to access these datasets should be directed to RO, rokubo0425@gmail.com.

Ethics statement

The studies involving humans were approved by the Research Ethics Committee of the Osaka International Cancer Research Institute and the Research Ethics Committee of the Musashino University. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin because in accordance with national legislation and institutional requirements, written informed consent was not required for this study.

Author contributions

YS and RO performed the data analysis. YS, RO, and KS drafted the manuscript. RO and TT designed the survey and collected the data. All authors contributed to the manuscript and agreed to submit it for publication.

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Conflict of interest

SI has received honoraria for lectures from Boehringer Ingelheim Pharmaceuticals, Inc., H. Lundbeck A/S, Otsuka Pharmaceutical Co., Ltd., Sumitomo Pharma Co., Ltd., and Takeda Pharmaceutical Company Limited, has received support for attending meetings and/or travel from Boehringer Ingelheim Pharmaceuticals, Inc., H. Lundbeck A/S, and Takeda Pharmaceutical Company Limited, and has received consulting fees from Boehringer Ingelheim Pharmaceuticals, Inc.

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The relationship between self-control and mental health problems among Chinese university students

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Background: Mental health issues are often associated with poor self-control. Therefore, effective interventions against mental health problems should include self-control training. However, it is unclear whether the effect of self-control varies across different types of mental health problems.

Methods: A cross-sectional survey was conducted using the convenience sampling method at five universities in Chongqing, China, where 1,409 students reported their demographic information, level of self-control, and symptoms of irritability, depression, and anxiety. Descriptive statistical methods and a network analysis approach were employed to explore the relationship between self-control and symptoms of irritability, depression, and anxiety among 1,409 students. The bridging links between self-control and the three mental health problems were analyzed.

Results: The findings revealed a negative correlation between self-control and symptoms of irritability, depression, and anxiety among university students. Impulse control was found to be the bridge between self-control and irritability or anxiety symptoms, while resistance to temptation was the bridge between self-control and depressive symptoms.

Conclusion: These results demonstrate the different relationship between self-control with irritability, anxiety, and depressive symptoms. The findings of this study may shed light on future mental health interventions for university students during potential public health emergencies, such as prior knowledge of the main types of psychological problems among university students, which may allow for the development of precise self-control intervention strategies, such as targeting impulsivity or resistance to temptation.

KEYWORDS

college students, impulse control, resisting temptation, mental health, network analysis, depression, anxiety

1. Introduction

The outbreak of COVID-19 has severely affected social activities and economic development (1). In response to the pronounced contagiousness exhibited by the virus during its initial phases, coupled with the grave manifestations and elevated fatality rate associated with the infection (2–4), China adopted stricter measures against the epidemic: a major nationwide blockade. As a result, university students had to change their lifestyle, such as switching offline classes to online classes, undergoing social isolation, and reducing outdoor activities (5, 6), which affected their physical and mental health (7). It was found that the mental health of university students deteriorated during the COVID-19 epidemic, with the prevalence of depression increasing from 23.8% (8) before the epidemic to 26.0% (9) and that of anxiety from 20.79% (10) to 25.0% (11). Therefore, it is important to investigate the mental health level of university students and find potential self-interventions.

Irritability is commonly associated with depression and anxiety (12). Irritability is considered a temporary emotional state characterized by impatience, intolerance, and uncontrollable anger (13), which may lead to verbal or behavioral outbursts that elicit internal or external aggression. However, emotional manifestations may not be observed, and irritability is subjectively unpleasant, which can be short or prolonged (14, 15). The impact of irritability on adults is often overlooked by researchers, and in the DSM-5, irritability is defined as a cross-diagnostic symptom, involving multiple psychiatric disorders such as depression and anxiety (16). Research on the relationship between irritability and anxiety and depression yielded inconsistent results (17), with network analysis results demonstrating a co-morbid relationship between irritability, anxiety, and depressive symptoms, as well as their separation relationship (18). In particular, university students are more likely to exhibit irritability symptoms when depressed or anxious (19). As a favorable predictor of future mental disorders (e.g., depression, anxiety) (20), irritability needs to be included in more empirical studies on the mental health of university students to promote their overall mental health level.

Research related to self-control has attracted increasing attention from researchers in recent years (21), often involving the integration of disciplines such as social and behavioral sciences. Self-control is considered to be an umbrella structure involving concepts of different disciplines, such as impulsivity, responsibility, self-regulation, executive function, and other cognitive domains that play an important role in adaptation to society (22). Self-control is reflected in different situations, such as holding back anger and showing patience with others or refusing to smoke or drink for physical health, in which people manage to reduce the internal struggle associated with self-control. For example, people tend to convince themselves that drinking a little alcohol on birthdays will not affect their health, which often makes self-control difficult (23). Self-control is often associated with mental health. Research has found that extreme tendencies to exert over- and under-control are associated with higher levels of depression, while anxiety symptoms increase with under-control (24). Levels of self-control can act as a more stable predictor of an individual's mental health than depressive or anxiety symptoms that are more easily influenced by mood (25). Self-control is a protective factor in mental health (26), and according to the process model of ego depletion, performing self-control leads to a shift in motivation and attention, which increases positive emotional responses (27). Thus, self-control is a trainable and beneficial social competence (28). Considering the significant influence of self-control on mental health and the potential decline in self-control among university students during periods of isolation resulting from a lack of discipline (29), comprehending the interconnectedness between self-control and mental health within this demographic can effectively support the advancement of pertinent interventions.

As the mental health of university students during the COVID-19 epidemic is not promising, self-control training during isolation may need to be developed to help improve their mental health. Given irritability and anxiety symptoms play a more important role in the irritability, depression, and anxiety network compared with depressive symptoms (18), this study aimed to explore the bridging connections of self-control abilities with irritability, depression, and anxiety symptoms, respectively, through a network analysis approach. We hypothesized that (1) self-control is negatively correlated with irritability, depression, and anxiety symptoms; and (2) self-control is consistent with bridge symptoms in the irritability and anxiety networks while inconsistent in the depression network.

2. Methods

2.1. Participants

The present study utilized an online cross-sectional survey to collect data, which was conducted through the Questionnaire Star platform (www.wjx.cn) between 9 March 2020 and 12 March 2020. A convenience sampling method was adopted. The survey was uploaded onto the platform initially, and a QR code was, then, generated and disseminated to counselors from five universities and various social media platforms, including WeChat, Weibo, and QQ. The college counselors were asked to forward the survey QRs to the students in their charge, explain the purpose of the survey to the students, and require the students to voluntarily fill out the questionnaire. Only participants who were verified as university students were eligible to complete the survey. Before the survey, participants were informed about the purpose of the study and were required to provide their consent to participate. All survey questions were mandatory, and participants were randomly remunerated with 1–5 RMB for their participation. This study has been reviewed and approved by the Medical Ethics Committee of the Army Medical University (Project No. CWS20J007).

A total of 1,554 university students participated in the survey. Given the length of the questionnaire, which consisted of 48 items, participants were instructed to spend approximately 5 s on each question and the instructions, and a minimum completion time threshold of 300 s was set to ensure data accuracy. Consequently, after the exclusion of 145 participants who completed the survey in less than 300 s or were younger than 18 years (as minors in China) from the analysis, a final sample size of 1,409 participants was included. The validity of the survey was determined to be 90.67%.

2.2. Measurement tools

In this study, mental health problems among university students were assessed using the Irritability, Depression, and Anxiety Scale

(IDA) developed by Snaith et al. (13). The IDA consists of four dimensions, namely, inward irritability, outward irritability, depression, and anxiety and includes 18 entries that are scored using a four-point Likert scale. The reliability and validity of the scale were previously established by Wilson et al. (30). In the current study, Cronbach's α for the Chinese version of IDA was 0.846; McDonald's ω was 0.852.

Based on the Self-Control Scale (SCS) developed by Tangney et al. (31), we used a revised Chinese version of the scale (32) to measure the self-control of the university students. The revised scale contained 19 questions that can be divided into five dimensions, namely, impulse control, healthy habits, resistance to temptation, work or study performance, and moderation from recreation. A five-point Likert scale was used, with 1 representing complete non-compliance and 5 representing complete compliance. The scale has good reliability, Cronbach's α of the scale was 0.884, and McDonald's ω was 0.886 in the current study.

2.3. Data analysis

In this study, mental health problems were categorized into three separate clusters including irritability, depression, and anxiety. The structure of irritability and self-control (IS), depression, and self-control (DS), and anxiety and self-control (AS) was estimated using the Graphical LASSO network method for undirected network estimation. Since the survey data were rank data, the networks were estimated based on Spearman rho correlation. To ensure that the networks were sparse and stable, the graphical Least Absolute Shrinkage and Selection Operator (LASSO) algorithm was used to eliminate spurious edges (33, 34). We set the Extended Bayesian Information Criterion (EBIC) hyperparameter γ at 0.5 to ensure the sensitivity and specificity of the network (33). The qgraph package was used to visualize three networks in which nodes represented dimensions of symptoms or self-control and edges represented regularized biased correlations between two nodes. Red edges indicate negative correlations, whereas blue edges indicate positive correlations and thicker edges indicate stronger relationships.

In the present study, the analysis of bridge nodes was conducted in two separate pre-defined communities, one including the five dimensions of self-control and the other including psychiatric symptoms (irritability symptoms, depressive symptoms, and anxiety symptoms). Bridge expected influence (BEI) values were calculated through the R package network tools (35) and were used to identify bridge nodes in both communities. The bridge expected influence referred to the sum of the edge weights of all nodes of a node connected to another community, and higher values of bridge expected influence indicated a higher likelihood of activation to the other community (35, 36).

The stability and accuracy of the network were calculated using the R package bootnet (37). The accuracy of each edge in the network was assessed by a 95% confidence interval (CI) of the edge weights (nboot = 2,000). Bridge expected influence stability was calculated by case-dropping bootstrap (nboot = 2,000) approach to calculate the correlation stability (CS) coefficient; CS coefficient represents the correlation between the original and subsample indices that remains at least 0.70 (95% of probability), and the maximum percentage of case data can be excluded. According to the recommendations, the ideal CS coefficient should be above 0.5 and not below 0.25 (37). The bootstrapped difference test was also used to determine the difference between edge and bridge nodes (38).

Finally, to assess the impact of gender as a potential confounding variable on the networks, we used the Network Comparison Test (39) to compare the gender variable in three networks. Comparison metrics included global strength and network structure differences (40).

3. Results

3.1. Descriptive statistics

In the present study, 1,409 university students were evaluated, of whom 326 (23.14%) were men. The participants' ages ranged from 18 to 23 years, with a mean age of 20.14 ± 1.46 years (see Table 1). The total scores of all variables were significantly correlated (see Supplementary Table S1).

3.2. Irritability and self-control network analysis

The network structures of IS are presented in Figure 1A. Out of the 78 edges with possible connections, 61 exhibited non-zero values (78.21%). The edges that demonstrated the strongest connections within the IS network were IR1-IR2 (weight = 0.35), F3-F4 (weight = 0.34), and F1-F5 (weight = 0.33), ranking in descending order. With the exception of SC2-IR1, which displayed a positive correlation (weight = 0.03), all other linked edges exhibited a negative correlation (weight ranged from 0.00018 to 0.18) in both communities. The relatively narrow bootstrapped 95% confidence interval provided credibility to the accuracy of the IS network edges

TABLE 1 The descriptive statistics of the participants (*N* = 1,409).

Variables	*n*(%)/*M* (SD)
Gender	
Male	326 (23.14)
Female	1,083 (76.86)
Age (years)	20.14 (1.46)
Grade	
Freshman	609 (43.22)
Sophomore	382 (27.11)
Junior	339 (24.06)
Senior	79 (5.61)
Majors	
Liberal arts	871 (61.82)
Science	538 (38.18)
Internet at home	
Yes	1,219 (86.52)
No	190 (13.58)

Age is the mean and standard deviation, the others are frequencies and ratios.

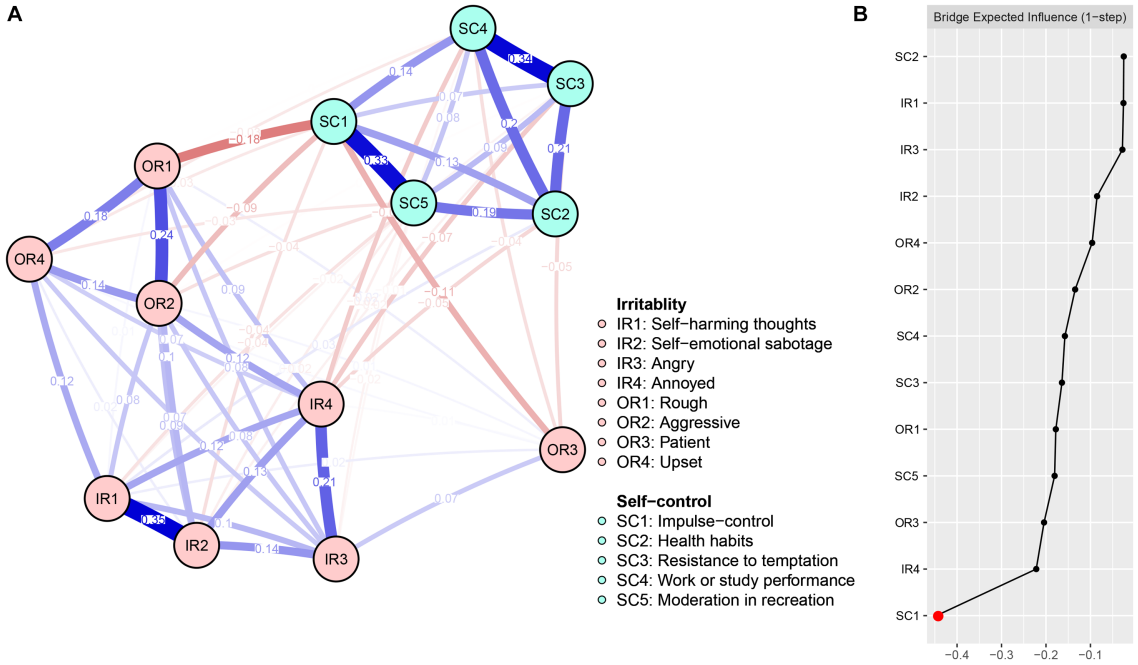

FIGURE 1
Network structure **(A)** and bridge expected influence **(B)** of IS among university students.

(Supplementary Figure S1). The present network edge weight CS coefficient achieved 0.75, exceeding the recommended value of 0.5 (37). Supplementary Figure S2 illustrates the bootstrapped difference test for edge weights.

Figure 1B shows the centrality of the IS network bridge expected influence. Among the IS network, Node SC1 (BEI = −0.44) demonstrated the lowest bridge expected influence value. The correlation stability coefficient of 0.75 for the bridge expected influence is presented in Supplementary Figure S3, indicating an acceptable level of stability. The bootstrapped difference test for the node's bridge expected influence is displayed in Supplementary Figure S4.

3.3. Depression and self-control network analysis

The network structures of DS are illustrated in Figure 2A, showing that among the 45 edges connecting the nodes, 80% (36) were non-zero. The DS network displayed the highest strengths for edges F1-F5 (weight = 0.38), D1-D3 (weight = 0.37), and F3-F4 (weight = 0.35), ranging in descending order. The association between all dimensions of self-control and depressive symptoms was negative (weight range: 0.005–0.073). The DS network edges were accurate, with relatively narrow bootstrapped 95% CI (Supplementary Figure S5). The current network edge weight CS coefficient was 0.75, surpassing the recommended value of 0.5 (37). The bootstrapped difference test for edge weights is displayed in Supplementary Figure S6.

Figure 2B shows the centrality of the DS network bridge expected influence. Node SC3 (BEI = −0.22) exhibited the lowest bridge expected influence among nodes in the self-control community. The correlation stability coefficient of the bridge expected influence was 0.44 (refer to Supplementary Figure S7), indicating that the bridge expected influence was acceptably stable. The bootstrapped difference test for node bridge expected influence is presented in Supplementary Figure S8.

3.4. Anxiety and self-control network analysis

The network structures of AS are presented in Figure 3A, with 37 out of 45 possible edges (82.22%) being non-zero. The edges with the highest connections in the AS network were A3-A4 (weight = 0.40), F1-F5 (weight = 0.37), and F3-F4 (weight = 0.35), ranking in descending order. The association between all dimensions of self-control and anxiety symptoms was found to be negative, with the weight ranging from 0.006 to 0.092. Additionally, the AS network edges were accurate, with relatively narrow bootstrapped 95% confidence intervals (refer to Supplementary Figure S9). The current network edge weight CS coefficient was 0.75, exceeding the recommended value of 0.5 (37). The bootstrapped difference test for edge weights is illustrated in Supplementary Figure S10.

Figure 3B displays the centrality of the AS network bridge expected influence. Among the nodes in the AS network, SC1 (BEI = −0.29) exhibited the lowest expected influence. The stability coefficient for the correlation of the bridge expected influence was 0.60 (refer to Supplementary Figure S11), indicating that the bridge expected influence was adequately stable. The bootstrapped difference test for node bridge expected influence is presented in Supplementary Figure S12.

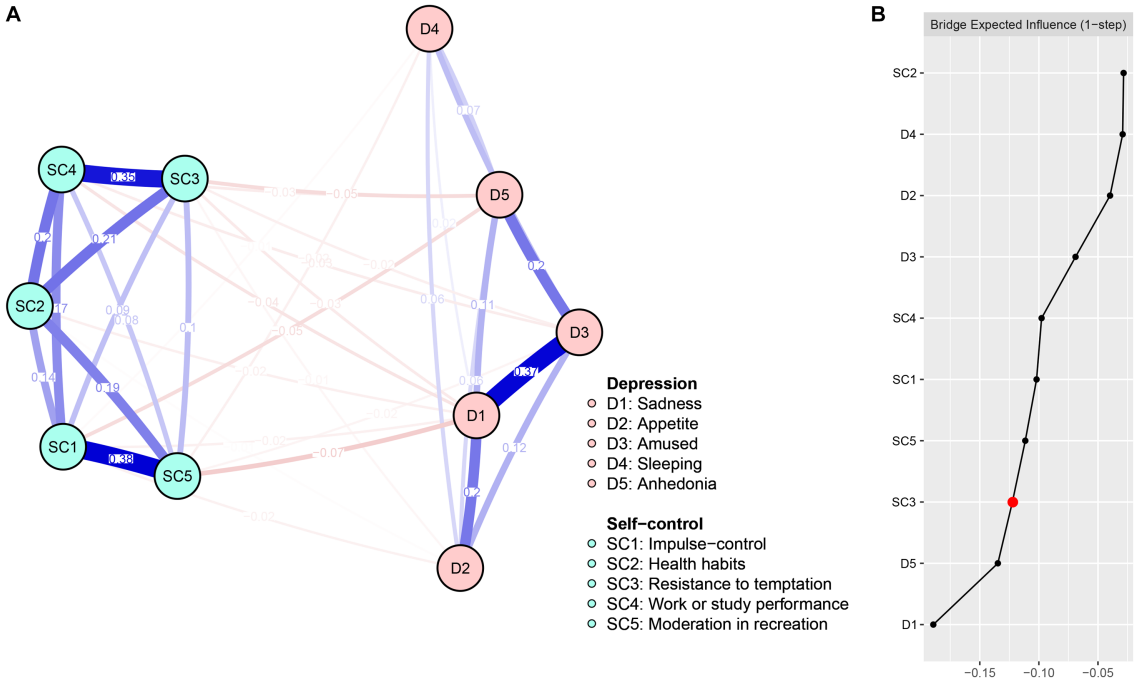

FIGURE 2
Network structure **(A)** and bridge expected influence **(B)** of DS among university students.

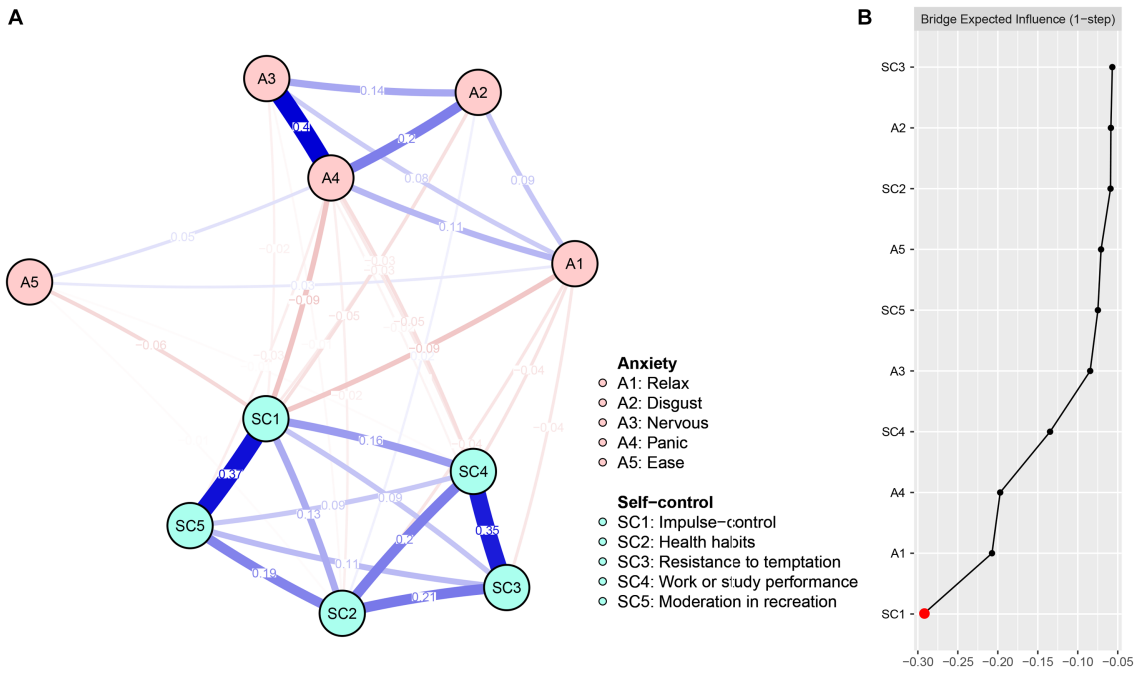

FIGURE 3
Network structure **(A)** and bridge expected influence **(B)** of AS among university students.

The results of the comparative network analyses showed that there were no significant differences regarding gender variables among the three networks (irritability and self-control network: $M = 0.16$, $p > 0.05$; $S = 0.03$, $p > 0.05$; depression and self-control network: $M = 0.11$, $p > 0.05$; $S = 0.13$, $p > 0.05$; and anxiety and self-control network: $M = 0.13$, $p > 0.05$; $S = 0.28$, $p > 0.05$). The results suggest that the gender variable is not a potential confounding variable influencing the network.

4. Discussion

The quarantine during the COVID-19 epidemic forced a rapid shift in the way university students live and study (41), leading to social isolation, increased anxiety, and depression (42). Self-control may be compromised because of campus closures, which resulted in a shift from offline to online courses, a change in study locations from classroom to home, and a lack of proper supervision. The current study investigated the interrelationship between self-control and symptoms of irritability, depression, and anxiety among university students during COVID-19 isolation. In general, self-control is related to irritability and anxiety symptoms in a similar way while related to depressive symptoms in a different way, and attention should be paid to the identification of these relationships when conducting interventions.

In the three networks constructed, the correlations of self-control with irritability, depression, and anxiety symptoms were overall negative, except for a positive correlation of SC2 (healthy habits)-IR1 (self-harm thoughts). These results are generally consistent with those of the previous research in which self-control is negatively correlated with depression and anxiety (43, 44). The findings support self-control training as a potential way to intervene in psychological problems. There are two potential explanations for the observed positive correlation between SC2 and IR1. On the one hand, COVID-19 isolation disrupts pre-existing habits, affecting adherence to healthy habits, such as getting up early, and leads to the development of bad habits, such as staying in bed during home isolation (45, 46). On the other hand, decreased self-control increases unhealthy activities of university students, such as internet or smartphone addiction, reduced study motivation, and other behaviors that can easily lead to guilt and self-harm thoughts. These two aspects become unstable during COVID-19 isolation, which may blur the SC2-IR1 relationship, based on a weaker marginal weight (weight = 0.03) that may support this idea. However, further studies in different scenarios are still needed to determine the real relationship.

The bridge linkage analysis showed that node SC1 (impulse control) was connected to irritability and anxiety symptoms as the bridge node with the strongest self-control, supporting our first study hypothesis. Notably, many studies have shown that irritability predicts depression and generalized anxiety disorder (47–49). Our results reveal that irritability is similar to anxiety symptoms rather than depressive symptoms at a symptom level. In the DSM-5, irritability is described as a symptom of generalized anxiety disorder, and persistent irritability is present in 90% of patients with generalized anxiety disorder seeking treatment (50). Studies have shown that abnormalities in the amygdala-prefrontal-parietal circuitry in young adults underlie the neurological coexistence of anxiety and irritability (51). This evidence indicates a greater resemblance in the clinical manifestation and physiological attributes of anxiety and irritability. However, it should be noted that the current study investigated depressive symptoms as generalized depressive symptoms rather than distinguishing subtypes of depressive symptoms, such as manic depression or disruptive mood dysregulation disorder that was shown to be significantly associated with irritability (52). Future research is needed to further confirm the relationship between provocation and different subtypes of depression.

Impulse control disorder (ICD), which usually manifests as difficulty controlling emotions and behaviors (53), is prevalent among university students and has a high prevalence (10.4%) (54). The study has demonstrated a significant correlation between impulse control disorders and irritability. Irritability, a multifaceted issue, is regarded as a physiologically induced emotional complex marked by heightened sensitivity to sensory stimuli and a simultaneous reduction in thresholds, not primarily influenced by cognitive processes. This condition frequently manifests as angry or aggressive responses to stimuli that are typically less bothersome and is directly linked to physiological or biological factors such as hunger, sleep deprivation, and chronic physical isolation (55). Previous research has found that emotion-driven impulsive control plays a potential role in reducing aggression, particularly aggression that exhibits angry and impulsive responses to perceived acute stress (56, 57). Given the comorbidity of irritability and anxiety (58), impulse control may similarly reduce anxiety levels. Research suggests that greater effort of control is associated with lower anxiety, possibly due to the ability of greater control effort to distract the anxious person from "slowing down" and objectively interpreting internal experiences or suppressing inaccurate thoughts about anxiety-related feelings (59). This evidence suggests that impulse control may be one way to reduce irritability and anxiety symptoms and that interventions of cognitive and behavioral training (CBT) (60) and self-control training (SCT) (61) may be considered for coping with irritability and anxiety in university students.

One view is that trait self-control is not usually achieved through efforts to resist temptation but rather a healthy habit that keeps individuals less tempted from straying away from their goals (62). Research suggests that when self-control is low, people are more likely to develop unhealthy behaviors such as smoking, excessive alcohol consumption (63), and internet addiction (64). In contrast, our study suggests that self-control is primarily linked to depressive symptoms through resisting temptation (a bridge node between self-control and depressive symptoms) rather than healthy habits, and the degree and type of temptation may affect this linkage (65). Taken together, these findings may explain the negative correlation between self-control and depressive symptoms. The mechanism underlying this correlation is that more exposure to temptations because of bad habits makes individuals fail to fulfill their goals, leading to depressive symptoms. For example, university students suffer from sleep problems due to internet addiction, causing depressive symptoms (66–68). Therefore, we emphasize the role of resistance to temptation in depression and found the strongest negative correlation between resistance to temptation and anhedonia. Many temptations may lead to addiction, such as the temptation of money leading to gambling addiction, the temptation of surfing online leading to internet addiction, and the temptation of alcohol leading to alcohol addiction. These addictive behaviors will cause euphoria in individuals, and withdrawal from addiction will lead to anhedonia (69). Therefore, we suggest that university students should first develop good habits, such as staying away from tempting stimuli such as alcohol and tobacco, and trying to resist temptation when faced with it. In addition, studies have shown that positive emotions can increase resistance to temptation when temptation activates long-term health goals (70). On the one hand, positive emotions can promote resistance to temptation; on the other hand, positive emotions can directly alleviate depressive symptoms. The above results suggest that developing positive emotion regulatory preferences in university students (71) may have an enhancing effect on resistance to temptation and depressive symptoms.

There are two limitations in this current study. First, the data were collected from university students isolated during the COVID-19

epidemic. As isolation may affect the self-control of university students, it is unclear whether the findings can be generalized to the current non-isolated university students, and future research should examine the relationship between self-control and psychological symptoms among non-isolated university students. In addition, as the university students were selected as participants through convenience sampling methods, the results should be interpreted with caution when generalized to other groups. Future studies should include adolescents and adults. Moreover, this study adopted a cross-sectional survey, and we did not use a double sample or conduct experimental validation of the bridge node. Future research should consider the use of longitudinal research design and multi-sample analysis or the use of experimental validation of the effectiveness of the core objectives of the intervention.

5. Conclusion

Our research sheds light on the complex relationship between self-control and mental health problems by demonstrating that controlling impulses is a protective factor against irritability and anxiety symptoms, and resisting temptation is a protective factor against depressive symptoms. Our findings suggest that self-control interventions among university students isolated during public health emergencies could target impulse control (for irritability and anxiety symptoms) and resisting temptation (for depressive symptoms). For future intervention, the types of mental health problems among university students need to be assessed first to determine the targeted intervention goals. In conclusion, future research should focus on the effectiveness of self-control as a target for intervention, such as the effectiveness of self-control training (working memory training or episodic future thinking) in reducing mental health problems among university students.

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 authors.

Ethics statement

The studies involving humans were approved by Medical Ethics Committee of the Army Medical University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

MH, XZ, KL, and XL contributed to the conception and design of the study. XJ and LL organized the database. LR and KL performed the statistical analysis. MH, XZ, and KL wrote the first draft of the manuscript. CL, LR, KL, and XL wrote sections 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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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1224427/full#supplementary-material

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Changes in mental health among Chinese university students before and during campus lockdowns due to the COVID-19 pandemic: a three-wave longitudinal study

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The campus lockdown due to the COVID-19 pandemic has adversely affected mental health among university students. However, the heterogeneity in responses to campus lockdown is still poorly known. We collected three-wave prospective data on university students' mental health in Shanghai, China, in 2022: (i) in February before the pandemic; (ii) in April at the initial COVID-19 campus lockdown; and (iii) in May amidst the citywide lockdown. Overall, 205 university students completed sociodemographic questionnaires, the General Health Questionnaire-12 items (GHQ-12), and the Depression, Anxiety and Stress Scale-21 items (DASS-21). Generalized estimating equations were used to examine the longitudinal changes in mental health and symptoms of depression, anxiety, and stress. Latent class mixed models (LCMM) were constructed to identify distinct trajectories. Multinomial regression models were used to identify factors associated with status variation patterns. Mean GHQ-12 scores were 8.49, 9.66, and 11.26 at pre-pandemic and lockdown T1 and T2, respectively (p<0.001). Mean scores for depression, anxiety, and stress were (5.96, 10.36, and 8.06, p<0.001), (7.13, 6.67, and 7.16, p=0.243), and (9.83, 7.28, and 11.43, p<0.001), respectively. Changing trends of numbers of participants with clinical symptoms were consistent with those of mean scores. LCMM fitted three distinct trajectory classes, respectively, for GHQ-12, depression and anxiety symptoms, and four classes for stress symptoms. Participants with fair or poor peer relationships were more likely to belong to vulnerable trajectories concerning depression, anxiety, and stress symptoms. This study proves heterogeneity in mental health of university students in response to pandemic campus lockdown and highlights the necessity for identifying vulnerable groups to provide targeted support in future pandemics.

KEYWORDS

COVID-19, campus lockdown, mental health, university students, longitudinal study

Introduction

Since the World Health Organization (WHO) declared the outbreak of the SARS-CoV-2 coronavirus (COVID-19) a pandemic on 11 March 2020, the virus and consequent lockdown measures have negatively affected public mental health. Among the general population, university students were at a higher risk for mental distress during the COVID-19 pandemic

(1–6) and appeared particularly susceptible to the adverse impacts of campus lockdown (7, 8), leading to significant changes in students' lives, such as social isolation, uncertainty about the professional and academic career, and financial constraints (9–12).

The evolution of the COVID-19 pandemic is undetermined and may have long-term effects on mental health. Recent evidence has shown that psychological responses to the COVID-19 pandemic are heterogeneous (13, 14). Nevertheless, whether mental health responses to the pandemic lockdown among university students are heterogeneous remains to be clarified, which has limited our understanding of the specific effect of the campus lockdown due to the pandemic on mental health. Although extensive cross-sectional studies worldwide have shown deteriorating mental health, elevated symptoms of depression, anxiety, and stress among university students during the COVID-19 crisis (1, 15–17), there is still a lack of longitudinal data comparing the same populations before and during the pandemic lockdowns, making it difficult to interpret the exact changes in mental health among university students in response to the COVID-19 lockdowns. A few longitudinal studies have demonstrated worsened symptoms of depression, anxiety, and stress among university students before and during the COVID-19 lockdown (18), whereas others have reported relatively unchanged mental health (19), or only deterioration in depression but not anxiety (20) or increased symptoms for anxiety but not for depression (21). These findings have implied that responses to the COVID-19 lockdown are heterogeneous, not homogeneous, among university students. Accordingly, identifying subgroups of students with different trajectories of change in mental health to provide them with efficient help and intervention is needed.

Notably, studies on the distinct trajectories of mental health conditions before and across different lockdown phases among university students are still lacking. Further, exploring the sociodemographic factors involved in the distinct trajectories of mental health status is also warranted to identify university students more vulnerable to the adverse effects of the COVID-19 crisis and supply key targets for interventions.

Hence, we conducted a study of the evolution of mental health and emotional well-being among university students over the two lockdown phases in Shanghai, using a pre-pandemic cohort to overcome the scarcity of longitudinal studies including pre-pandemic data. This study aimed to investigate longitudinal changes in mental health among university students before and during the COVID-19 pandemic, identify the potential distinct trajectories of general mental health and symptoms for depression, anxiety, and stress, and explore the associations between sociodemographic factors and mental health trajectory classes.

Methods

Study design and data collection

Data were collected as part of a longitudinal survey study investigating university students' mental health, belonging to the Participation in Research Program of Shanghai Jiao Tong University (SJTU) (No. T080PRP41017). The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. Participants were recruited from SJTU students through online advertisements using convenience sampling method. A three-wave online survey was used to assess the effect of the campus lockdown due to the COVID-19 pandemic on the general mental health and emotional well-being of university students.

The first wave of data was collected on 26–27 February 2022 (baseline pre-pandemic data) with 228 participants completing surveys; the second wave on 8–13 April 2022 (lockdown T1) with 227 participants completing surveys, when campus lockdown measures had been introduced for approximately 4 weeks at SJTU and Shanghai had implemented citywide quarantine measures for around 1 week; the third wave on 21–27 May 2022 (lockdown T2) with 213 participants completing surveys, when SJTU had been locked down for over 10 weeks and Shanghai began to ease the quarantine measures. A total of 205 participants completed three-wave data collection.

Measures

Sociodemographic information

Sociodemographic characteristics including age, gender, height, weight, major, grade, family residence, number of children in the family, parents' education level, annual household income, and smoking and drinking habits, were collected. Additionally, self-reported peer relationships were also recorded with a score of 0–10.

Mental health outcomes

The General Health Questionnaire-12 items (GHQ-12) (22), validated within a Chinese population (23), was employed to assess the recent mental health status of university students. Each item is graded on a 0 to 4 Likert scale: 0, not at all; 1, no more than usual; 2, rather more than usual; or 3, much more than usual. A total score derived for each wave is calculated as the sum of each item, ranging from 0 to 36, and a score of >15 is considered to experience psychosocial malaise (24). In addition to the total score used to generate a mean score, a bimodal GHQ scoring method (0–0–1–1) is derived to identify those reporting clinical mental distress with a threshold $\geq$4. Cronbach's alpha of the measure is 0.862.

The Depression, Anxiety, and Stress Scale-21 items (DASS-21) (25), validated within Chinese university student populations (26, 27), measured the emotional well-being of university students. This scale comprises 21 items grouped into three subscales: depression, anxiety, and stress. Each item is rated on a 4-point Likert scale: 0, never; 1, sometimes; 2, often; 3, almost always. Each subscale contains 7 items, and a total subscale score, ranging from 0 to 42, is calculated by summing the scores of the relevant items and then multiplying the sum by 2. Scores of >9, > 7, and > 14 are considered to represent depression, anxiety, and stress symptoms, respectively. The corresponding Cronbach's alpha of the measure is 0.805, 0.712, and 0.790, respectively.

Sample size

The sample size was determined based on a previous prospective longitudinal study that investigated the impact of the COVID-19 outbreak on the mental health of undergraduate students, where the authors employed the DASS-21 to assess variations in depression, anxiety, and stress scores (21). To detect an effect size of 0.8 at a significance level of 5% with 80% statistical power, assuming a

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standard deviation of 7.86, a minimum of 121 participants was required.

Statistical analysis

The Shapiro–Wilk test was performed to examine the normality of continuous variables. A Chi–Square test was conducted to compare categorical variables in mental health-related characteristics among three waves. Generalized estimating equations (GEEs) were performed to analyze three-wave longitudinal data of GHQ-12 and DASS-21 to determine the effect of campus lockdown due to COVID-19 pandemic on mental health. GEEs were selected due to their capacity for population-averaged inference, ability to model non-Gaussian distributions, and consideration of within-subject correlation. Latent class mixed models (LCMM) were constructed to identify distinct trajectories of GHQ-12 and DASS-21 depression, anxiety, and stress symptoms before and during the pandemic lockdowns using the R "lcmm" package (28). These models included fixed effects for time and discrete random variables for the latent classes and were fitted with one to 5 latent classes. Each model with two or more classes used random starting values from the model with the 1-class and a grid search function with 50 iterations was used to avoid the model identifying local maxima. Model fit was determined using the Bayesian information criterion (BIC), the sample size-adjusted Bayesian information criterion (SABIC), a measure of entropy, higher posterior probabilities of class membership, and interpretability. Besides, the results for LCMM followed the Guidelines for Reporting on Latent Trajectory Studies (29). Multinomial regression models were fitted to investigate associations between sociodemographic characteristics and distinct trajectories of each health outcome, and the adjusted odds ratio (aOR) and 95% confidence interval (CI) were used to represent the potential correlations. A $p < 0.05$ was considered statistically significant. All analyses were performed using R 4.1.0.

Results

Descriptive statistics

In total, this study included 205 university students (mean age = 19.4 years) who had data available for all three phases (pre-lockdown, lockdown T1, and lockdown T2). Among these participants, 97 were female, 179 were undergraduates, and 107 were majoring in engineering. Detailed sociodemographic characteristics are summarized in Table 1.

Figure 1 and Table 2 show the descriptions of mental health outcomes before the pandemic and during lockdowns T1 and T2. Mean GHQ-12 scores progressively increased in a stepwise manner from pre-pandemic (8.49) to lockdown T1 (9.66) to T2 (11.26) (Figure 1A), suggesting that the mental health status of university students worsened in response to campus lockdowns amid the COVID-19 pandemic. Furthermore, the mean DASS-21 depression scores improved sharply from 5.96 during the pre-pandemic period to 10.36 at lockdown T1 but declined to 8.06 at lockdown T2 (Figure 1B). In contrast, the mean DASS-21 stress scores decreased

TABLE 1 Demographic characteristics of the study population.

Variables	N (%)
Students	205 (100)
Gender	
Male	108 (52.68)
Female	97 (47.32)
BMI	
Underweight ≤18.5	25 (12.20)
Normal weight 18.5–24.9	157 (76.59)
Overweight 25–29.9	21 (10.24)
Obesity ≥30	2 (0.97)
Smoking habits	
Yes	1 (0.49)
No	204 (99.51)
Drinking habits	
Yes	184 (89.76)
No	21 (10.24)
Grade	
Undergraduate	179 (87.32)
Postgraduate	26 (12.68)
Major	
Engineering	107 (52.20)
Liberal arts	14 (6.83)
Science	63 (30.73)
Medicine	21 (10.24)
Family residence	
North	80 (39.02)
South	125 (60.98)
Only-child family	
Yes	134 (65.37)
No	71 (34.63)
Peer relationships	
Poor 0–3	4 (1.95)
Fair 4–7	89 (43.42)
Good 8–10	112 (54.63)
Father's education level	
Junior high school or below	43 (20.98)
High school	44 (21.46)
College or above	118 (57.66)
Mother's education level	
Junior high school or below	45 (21.95)
High School	58 (28.29)
College or above	102 (49.76)
Annual household income (CNY)	
<80,000	44 (21.46)
80,000–300,000	124 (60.49)
>300,000	37 (18.05)

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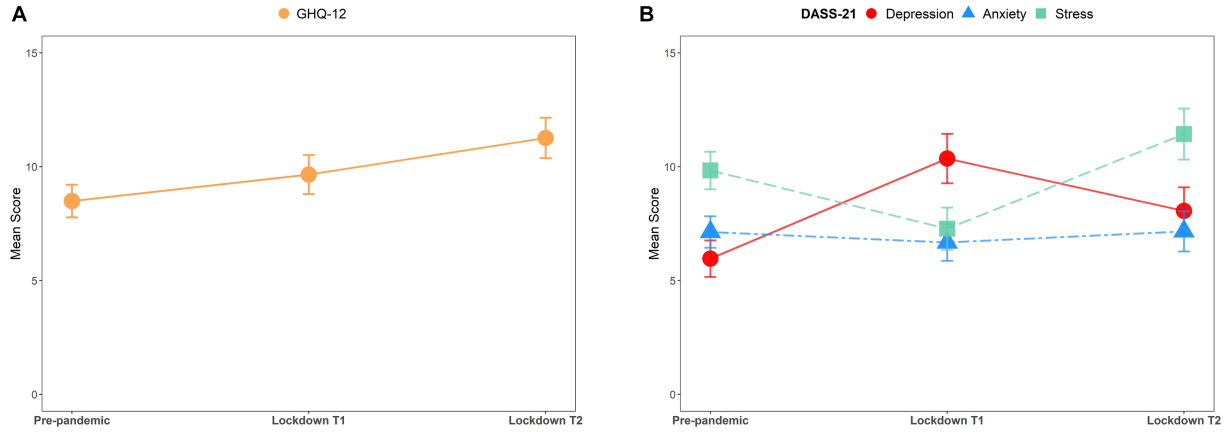

FIGURE 1
Mean GHQ-12 and DASS-21 scores over three data collection waves before and during the COVID-19 pandemic. **(A)** GHQ-12 scores (mean ± 95% CI) in each period. **(B)** DASS-21 scores (mean ± 95% CI) for depression (red), anxiety (blue), and stress (green) in each period.

TABLE 2 Descriptions of mental health outcomes across three phases.

Variables	Pre-pandemic	Lockdown T1	Lockdown T2	*p*-value
	Mean (SD)	Mean (SD)	Mean (SD)	
GHQ-12	8.49 (5.20)	9.66 (6.23)	11.26 (6.44)	< 0.001[a]
DASS-21 depression	5.96 (5.82)	10.36 (7.89)	8.06 (7.52)	< 0.001[a]
DASS-21 anxiety	7.13 (5.01)	6.67 (5.86)	7.16 (5.99)	0.243[a]
DASS-21 stress	9.83 (5.99)	7.28 (6.75)	11.43 (8.13)	< 0.001[a]
	N (%)	N (%)	N (%)	
Mental distress				<0.001[b]
No	169 (82.44)	144 (70.24)	124 (60.49)	
Yes (GHQ-12 score ≥ 4)	36 (17.56)	61 (29.76)	81 (39.51)	
Depression symptoms				<0.001[b]
No	163 (79.51)	92 (44.88)	130 (63.41)	
Yes (DASS-21 depression score > 9)	42 (20.49)	113 (55.12)	75 (36.59)	
Anxiety symptoms				0.832[b]
No	127 (61.95)	129 (62.93)	114 (55.61)	
Yes (DASS-21 anxiety score > 7)	78 (38.05)	76 (37.07)	91 (44.39)	
Stress symptoms				<0.001[b]
No	168 (81.95)	178 (86.83)	143 (69.76)	
Yes (DASS-21 stress score > 14)	37 (18.05)	27 (13.17)	62 (30.24)	

[a]Generalized estimating equation models. [b]Chi-square test.

from 9.83 during the pre-pandemic period to 7.28 at lockdown T1, and then increased to 11.43 at lockdown T2 (Figure 1B). The mean DASS-21 anxiety scores were relatively stable across the three periods (Figure 1B). Additionally, the changing trends in the number of participants experiencing depression, stress, or anxiety symptoms were in line with the trends observed in the mean scores for the three subscales (Table 2). These results showed that depression and stress but not anxiety symptoms of university students were significantly affected by the abrupt onset of COVID-19 pandemic and campus lockdown durations, and that depression symptoms changed in stark contrast to stress symptoms before and during the pandemic lockdowns.

Trajectories of mental health outcomes

LCMM models were fitted with up to five latent classes, and the goodness of fit indices is presented in Supplementary Table S1. The 3-class model was selected as the optimal solution for GHQ-12 scores, DASS-21 depression scores, and DASS-21 anxiety scores, while the

4-class model was chosen for DASS-21 stress scores. Figure 2 shows the identified class-specific trajectories of the observed scores for GHQ-12 and DASS-21.

Of the total participants, 40% belonged to the "consistently good" class, while 52.7% were in the "consistently fair" class, representing good or fair mental health status over time (Figure 2A). Additionally, 7.3% of the participants followed a "good but deteriorating at lockdown T2" trajectory, with a good pre-pandemic status, then a slight improvement from pre-pandemic to lockdown T1, but a sharp deterioration from lockdown T1 to T2.

Regarding depression symptoms, 3 distinct DASS-21 depression trajectories emerged (Figure 2B). A proportion of 38.0% of the participants belonged to the "consistently good" class, showing no clinical depression symptoms. A "deteriorating" group (25.4% of the participants) had initial clinical depression symptoms before the pandemic, and reported a sustained deterioration in depression symptoms over lockdown durations. Another "recovery" group showed no clinical depression symptoms prior to the pandemic, worsened depression symptoms at the initial lockdown, and then returned to around pre-pandemic levels of DASS21 depression scores at lockdown T2.

Most of the participants (63.4%) had no clinical anxiety symptoms across pre-pandemic and lockdown periods (Figure 2C), belonging to the "consistently good" class. A "consistently poor" group (31.7% of the participants) had pre-pandemic clinical anxiety symptoms that were sustained with high scores after campus lockdown. A "poor and deteriorating at lockdown T1" group (4.9% of the participants) showed worsened anxiety symptoms across the three periods and reported a sharp deterioration in anxiety symptoms at the initial shock of the pandemic lockdown.

Regarding stress symptoms, most of the study population belonged to either "consistently good" (48.3% of the participants) or "consistently

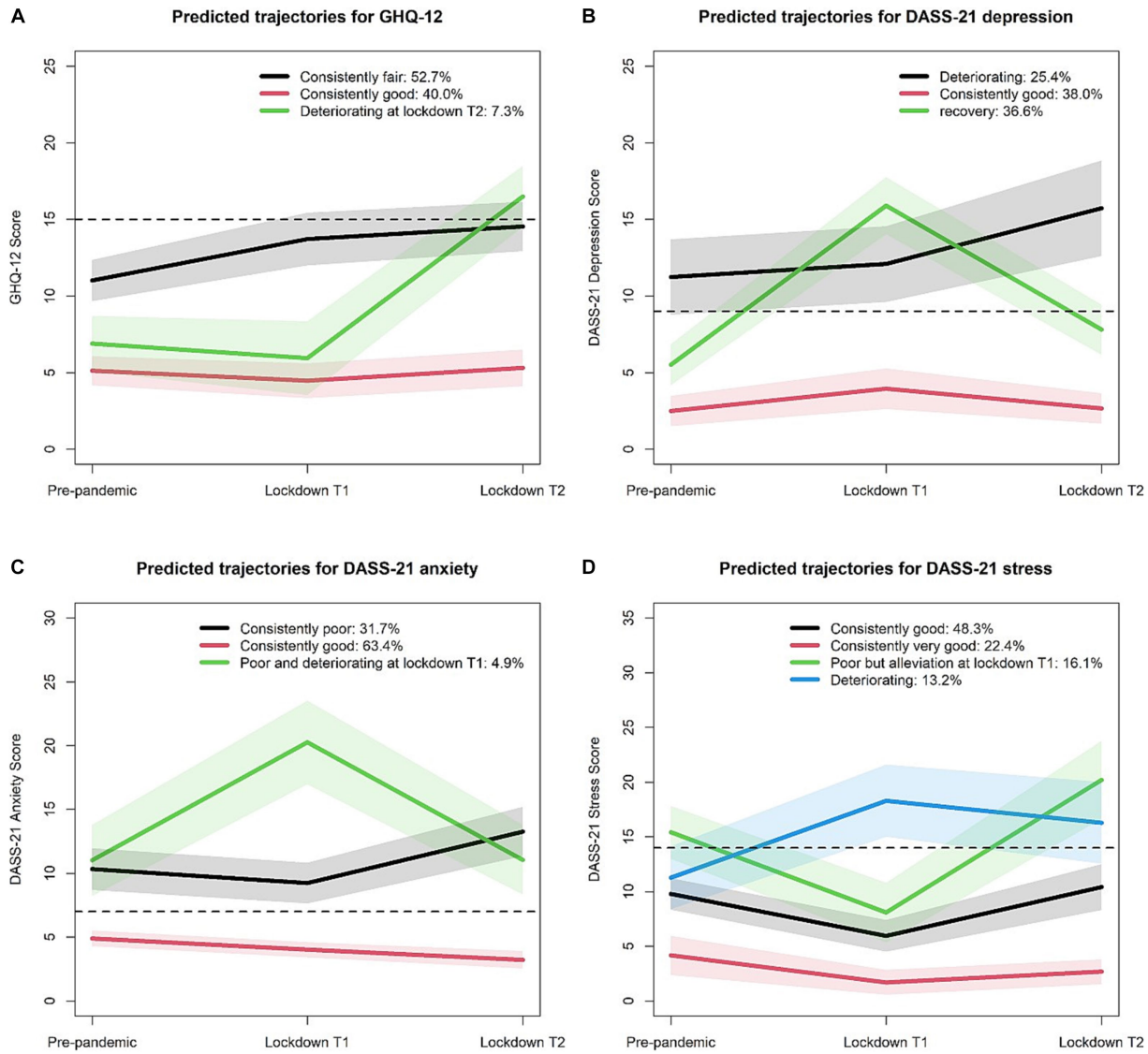

FIGURE 2
Mean scores for GHQ-12 and DASS-21 from class-specific trajectories across three waves of data collection before and during the pandemic. Mean scores for GHQ-12 **(A)**, DASS-21 depression **(B)**, and DASS-21 anxiety **(C)** from 3-class trajectories and for DASS-21 stress **(D)** from 4-class trajectories across three periods. Shaded ribbons represent the 95% CI for each period, and dashed lines indicate the clinical symptom cutoff scores.

very good" (22.4% of the participants) class across pre-pandemic to lockdown T2, with little divergence from their pre-pandemic scores (Figure 2D). A proportion of 16.1% of the participants belonged to "poor but alleviation at lockdown T1," with an initial worsened status, then an alleviation at lockdown T1, and then a sharp deterioration at lockdown T2. A "deteriorating" group (13.2% of the participants) had a good status before the pandemic but a sharp deterioration at lockdown T1 and remained high scores at T2.

Factors associated with mental health trajectories

To explore factors associated with distinct mental health trajectory classes, multinomial regression models were fitted. The associations between sociodemographic characteristics and distinct trajectories of GHQ-12 scores are shown in Supplementary Table S2. Participants with fair or poor peer relationships or those with father's education levels of junior high school or below were more likely to belong to the "consistently fair" class rather than the "consistently good" class. Participants with an annual household income exceeding 300,000 CNY were more likely to develop psychosocial malaise at lockdown T2 and less likely to belong to the "consistently fair" class compared to the "consistently good" class.

For the trajectory classes of DASS-21 depression, participants with fair or poor peer relationships were more likely to belong to the "deteriorating" or "recovery" class than the "consistently good" class (Supplementary Table S3).

Supplementary Table S4 displays the associations between sociodemographic characteristics and latent classes for DASS-21 anxiety scores. Participants with fair or poor peer relationships were more likely to develop anxiety symptoms.

Concerning the trajectory classes of DASS-21 stress (Supplementary Table S5), participants with fair or poor peer relationships were more likely to belong to the "deteriorating," "poor but alleviating at lockdown T1," or "consistently good" classes than the "consistently very good" class. Participants whose father's education level was at or below junior high school were more likely to belong to the "deteriorating" class than the "consistently very good" class.

Discussion

After the worldwide COVID-19 pandemic over 3 years ago, the Shanghai government announced the citywide lockdown on April 1, 2022 to stem the outbreak and spread of the pandemic. Before the citywide quarantine measures were implemented, universities in Shanghai had locked down the campuses and confined students to their dormitories to prevent the spread of COVID-19 in March 2022. This study took advantage of a three-wave longitudinal survey to identify disparate trajectories of mental health among university students across before and during the COVID-19 campus lockdowns and to explore factors associated with these mental health trajectories. The findings contribute to our understanding of how pandemic campus lockdowns specifically impact the mental health of university students and underscore the importance of identifying vulnerable groups, which can inform the development of targeted support and psychological services for students during future pandemics.

This study demonstrated that campus lockdown due to the COVID-19 pandemic had distinct effects on different emotional symptoms of university students. Specifically, we proved that average mental health progressively and significantly worsened from pre-pandemic to COVID-19 campus lockdowns, which was in line with two prior studies reporting impaired mental health in UK university students from before to during the COVID-19 pandemic (30, 31). Furthermore, previous longitudinal studies consistently reported elevated depression symptoms among university students during the pandemic compared to pre-pandemic (18, 20, 31–35), while our study further demonstrated that average depression symptom peaked at the initial COVID-19 outbreak (i.e., lockdown T1), and relieved after 1 month later (i.e., lockdown T2). Studies on anxiety symptoms of university students often reported mixed findings. Some studies reported increased anxiety symptoms during COVID-19 relative to pre-pandemic (18, 32–35), but others as well as this study showed that anxiety symptoms were stable before and during COVID-19 (20, 31, 36, 37). Regarding stress symptoms, evidence indicates that university students had higher stress levels during the pandemic compared to before (21, 30, 32, 38), while our results further showed that average stress symptoms improved from pre-pandemic to the initial COVID-19 outbreak and deteriorated 1 month later. Overall, our findings underlined the need to reinforce targeted prevention, surveillance, and accessible mental health care for university students at different stages of the pandemic lockdowns.

Although emerging evidence has suggested heterogeneous mental health responses to the pandemic (13, 14, 39), there is a lack of data on mental health trajectories among university students before and during COVID-19 campus lockdowns. Only one study, using piecewise latent growth models, reported stable mental health among 141 Dutch university students over a 3-month period, assessed before (Times 1–4) and during the COVID-19 lockdown (Times 5–8) with a 14 self-report item mental health continuum short-form (19). In contrast, our study found that the mental health of Chinese university students deteriorated during the COVID-19 campus lockdowns, identifying three distinct trajectories across three phases using LCMM. One possible explanation for the disparities in the mental health status of university students between our study and the previous one may be attributed to variations in assessment tools and data analysis methods employed. Additionally, differences in the COVID-19 epidemic situation, the implementation of campus lockdown measures, and pandemic control measures across various countries, cities, and universities could also contribute to these discrepancies. Furthermore, our study identified three distinct trajectories for depression and anxiety symptoms, as well as four distinct trajectories for stress symptoms. To our knowledge, this study provided the first evidence for the heterogeneity in the psychological impact of pandemic lockdowns on university students before and during the COVID-19 pandemic.

Further, students with fair or poor peer relationships were more likely to be in the vulnerable trajectories of depression, anxiety, and stress symptoms. Similarly, Sun et al. reported that perceived available peer support negatively contributed to depression symptoms among university students during the COVID-19 pandemic (40). Participants whose father had an education level of junior high school or below were found to be more vulnerable to experiencing deteriorating stress symptoms. Coincidentally, Villaume et al. found that adolescents from low parental education households had more negative changes in stress and mood in the COVID-19 pandemic (41).

Compared to previous studies employing either cross-sectional or longitudinal designs, this study contributes to the existing literature by unveiling the heterogeneity in the psychological impact of COVID-19 on university students before and during the pandemic lockdowns. It also sheds light on specific vulnerable subgroups that may necessitate tailored support during future crises. However, it is essential to acknowledge several limitations. First, our study employed a convenience sampling method and had a modest sample size, which could limit the generalizability of our findings to a broader population. Second, while GHQ-12 and DASS-21 have undergone validation in Chinese populations, it is essential to recognize China's cultural and ethnic diversity. Our study focused on a specific group of participants, and the validation status may not fully encompass the richness of diversity across China. Third, the effectiveness of the LCMM utilized in this study might be compromised due to the limited availability of only three phases (42). Last, the relatively short duration between the second and third waves of data collection could limit the examination of the long-term effects of the lockdown on mental health.

In summary, this three-wave longitudinal study has provided valuable insights into the diverse landscape of mental health experiences among university students facing the COVID-19 pandemic campus lockdown. Our findings emphasize the significance of acknowledging and addressing this heterogeneity in mental health outcomes. It is imperative for universities to adopt a proactive approach in identifying and supporting vulnerable students while laying the groundwork for the development of more effective support systems and policies aimed at enhancing student well-being in preparation for future health crises. Additionally, there is a need for conducting long-term follow-up studies to assess the lasting impact of the post-pandemic period on the mental health of university students in future.

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 humans were approved by the Institutional Review Board for Human Research Protections of Shanghai Jiao Tong University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

YQ: Conceptualization, Formal analysis, Funding acquisition, Methodology, Supervision, Visualization, Writing – original draft. ZL: Data curation, Formal analysis, Investigation, Project administration, Writing – review & editing. YZ: Data curation, Formal analysis, Investigation, Project administration, Writing – review & editing.

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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/fpsyt.2023.1267333/full#supplementary-material

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Exploring the lived experiences of participants and facilitators of an online mindfulness program during COVID-19: a phenomenological study

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The coronavirus pandemic (COVID-19) has placed incredible demands on healthcare workers (HCWs) and adversely impacted their well-being. Throughout the pandemic, organizations have sought to implement brief and flexible mental health interventions to better support employees. Few studies have explored HCWs' lived experiences of participating in brief, online mindfulness programming during the pandemic using qualitative methodologies. To address this gap, we conducted semi-structured interviews with HCWs and program facilitators (*n* =13) who participated in an online, four-week, mindfulness-based intervention program. The goals of this study were to: (1) understand how participants experienced work during the pandemic; (2) understand how the rapid switch to online life impacted program delivery and how participants experienced the mindfulness program; and (3) describe the role of the mindfulness program in supporting participants' mental health and well-being. We utilized interpretive phenomenological analysis (IPA) to elucidate participants' and facilitators' rich and meaningful lived experiences and identified patterns of experiences through a cross-case analysis. This resulted in four main themes: (1) changing environments; (2) snowball of emotions; (3) connection and disconnection; and (4) striving for resilience. Findings from this study highlight strategies for organizations to create and support wellness programs for HCWs in times of public health crises. These include improving social connection in virtual care settings, providing professional development and technology training for HCWs to adapt to rapid environmental changes, and recognizing the difference between emotions and emotional states in HCWs involved in mindfulness-based programs.

KEYWORDS

healthcare workers, COVID-19, mindfulness, mental health, resilience, interpretative phenomenological analysis

1 Introduction

The first case of Coronavirus disease (COVID-19) was reported in Wuhan, China in December of 2019 (1). By March of 2020, the World Health Organization (WHO) declared COVID-19 a global pandemic (2). Internationally, public health responses to COVID-19 included travel bans, social distancing, quarantines, school and business closures, masking

policies, and the switch to virtual healthcare delivery where possible (3). Despite these measures, COVID-19 caused an unprecedented burden on healthcare systems, arising from increased workloads, shortages of personal protective equipment (PPE), distress associated with ventilator triaging, increased patient deaths, and fears about protecting oneself and their families (4–6). Taken together, these work-related stressors adversely affected the mental health and wellness of healthcare workers (HCWs) around the world (7–10). In attempts to mitigate distress, research concerning mental health interventions for HCWs became a burgeoning area of study, with evidence pointing toward online mindfulness-based programs as a promising intervention (11, 12). While there is a breadth of research concerning in-person mindfulness programs, the delivery of programming to the general public, and quantitative evaluation studies, qualitative research examining the lived experiences of HCWs participating in online mindfulness programs is lacking (13). Given that individual experiences are situated within the broader social, political, and economic dimensions of a global pandemic, further exploration into participants' and facilitators' lived experiences is necessary to capture nuances not previously considered (14). To our knowledge, this is the first study that utilizes a phenomenological approach to understand the lived realities of HCWs delivering or participating in an online mindfulness program during the COVID-19 pandemic.

2 Background

Many studies detail the toll the pandemic had and continues to have on the mental health of HCWs. Over the last few years, HCWs have reported increased symptoms of anxiety, depression, psychological distress, emotional exhaustion, burnout, moral injury, and post-traumatic stress disorder (15–22). According to a report by the Mental Health Commission of Canada, during the first few years of the pandemic, 40% of healthcare workers experienced burnout, only 60% were satisfied with the quality of care they could provide, and 50% intended to leave the profession (15). Despite the increased distress HCWs were experiencing, research in service utilization of organizational supports during the pandemic revealed that only 17.5% of HCWs opted to participate in counselling or psychotherapy services, whereas 50.4% of HCWs utilized online resources to learn about coping tools and strategies to support their mental health and well-being (23, 24). This suggests that having mental health interventions available online may help to meet HCWs' needs and cultivate resilience (13, 25, 26).

Mindfulness is a practice rooted in Buddhism that has had a significant influence on Western science, largely through the work of Jon Kabat Zinn (27). According to Kabat Zinn, mindfulness can be defined as "the awareness that emerges through paying attention on purpose, in the present moment, and nonjudgmentally to the unfolding of experience moment by moment" (28) (p.145, par. 3). The benefits of mindfulness-based interventions are well-documented. Recent research suggests that they may help HCWs cultivate self-compassion, self-efficacy, positive emotions and increase present awareness and understanding (26, 28–30). Similar studies have found that mindfulness interventions may help to reduce stress, burnout, and depression, mitigate psychological distress, and reduce symptoms of post-traumatic stress disorder (31–33). Additionally, evidence supports the use of mindfulness-based interventions as a tool to help HCWs cope with work-related and pandemic-related stressors (34–36).

There is a growing focus on examining the effectiveness of short mindfulness-based interventions to support the mental health of HCWs during the pandemic (26, 37). While research about these interventions has yielded mixed results, a recent mixed-methods study from Kim and colleagues demonstrates that brief, online mindfulness interventions, such as the Mindfulness Ambassador Program (MAP), may improve resilience in HCWs (13). While Kim and colleagues' study offers a brief glimpse into HCWs' lived experiences, only participants' experiences are considered, and facilitators experiences delivering the MAP as HCWs are largely unknown.

This paper offers a novel contribution by capturing the lived experiences of facilitators and participants in a brief online mindfulness program during the third wave of the pandemic (January/February 2021 to June/July 2021). The findings from this study can help inform program design and delivery and provide directions in tailoring mindfulness programs to the unique needs of HCWs (13). More importantly, this study elucidates the rich meanings and experiences facilitators and participants had in relation to a mindfulness-based intervention program during COVID-19.

3 Methodology

Using interpretive phenomenological analysis (IPA), this paper aims to elucidate the meanings that healthcare workers and facilitators attributed to their experiences in a four-week, online, synchronous delivery of an adapted version of the MAP during the first year of the pandemic. This paper deploys a relativist ontology, understanding that lived realities are expressed and understood within specific cognitive, social, and political boundaries. Our epistemological commitment is to phenomenological interpretivism, as the experiences of HCWs are culturally, socially, and historically situated, and knowledge is constituted through lived experiences. IPA was a natural methodology to select, given our commitment to exploring participants' and facilitators' lived experiences with MAP.

The research team made sure to situate this work within our own understanding of the connections between ontology, epistemology, and methodology and within our own positionalities in the world. Positioning epistemological perspectives is instrumental to IPA, as each researcher brings their own interpretation of individuals' lived experiences (38). The first author (A.M.) acknowledges her position as a white, cis-gender woman, member of the LGBTQIA+ community, and undergraduate student of counselling psychology employed in research in a healthcare setting. She brings a constructivist-interpretivist epistemology with limited prior exposure to phenomenology. The co-first author (C.C.) acknowledges his position as a white, cis-gender, heterosexual man. He has a background in realist and constructivist epistemological approaches to qualitative research. While new to interpretive phenomenological analysis, his research has focused on the history of phenomenology in mental health social movements and the importance of centring lived experiences in research, practice, and policy.

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TABLE 1 Participant information.

#	Age group	Gender	Current healthcare worker status	Role	Years of healthcare work experience
P1	31–50	F	Yes	Virtual Care	<11
P2	>65	F	Yes	Non-clinical support	>20 yrs
P3	31–50	F	Yes	Non-clinical support	>20
P4	31–50	F	Yes	Direct patient care	>20
P5	31–50	F	Yes	Direct patient care	11–20
P6	31–50	F	Yes	Non-clinical support	N/A
P7	51–65	F	Yes	Non-clinical support	N/A
P8	<30	F	Yes	Direct patient care	<11
P9	31–50	F	Yes	Direct patient care	<11
F1	<30	F	Yes	Direct patient care	<11
F2	31–50	F	Yes	Non-clinical support	<11
F3	31–50	F	Yes	Direct patient care	<11
F4	31–50	F	Yes	Non-clinical support	11–20

The research team used the consolidated criteria for reporting qualitative research (COREQ) checklist to enhance transparency of our qualitative processes and ensure comprehensive reporting of our findings (39).

This study was approved by the Institution's Ethics Review Board (Waypoint Center for Mental Health Care, Protocol ref. # HPRA#20.07.27).

3.1 Recruitment and sample

We used a purposive sampling recruitment approach because it allowed us to select participants who had rich knowledge concerning a particular phenomenon (40). Participants and facilitators were recruited via email from having registered and participated in the MAP. To be eligible for participation in this study, individuals must have attended a minimum of one mindfulness session, be aged 18 or older, and be actively employed in either direct care or indirect care roles within the healthcare sector. The sample (n = 13) was comprised of participants (n = 9) and program facilitators (n = 4), aligning with the smaller sample sizes utilized in IPA (40). All participants were women, with 69% between the ages of 31 and 50 years old, 46% employed in a non-clinical support position, and 46% employed in a direct patient care role. Only one participant worked in virtual care during the COVID-19 pandemic. Participant descriptions are outlined in Table 1.

3.2 Data collection

After giving consent, interviewees were provided access to a secure Zoom link, and interviews took place from October 2020 to March 2021. Interviews were scheduled for 60 min to allow enough time to gain a rich understanding of their experiences in the program. Interviews were guided by a semi-structured interview protocol. The protocol was developed in collaboration with the advisory committee, which was composed of the research team and experienced mindfulness practitioners. The advisory committee started with the following two overarching questions:

1) What was the role of the online mindfulness program on social connectedness, empathy, and resiliency during the COVID-19 pandemic?
2) What were the experiences of both participants and certified facilitators delivering the online course to strengthen the online facilitation?

Drawing upon these overarching questions, the advisory committee developed five open-ended interview questions to guide meaningful conversations about participants' and facilitators' lived experiences. Semi-structured interview questions were designed with rapport-building at the forefront of each interview (40). Questions were limited to allow participants to articulate their experiences in detail. Sample participant questions included:

1) Can you tell me a bit about the impact of the pandemic on your overall physical and mental well-being?
2) What drew you to the four-week mindfulness program? What were you hoping to learn or experience in the program?
3) How do you feel the four-week program impacted your overall well-being and your work performance?

Sample facilitator questions were:

1) What is your experience facilitating mindfulness programs, both online and face-to-face?
2) What challenges, if any, did you experience as a facilitator when you moved to deliver the program in-person to online?
3) How would you describe the well-being of the participants at the onset of your course?

All interviews were conducted by S.H. and recorded with the consent of participants for the purpose of transcription. At the end

of the interview, participants were sent an honorarium in the form of a $25 gift card. Interviews were transcribed verbatim, and participant numbers were assigned to uphold confidentiality. All transcriptions were conducted using Nvivo and were checked by the research team (F.C. and S.H) for accuracy, quality, and integrity and were sent back to each participant for member-checking. At this time, participants had the opportunity to layer in detail and expand on experiences.

3.3 Data analysis

Participant interviews were analyzed using IPA (41). To adhere to the idiographic and reflexive nature of IPA, each author acknowledged their own epistemological views and practiced reflexivity throughout all phases (41). During phase one, A.M. and C.C. immersed themselves in the data by reading and re-reading the transcripts multiple times. In phase two, A.M. and C.C. took descriptive, linguistic, and conceptual notes of each transcript separately. In phase three, A.M. and C.C. independently identified emergent themes within each case. In phase four, A.M. and C.C. reviewed, compared, and connected themes. Each author made connections between themes within each case and started to review, synthesize, and connect themes. Phases one through four were repeated for each participants' transcript, with bracketing used between participant transcripts. A summary of these emergent themes can be found in Table 2. In phase five, the team used cross-case analysis to identify and prioritize patterns, including convergent and divergent themes, a practice that can be used when analyzing multiple interviews in IPA (42). A.M. and C.C. independently conducted a cross-case analysis, noticing commonalities of themes across all participants. In phase six, A.M. and C.C. shared results from the cross-case analysis, finalized themes inductively, and identified quotes that provided rich descriptions of the shared patterns of experiences, forming the interpretation of the final themes. A summary of this process can be found in Table 3.

4 Findings

The methodological approach utilizing IPA resulted in four themes: (1) changing environments; (2) snowball of emotions; (3) connection and disconnection; and (4) striving for resilience, defined as "a dynamic process encompassing positive adaptation within the context of significant adversity." (43) (p.543, par. 1).

4.1 Theme 1: changing environments

The first theme that emerged was *changing environments*. This was derived from the lived experiences of participants and facilitators as their external environments shifted dramatically in response to the COVID-19 pandemic. The pandemic increased work-related stressors leading up to those taking the mindfulness-based program and seeking support. For example, Participant 7 said, "It is stressful, and it is challenging, especially when you have got COVID-positive patients, and you want to make sure that you are doing everything properly to protect yourself." Similarly, as the pandemic progressed, caring for patients changed and bearing witness to suffering was very challenging. As Participant 8 said:

> You would hold the video for someone who is dying of COVID, and at the time, family was just not allowed to come in if you were dying. But now, in wave three, I'm holding the video for someone dying of it, if I even can, because not only does the whole family have COVID, but half of their family is in the hospital.

Participant 8 went on to describe the stress that arose out of inconsistent institutional policies and practices and the effect these had on patients' families who were caught in the middle:

> Being in a role where I'm on all the units in the hospital, I really struggle with different interpretations from different managers the frustration of families whose loved one gets moved between different floors. They were allowed to visit twice a week and then they're not allowed to visit at all just because different managers [manage] differently.

Two facilitators also experienced changes in their work environment as the mindfulness-based program transitioned to online delivery. This transition was a steep learning curve for some. Facilitator 4 stated: "The biggest challenge was sorting out how to use the camera on Zoom while referring to your notes." Facilitator 2 echoed this when discussing their experiences in learning how to use software to deliver the program: "Using PowerPoint to … guide people through mindfulness is hard … it's just not natural." Facilitator 2 also explained that participants' technological issues were disruptive to the mindfulness sessions: "Participants [had] technological challenges and [reached] out to me thinking I can kind of solve that for them [and] added obstacle[s] to having successful sessions."

Although the online switch was challenging, facilitators also shared how they adapted and supported each other during this transition. Facilitator 4 detailed: "One of the things we did that I think was helpful for the facilitators was just booking some mock sessions in advance. We also incrementally increased what they needed to do while they were delivering." Facilitator 4 explained further that part of adapting was adjusting their expectations for participants:

> Part of the communication I made was letting people know they had permission to have no camera on, and that was important. Some people even would put a different name up and then would privately let me know who was there like they wanted to be anonymous.

4.2 Theme 2: snowball of emotions

The second theme that emerged from our analysis was the *snowball of emotions*. This theme describes the complicated, overlapping, and accumulating emotions and emotional states participants and facilitators experienced leading up to and participating in the program. Participants and facilitators often spoke

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TABLE 2 IPA emergent themes.

Participant	IPA Emergent themes (C.C.)	IPA Emergent themes (A.M.)
P1	Zoom fatigue The connection between burnout and isolation Overcoming isolation through connection Importance of routine Overwhelm, fatigue, stress	Overwhelm and Zoom fatigue Scheduled self-care Community and connection refreshing Offset challenges at work Emotional shift
P2	Isolation and loneliness Compounding life stressors Mindfulness helped when they felt they were "losing control" Sense of connection "to a point" in online spaces	Loneliness, fear, guilt Connection but limited Facilitated use of self-help Grounding experience
P3	Connection over Zoom Support from others Many challenging emotions piled up	Feelings compounded over time Work and mood changed Connection to others through activities Emotional/mindset shift More control
P4	Loss of community and connection Looking for coping strategies Challenges with COVID	Change in work environment and in activity levels Self-care is needed and important Connection was limited
P5	Stressed that mindfulness was so hard Never knew anxiety before The course did not do what they had hoped or wanted Feeling overwhelmed Doing what they could to get by	Stressed about mindfulness, work, and challenges at home Heightened guilt, anxiety, and stress Online program fell flat
P6	Shared community Connection through mindfulness practice Just doing what you could Virtual saved time	Constant change Mindfulness to cope Connection needs met Structure, routine, schedule Enjoyed the structure of the sessions Connected to the practice
P7	Stress with work and family during COVID Program short but took small things from it Didn't find social connection with participants Very social person	Separating work from home challenging Community/connection lacking Program too brief Structure was beneficial
P8	Complicated grief Complex and compounding emotions Lack of attention Course reminded them to pay attention and do what they can to focus on their mental health	Increasing anxiety, fatigue, exhaustion Lots of goodbyes Chaos, falling apart, relentless No connection, felt alone It was hard to practice mindfulness Timing was difficult Interruptions/distractions Operational stressors adding to stress
P9	Emotional exhaustion Changes to routine Practicing self-care Finding the time to maintain the practice Lacking a sense of community yet longed for connection Resilience is in connection	Changing work environment No routine Struggling to function Self-care, routine, back on track. No community Community is self-care
F1	Importance of self-care Bearing witness to suffering and burnout Finding connection in whatever way possible Zoom challenges Do what you can for self care	Uncertain about program reach Observed burnout and emotional distress Planting seeds of self-care

(Continued)

TABLE 2 (Continued)

Participant	IPA Emergent themes (C.C.)	IPA Emergent themes (A.M.)
F2	Disconnect over Zoom/Zoom challenges Witness to so much burnout but that people were doing what they could Witness to resilience Shared experiences Different forms of connection	People left better than they came People are resilient Facilitators were also resilient Connection present, but limited Zoom challenges
F3	Difficulties with online and family life Compounding emotional toll of participants Zoom challenges Importance of care of the self Found connection with participants	Advantages and disadvantages Connection different online Recognized role of organization Technology issues Timing of program difficult
F4	Caring for the self and doing what you can Witness to a lot of stress and big emotions Togetherness emerged in the sharing of emotions in a shared space Zoom challenges Some disconnect with lack of real time feedback Loss of "essence" of the program	Participants were in a sensitive place Resilience/self-lessness Community through Zoom chat Zoom issues Facilitation was not as natural Benefited personally and professionally

about specific emotions (e.g., fear, sadness, worry) interchangeably with emotional states (i.e., anxiety, fatigue, and burnout). In our discussion below, we differentiate between the two to provide a richer interpretation of these complex experiences.

Participant 5 experienced anxiety, which was new and distressing for them: "I've never really had anxiety before. Now … my thoughts are a lot more disorganized." Participant 1 described compounding effects of exhaustion, uncertainty, and overwhelm: "I think there's … emotional exhaustion, like worrying about people … [and] more uncertainty in terms of working with people in crisis." These complicated emotions led to burnout for some participants and were a reason they looked to the mindfulness program for support. Participant 1 explained, "I was … looking for some resources and support. If it wasn't COVID … I might not have felt burnt out."

The emotional toll and burnout among people in the healthcare field was evident, as Participant 8 described: "It was harder than I was expecting it to be. Probably harder emotionally and just a lot of fatigue and exhaustion and burnout and feeling that not only in myself but in my colleagues and in … all the healthcare providers I'm interacting with." It was clear that for these participants, caring for patients amidst the pandemic when the demand was significant brought compounding challenges.

Facilitators were in a unique position experiencing their own heightened emotions while witnessing the struggle of HCWs. Facilitator 4 said, "There were times where I was really stressed and teaching virtually and the dog might bark, and things might happen, and there are many things in life going on, and there's a lot of anxiety because you want it to be perfect." When reflecting on how participants appeared to be struggling, Facilitator 1 also noted that there was a stark awareness of the degree of burnout among HCWs:

> I think it really showed me how much impact this pandemic is making on people. Within a health-helping profession, there's always going to be stress, and there's going to be burnout. With this pandemic, I truly understood the definition of burnout and not just using it as a loose term … I was surprised how many people were staying lower on the emotions thermometer.

Facilitator 4 shared similar sentiments: "People did not want to be necessarily seen … they wanted to be heard. I noticed that piece just giving permission not to have your video on. People were present, but they were fragile. The [course] was a place for them to be safe and fragile and take what they need."

The online MAP met participants at a time when emotions were high and when support was needed most. Facilitators saw participants' emotional burden in sessions and aimed to create a non-judgmental environment where such vulnerabilities could be held. The facilitators' efforts to provide care in an online environment were felt by the participants in different ways. The third theme, connection and disconnection, further explores this sense of community for some people along with barriers to togetherness for others.

4.3 Theme 3: connection and disconnection

The third theme that emerged from the interviews is *connection and disconnection*. Despite the many challenges within changing environments and the compounding factors that led to complex emotions and emotional states, participants and facilitators mostly saw the course as a tool for connection. Unfortunately, the course seemed to exacerbate a sense of disconnection for others who found online life challenging.

Participant 1 felt that connection came in the form of a community of HCWs seeking help amidst the pandemic out of a shared necessity: "There's this sense of community that we all [have] coming with different struggles," they remembered. Similarly, Participant 3 felt this sense of community, particularly with their peers within the group: "[I was] feeling connected. We were sending good thoughts to people … over Zoom." Participant 1 had similar reflections: "The facilitator really did a good job of creating a sense of safety and community," they recalled.

When discussing the connections they observed in the mindfulness program, Facilitator 4 shared: "I think there is a togetherness because people chose to be there. This was a choice, and

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TABLE 3 IPA analytic process.

Emergent themes	Cross-case analysis: superordinate and subordinate themes				Final themes
	Work, home, and online life	Complex emotions and states	Community and connection	Doing what you can	
Case-by-case IPA (C.C.; see Table 2)	Shared environments Uncertainty and isolation Everything is changing, falling apart Strains on healthcare systems Hectic work and family lives Technology/Zoom challenges Challenges and benefits of the online switch	Heightened and overlapping emotions Complex emotional states Concern for self and others Witness to suffering Compounding emotions	Connection between facilitators and participants Connection between participants Facilitators fostering connection Something was missing Lack of community, connection, & accountability in online life	Integrating mindfulness into daily life Maintaining a sense of normalcy Simple practices and tools Structure & routine Acceptance Small steps towards self-care	Changing environments
Case-by-case IPA (A.M.; see Table 2)					Snowball of emotions
					Connection and disconnection
					Striving for resilience

using the chat box [enforced] that togetherness … I think that really made a community … the chat would fire up with support, positivity and validation for people where they were." While Facilitator 4 noted the connection between the group members, Facilitator 3 felt that the connection was stronger between themselves and the participants directly:

> I think more connection was between myself and the participants. There were, I would say, like a dozen occasions where one participant would share something and then somebody would immediately type afterwards like me too … I think probably the greater connections are the ones between myself and the repeat participants.

Although some participants and facilitators thought the program fostered community and connection, some felt disconnect in the way the program was delivered. For Participant 4, the lack of participant consistency contributed to the disconnect: "There wasn't the consistency week to week of participants …I do not know what happened to all those people from week one." For Participant 5, the online environment limited accountability in adopting the skills that the mindfulness program offered: "Things that require a lot of willpower and effort and … anything that requires willpower, it's always helpful to be accountable in some way." For Participant 8, being in a Zoom meeting with others who had their cameras off fuelled a sense of disconnection: "I did not feel a sense of connection or community in the group," they said, "partly because they are just names on a screen that I do not actually see them or get to know who anybody is."

Facilitator 2 described some of the factors they believed contributed to participant disconnection: "They [participants] stopped [coming] … They just did not know if it was right for them. There was nothing really holding them from showing up to this free Zoom commitment that they have made for half an hour once a week."

While not all participants experienced connection and community in the program, the following theme demonstrates that most participants and facilitators took strides towards bettering their mental health in whatever small way they could.

4.4 Theme 4: striving for resilience

The final theme that emerged from participant and facilitator interviews was *striving for resilience*. Even with pandemic-related stressors, workplace demands, and challenges with the shift to online life, participants put effort into bettering their mental health. For example, Participant 1 said, "[The program] really helped to kind of put everything back into perspective, kind of close the lid on some of the feelings that would have led to burnout and taking stress leave. It did help for sure." Others shared that the mindfulness program enhanced self-awareness, self-compassion, acceptance, and the ability to shift emotions. Participant 1 said: "Where instead of feeling overly emotional or overwhelmed, [the course] brought me back to a sense of calm."

Some participants commented on how the program provided structure and routine, a space for them to integrate mindfulness practice into their daily lives as a practice of self-care. Participant 1 stated: "[The program] really helped me with setting a routine again and getting back into my mindfulness practice more regularly because … there was sort of this reminder." Participant 9 shared similar thoughts:

> Sometimes when you start working, the daily routines get in the way and you're not allotting time to engage in self-care … [MAP] was a reminder [and] was one of the reasons I joined … I need structure… I'm very committed as long as it's in my calendar.

According to Participant 1, self-care does not have to be complicated to be effective. "The emotion thermometer stood out to me," they said, "because it was such a simple practice, but such a good way of checking [in]. It made such a nice thing to do it in a group format where people could kind of put in a number on a scale to give it in chat or look at colour and kind of see where they are at."

Two facilitators also shared their experiences as bearing witness to participants aspiring to resilience. Facilitator 4 shared:

> One group I worked with were people who worked with geriatrics. They knew what was coming their way. They were preparing. That was eye-opening. They were trying to really manage that emotional exhaustion they were feeling now. It showed me how incredibly strong and … how selfless they are … because they were doing it to care for themselves [and] to care for other people.

Facilitator 1 reiterated this sentiment: "[It speaks] to the resilience that people have when they are attending or seeking out these services, that they are recognizing perhaps that there's something within them that they want to improve or maintain." In sharing observations about participant progress in the program, Facilitator 1 continued, "I've noticed quite a bit of improvement [in] people's moods, even though I'm not able to see them and see the nonverbal side of it."

Experiences leading up to the mindfulness program, through its completion, were unique to everyone. At the same time, participants and facilitators shared a common experience: rapid environmental changes to a major world event led to heightened and complex emotions and emotional states that fuelled a desire to find relief through mindfulness.

5 Discussion

This study explored the lived experiences of HCWs participating in or delivering an online mindfulness program during COVID-19 and the impact of mindfulness on their personal and professional lives. The study found four themes: changing environments, snowball of emotions, connection and disconnection, and striving for resilience.

The first theme, *changing environments,* articulates how participants and facilitators experienced rapid changes to work, family, and social relationships, and how they faced challenges with the shift to online life during the first year of the pandemic. This shift posed significant challenges for both groups. Participants and facilitators, all of whom were HCWs, found themselves contending with feelings of loss, longing, and loneliness, as well as fear and grief. These findings align with existing studies detailing how fear and distress were attributed to changing workplace environments during COVID-19 (6, 44–46). For most facilitators, the switch to delivering the mindfulness program over Zoom brought frustration. This was caused by inexperience with delivering courses online, and factors such as participants having poor internet connections or trouble accessing course materials. Despite these challenges, facilitators demonstrated adaptability and supported each other. Simultaneously, many grappled with feelings of loneliness, sadness, and disconnection in other facets of their lives. Previous qualitative research echoes these findings, highlighting the difficulty of adapting to rapid changes within healthcare environments during COVID-19, whether in person or virtually. Emotional stressors were compounded by critical shortages of PPE (44, 45). Accelerated organizational changes placed an undue burden on HCWs, leaving them unprepared for increased patient demands and shifting organizational policies that influenced personal safety and the delivery of patient care (45).

The second theme, *snowball of emotions,* describes the complicated and compounding emotions participants and facilitators experienced in response to these rapidly changing environments. Every participant and facilitator spoke about how the pandemic, resulting public health measures, and changing work and social environments contributed to emotions like anger, fear, and sadness and more complex emotional states like exhaustion, isolation, and burnout, consistent with prior research (6, 8, 9, 15, 17, 22, 25). Participants described experiencing overwhelm and grief while witnessing suffering during wave after wave of the pandemic when not much was known about the virus. Participants all described anxiety about their mental health while trying to care for others in healthcare roles. They spoke openly about loneliness, isolation, disruption to routines, the compounding effect of burnout, and their desire to find mindfulness or other mental health resources to cope in response. On the other hand, most facilitators also articulated positive emotions, including empathy towards their colleagues, pride from being able to help others through mindfulness, and gratitude for fostering a sense of connection in online spaces. Similar results concerning co-occurring or gradually emerging positive emotions during public health crises have been reported in other studies (46–48). However, our finding that facilitators experienced positive emotions while delivering the online mindfulness program is unique.

The third theme, *connection and disconnection,* explores how some participants and facilitators found the program to be a space for social connection during a crisis, while others found it to be frustrating and difficult. Those who appreciated the course tended to express hope and gratitude about having a community of people with whom they could connect. Participants who found the course frustrating often expressed grief about losing in-person connections; an online course did not seem to alleviate feelings of loneliness. Nevertheless, most participants spoke positively about how the program helped offset work and family life challenges. Previous research has similarly demonstrated that social support can facilitate psychological adjustment during a pandemic (46, 49, 50). Some participants found a connection through specific program elements, such as question and answer periods, and shared reflections on gratitude. The emotions thermometer was cited most often as helping with connection because it allowed participants to express the range of emotions they were experiencing without judgment, in community. Others felt disconnected when participants changed week to week, when some people turned cameras off, or when technological issues occurred. In contrast to previous research, some participants felt that the online delivery took away from a sense of connection, exacerbating emotional states such as loneliness and burnout (51). Overall, facilitators appreciated most aspects of the program and the community it created. However, one missed the somatic and nonverbal elements of an in-person program, such as eye contact, facial expressions, and physical closeness.

The final theme, *striving for resilience*, highlights how participants and facilitators used strategies from the mindfulness program to cope. For participants, resilience materialized through routine and structure during a time that felt uncertain and chaotic. Some found ways to integrate small things they learned into their daily lives, such as breathing, gratitude, meditation, and the emotions thermometer. Almost everyone spoke about how the mindfulness program helped them learn self-care and reminded them of the importance of community. This finding aligns with research demonstrating that self-care mediates the relationship between social connection and psychological adjustment (49). However, self-care, we heard, can only take people so far before they need to connect with others and feel supported by broader social systems. This finding is consistent with research about how individual-level programs need to be coupled with

institutional and structural support to prevent burnout in the workplace (52). Facilitators also felt a sense of improved resilience through self-reflection, gratitude, adaptability during technological challenges, and their commitment to mindfulness. Facilitators' struggles were alleviated by witnessing participants being strong and selfless in doing what they could to get by, however incrementally. Overall, the online program supported participants in coping with the pandemic and provided a space for facilitators to build resilience by supporting others.

5.1 Study strengths and limitations

To our knowledge, this is the first study to utilize IPA to understand participants' and facilitators' lived experiences of an online, synchronous, four-week mindfulness program. Utilizing this methodology enabled a rich interpretation of participants' subjective experiences of participating in the MAP when COVID-19 caused significant institutional changes, human resource challenges, and increased strains on healthcare systems worldwide. This study offers a contribution to the limited qualitative research concerning HCWs' and facilitators' experiences as part of a mindfulness-based program.

This study had limitations that warrant further consideration. The respondents who agreed to participate all identified as women. The homogenous nature of our sample limits our understanding of the unique experiences of HCWs of other genders. Additionally, as in all qualitative research, and especially in phenomenological research, our results are not generalizable to other healthcare workers. A third limitation of our study is that some participants struggled to recall some of the mindfulness tools discussed in the program, which may have influenced a recall bias in some participants. A final limitation of our study were the challenges we faced in conducting web-based interviews. In some cases, this format limited our ability to connect with participants and was a barrier to interpreting non-verbal cues and other contextual details of participants' experiences.

6 Conclusion

The current study explored the lived experiences of HCWs who participated in and facilitated a brief, online mindfulness-based program during COVID-19. Although the results were mixed, this study demonstrates that when organizations provide HCWs with mental health resources, employees will try to improve their mental health and well-being. However, online mindfulness programs may not be effective for everyone. Additionally, wellness interventions targeted towards individual behavioural changes will only influence employee well-being to some degree. Employees require support from organizations to foster a psychologically safe and healthy workplace. To support and sustain HCW well-being, improvements must be directed at addressing discrepancies between institutional and worker concerns. A holistic approach to HCW mental health is crucial, integrating individual interventions like mindfulness with systemic support emphasizing proactive mental health initiatives in workplaces. To understand their long-term effects, continuous feedback mechanisms in programs and interventions are vital to ensure lasting benefits and adaptability in the demanding healthcare field.

As our findings produced mixed results, much is left to be learned about the benefits of online, brief mindfulness interventions for HCWs and program delivery during times of crisis. Enhancing connections in future online mindfulness-based programs will be essential. For participants who felt a sense of disconnection, consistency in the weekly participants and assigned facilitator was noted as a strategy that may be helpful in future cohorts. To ensure greater consistency, future programs could consider a closed group design. Additionally, being off-camera was cited as a barrier to developing peer-to-peer connections, whereas the option to remain anonymous drew others into the program. A possible solution would be to designate mindfulness programs specific to those who wish to participate with cameras on versus off so individuals can choose how they wish to participate. Hybrid program models that combine online and in-person sessions could also cater to diverse needs. As technology problems were a frequently cited concern with the online program, providing a space to check computer systems prior to a virtual session could help troubleshoot such issues.

Future research should explore methods for enhancing connection in virtual care settings. Future interventions can also prioritize professional development and technology training for HCWs to address rapid environmental changes promptly when they arise, along with potential barriers to adaptation. Virtual or hybrid mindfulness-based programs should emphasize a deeper understanding of specific emotions versus broader emotional states.

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 involving human participants was approved by the Institution's Ethics Review Board (Waypoint Center for Mental Health Care, Protocol ref. # HPRA#20.07.27). This study was conducted in accordance with the local legislation and institutional requirements. The 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

AM: Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. CC: Formal analysis, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing. FC: Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. SH: Investigation, Supervision, Writing – review & editing. SK: Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Writing – review & editing.

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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 emergence of COVID-19 over-concern immediately after the cancelation of the measures adopted by the dynamic zero-COVID policy in China

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Background: This study aimed to report the prevalence of COVID-19 over-concern and its associated factors after the relaxation of the health-protective measures in China.

Methods: A team of seven experts in psychiatry and psychology specializing in COVID-19 mental health research from China, Hong Kong, and overseas reached a consensus on the diagnostic criteria for COVID-19 over-concern. Individuals had to meet at least five of the following criteria: (1) at least five physical symptoms; (2) stocking up at least five items related to protecting oneself during the COVID-19 pandemic; (3) obsessive-compulsive symptoms related to the COVID-19 pandemic; (4) illness anxiety related to the COVID-19 pandemic; (5) post-traumatic stress symptoms; (6) depression; (7) anxiety; (8) stress and (9) insomnia. An online survey using snowball sampling collected data on demographics, medical history, views on COVID-19 policies, and symptoms of COVID-19 over-concern. Multivariate linear regression was performed using significant variables from the previous regressions as independent variables against the presence of COVID-19 over-concern as the dependent variable. Breush-Pagan test was used to assess each regression model for heteroskedasticity of residuals.

Results: 1,332 respondents from 31 regions in China participated in the study for 2 weeks from December 25 to 27, 2022, after major changes in the zero-COVID policy. After canceling measures associated with the dynamic zero-COVID policy, 21.2% of respondents fulfilled the diagnostic criteria for COVID-19 over-concern. Factors significantly associated with COVID-19 over-concern were poor self-rated health status ($\beta = 0.07$, $p < 0.001$), concerns about family members getting COVID-19 ($\beta = 0.06$, $p < 0.001$),

perceived usefulness of COVID-19 vaccine ($\beta = 0.03$, $p = 0.012$), impact on incomes, employment and studies ($\beta = 0.045$, $p < 0.001$) and impact on families ($\beta = 0.03$, $p = 0.01$).

Conclusion: After removing measures associated with the dynamic zero-COVID policy in China, approximately one-fifth of respondents met the diagnostic criteria for COVID-19 over-concern.

KEYWORDS

COVID-19, overconcern, China, dynamic zero-COVID, illness anxiety, depression, anxiety, stress

Introduction

In December 2021, China implemented the dynamic zero-COVID policy to contain localized COVID-19 flare-ups through timely interventions (1). This policy entailed a series of stringent control measures, including (i) medical isolation of close contacts of confirmed cases, (ii) massive nucleic acid testing, (iii) citywide home quarantine, (iv) electronic health pass to gain entry to public places, (v) travel restrictions, and (vi) quarantine on arrival for citizens and foreigners from other countries and enforcement of protective measures (e.g., wearing face masks in public areas) (2). While the policy kept the number of COVID-19 cases low by cutting off transmissions in the communities, it exerted downward pressure on the economy (2) and led to personal burnout (3). A significant turning point in this policy occurred on December 7, 2022, when China's National Health Commission announced the complete removal of the dynamic zero-COVID policy, which was immediately put into effect (4). This shift signaled the removal of certain measures that had become an integral part of daily life, signifying a new phase in China's battle against the pandemic.

After the relaxation of the above measures, there had been a rapid and substantial increase in the number of COVID-19 cases in China. Local news reported that specific abnormal illness behaviors occurred, including physical symptoms (e.g., sore throat, difficulty in breathing), hypochondriac thought of having COVID-19 infection despite the negative result, the compulsion to repeat COVID-19 testing and stocking of medications, depression, anxiety, insomnia and post-traumatic stress symptoms (5). Notably, the media's role in amplifying negative information during a pandemic, as Bagus et al. (6) highlighted, could contribute to mass over-concern among the population (6). While previous studies focused on COVID-19 panic under restrictive measures (7, 8), some scholars have observed an increase in COVID-19 over-concern when the Zero-COVID Policy is lifted (9). Considering the rapid transmission rate of COVID-19 and the typical recovery period for most individuals, there is a limited timeframe for conducting this study. Hence, it is crucial for the research team to investigate the prevalence of COVID-19 over-concern during this critical period, and our findings will serve as a historical reference.

This study was initiated and completed shortly after the policy changes, and at that time, diagnostic criteria or recommendations for COVID-19 over-concern had not yet been established. The study team which comprises academic and clinical experts from China, Hong Kong and Singapore with experience in COVID-19 research reached a consensus and defined the diagnostic criteria for COVID-19 over-concern. The seven experts include two clinical psychiatrists from China with experience in COVID-19 mental health research, one professor of psychiatry from China with experience in COVID-19 research, two academic psychologists from China with experience in COVID-19 mental health research, one academic researcher from Hong Kong with experience in COVID-19 mental health research and one professor of psychiatry outside China who specialized in COVID-19 research and served as an external advisor.

The diagnostic criteria are based on the chain mediation model, which shows that the perceived impact of the pandemic was sequential mediators between physical symptoms resembling COVID-19 infection (i.e., the predictor) and consequent mental health status (i.e., the outcome) (10). The previous questionnaires on the psychological impacts of the COVID-19 pandemic and zero-COVID policy in China were also reviewed (3, 11–14). A person must fulfill at least five out of nine criteria, including (1) at least five physical symptoms; (2) stocking up at least five items related to protecting oneself during the COVID-19 pandemic; (3) obsessive-compulsive symptoms related to the COVID-19 pandemic; (4) illness anxiety related to the COVID-19 pandemic; (5) post-traumatic stress symptoms; (6) depression; (7) anxiety; (8) stress and (9) insomnia. The primary aim of this study was to establish the prevalence of COVID-19 over-concern in China shortly after major changes to the dynamic zero-COVID policy. The secondary aim was to identify the associations between demographics, health status, COVID-19-related information, views toward dynamic zero-COVI policy and severity of an individual with the defined symptoms of COVID-19 over-concern.

The study team had three hypotheses: (1) The COVID-19 over-concern was a common condition, and the prevalence would be higher than 10% when the dynamic zero-COVID measures were lifted; (2) Higher severity of physical symptoms would be associated with higher severity of psychological symptoms, including obsessive-compulsive symptoms, illness anxiety, depression, anxiety, stress, PTSD symptoms and insomnia; (3) The severity of COVID-19 over-concern among individuals was positively associated with the extent to which they perceive various aspects of their lives being affected.

The results of this study can assist health authorities develop a series of measures to help the public effectively manage different stages of a pandemic, particularly when strict policies are suddenly canceled.

Materials and methods

Setting and participants

The cross-sectional study used an anonymous online survey to assess the presence and severity of COVID-19 over-concern symptoms and views toward the zero-COVID-19 policy. We adopted a snowball sampling strategy focusing on recruiting the general public living in mainland China. Snowball sampling was a recruitment strategy commonly used during the COVID-19 pandemic, in which existing research participants were asked to identify other potential research participants (15). A sample size of 385 would give a sample size sufficient to draw assumptions of the population size of China at 95% confidence level and 5% margin of error. Data collection took place over 3 days (from 25 to 27 December 2022) after major changes in the zero-COVID policy for 2 weeks.

The inclusion criteria included: (1) at least 18 years of age; (2) residing in China at the time of the survey; and (3) being able to read and understand simplified Chinese, a written language used in Mainland China. The exclusion criteria included: (1) known to be positive for COVID-19 infection at the time of the survey; and (2) currently being hospitalized due to COVID-19 infection at the time of the survey; (3) history of severe mental illnesses (e.g., schizophrenia, intellectual disability, dementia) that affect the capacity to provide informed consent and fill the questionnaires. People who were known to be positive for COVID-19 infection and hospitalized due to COVID-19 infection at the time of the survey were encouraged not to participate in this study.

To achieve good quality control of responses, the following measures were applied: (1) Only one questionnaire could be submitted from one IP address to avoid duplicated entries from a single IP address or participant; (2) Use reCAPTCHA acknowledgement to avoid completing the questionnaire by computers or artificial intelligence systems; (3) If a participant submitted the questionnaire within 420 s, the questionnaire would be classified as invalid; (4) If a participant reported the highest level of education as a bachelor, master or PhD degree but the reported ages were less than 18 years, 21 years and 23 years, respectively, the questionnaire would be classified as invalid because a Chinese citizen could not enter the universities to pursue the above degrees below the minimum entry age set by the government (i.e., 18 years for bachelor, 21 years of master and 23 years for PhD degrees); (5) If a participant reported as married but the reported age was younger than 20 years for female and 22 years for male participants, the questionnaire would be classified as invalid because a Chinese citizen could not get married below the legal age of marriage set by the government (i.e., 20 years for women and 22 years for men).

Procedure

Information about this study was posted on a dedicated website. All respondents provided informed consent before participation. The participants completed the online questionnaire through an online survey platform ('SurveyStar,' Changsha Ranxing Science and Technology, Shanghai, China) that could only reach participants who stayed in Mainland China (excluding Hong Kong and Macau Special Administrative Regions). The platform allowed each IP address to submit one questionnaire to avoid multiple submissions from the same participant. Expedited ethics approval was obtained from the Institutional Review Board (IRB) of the Huaibei Normal University, China (HBS-FDX-2022-012). The design of this study conformed to the principles embodied in the Declaration of Helsinki.

Survey development

The previous questionnaire on the psychological impacts of the COVID-19 pandemic and zero-COVID policy in China was reviewed (3, 11–14). The experts of the study team reached a consensus that COVID-19 over-concern was defined and characterized by obsessive and compulsive symptoms in thinking and checking for COVID-19 symptoms and related information, having an illness anxiety of contracting COVID-19 infection, having anxiety, depression, stress or post-traumatic stress symptoms due to strict measures associated with the dynamic zero-COVID policy. The experts from the authors' team selected questionnaires that were previously validated in Chinese and included additional questions related to the dynamic zero-COVID policy and the current situation in China. The structured online survey consisted of questions that covered the following areas: (1) demographics; (2) physical symptoms and health status in the past 14 days; (3) past COVID-19 history and strategies to cope with the COVID-19 pandemic; (4) views toward the measures associated with the dynamic zero-COVID policy; (5) the impact of dynamic zero-COVID policy; (6) the illness attitude scale with specific reference to COVID-19 infection; (7) Yale-Brown Obsessive Compulsive scale with specific reference to measures related to the dynamic zero-COVID policy; (8) Depression, Anxiety and Stress scale −21 items (DASS-21), (9) Impact of Event Scale–Revised (IES-R) and (10) Insomnia Severity Index (ISI).

Sociodemographic data, including age, gender, education level, marital status, living arrangement, occupation, and preferred place to work or study (e.g., home or office) were collected. Physical symptoms resembling COVID-19 infection in the past 14 days included chills, cough, coryza, difficulty breathing, dizziness, fever, headache, loss of taste and smell, myalgia, sore throat or other physical symptoms. Participants were asked to rate their physical health status and state any history of chronic medical illness. Past COVID-19 history includes the number of times contracting COVID-19 infection, vaccination history against COVID-19 infection, hoarding of the items to combat COVID-19 infection (e.g., antipyretics, alcohol swabs, facemasks, thermometers, traditional Chinese medicine to treat COVID-19 infection), last admission to Fangcang hospitals, a kind of large-scale, temporary, mobile hospitals built and used during the COVID-19 pandemic in China, number of times being lockdown, number of deaths due to COVID-19 infection in participants' families and concerns of family members contracting COVID-19 infection.

The participants rated their views toward procedures adopted by the dynamic zero-COVID policy on a Likert scale: (i) massive nucleic acid testing; (ii) citywide home quarantine; (iii) booster of COVID-19 vaccination; (iv) electronic health pass; (v) travel restrictions; (vi) working or attending classes from home; (vii) limitation on the sales of antipyretics and other medications to treat influenza over the counter, (viii) closure of public places (e.g., swimming pool, karaoke, etc.), (ix) restriction to dine at food and beverage establishments, (x) wearing facemasks at indoor and outdoor venues. The participants

also rated the impact of the COVID-19 pandemic and dynamic-zero COVID policy on a Likert scale: (i) on their lives; (ii) their incomes; (iii) families; and (iv) traveling.

Psychiatric scales

The illness attitude scale (IAS) measured the illness anxiety associated with COVID-19 infection, a 29-item scale that has nine subscales including (1) worry about COVID-19 infection, (2) concerns about the discomfort associated with COVID-19 infection, (3) health habits, (4) hypochondriacal beliefs, (5) fear of death, (6) phobia of COVID-19 infection, (7) bodily preoccupations, (8) treatment experience, and (9) effects of COVID-19 symptoms (16). The total score is between 0 and 108, with a cut-off score of 44 and above to classify as a case of illness anxiety for COVID-19 infection (17). The Cronbach's alpha reliability for the Chinese version of the IAS ranged from 0.68–0.82 for the four subscales (Patho-thanatophobia: 0.82; Symptom effect: 0.82; Treatment seeking: 0.74; Hypochondriacal belief: 0.68) (18). The test–retest reliability was 0.95 (18). For this study, the Cronbach's alpha reliability for IAS is 0.91.

The Yale-Brown Obsessive Compulsive Scale Mandarin Chinese version (Y-BOCS) has 10 questions (19). The first half of the scale assesses common obsessions: excessive fears of contamination and recurring doubts about danger. The second half of the questionnaire assesses compulsions that help to lessen feelings of anxiety or other discomfort. The Chinese version of the Y-BOCS demonstrated excellent psychometric properties, including high internal consistency (0.88) and a cut-off score of 16 and above to classify a case of being obsessive-compulsive (20). For this study, the Cronbach's alpha reliability of Y-BOCS is 0.83.

The post-traumatic symptoms associated with the COVID-19 pandemic and measures related to the zero-COVID policy were measured using the Impact of Event Scale-Revised (IES-R). The IES-R is a self-administered questionnaire validated in the Chinese population for determining the extent of post-traumatic stress in a public health crisis within 1 week of exposure to the COVID-19 pandemic in various cultures (21–26). The IES-R has been well-validated and extensively used for determining the extent of psychological impact in response to the COVID-19 pandemic among Chinese (27). The Cronbach's alpha reliability for the Chinese version of IES-R was 0.949 (10). For this study, the Cronbach's alpha reliability of IES-R is 0.96. The IES-R has three subscales measuring the avoidance, hyperarousal and intrusion (28). A total IESR score of 33 or over indicates the likely presence of post-traumatic stress disorder (28).

Depression, anxiety and stress associated with the cancelation of measures associated with the dynamic zero-COVID policy was measured by using the Depression, anxiety and stress scale (21-item) DASS-21 scale. The DASS-21 is a reliable and valid measure in assessing mental health in the Chinese (29), Filipino (30), Iranian (26), Polish (15), Spanish (23) and Vietnamese (31) during the COVID-19 pandemic. The cut-off score for the DASS-21 depression scale was ≥14; the DASS-21 anxiety scale was ≥10; andthe DASS-21 stress scale score was ≥19 (11). Wang et al. reported that the test–retest reliability over a 6-month interval was 0.39 to 0.46 for each of the 3 subscales of DASS-21 and 0.46 for the total DASS-21 score. Moderate convergent validity of the Depression and Anxiety subscales of DASS-21 demonstrated significant correlations with the Chinese Beck Depression Inventory and the Chinese State–Trait Anxiety Inventory (32). For this study, the Cronbach's alpha reliability of DASS-21 is 0.96. The Cronbach's alpha reliability of depression, anxiety and stress subscales are 0.9, 0.89 and 0.9, respectively.

Sleep quality was assessed by using the Insomnia Severity Index (ISI). The ISI assesses the severity of sleep difficulties, the extent to which sleep problems interfere with daily functioning and the impact of sleep problems on quality of life. The ISI was validated in Chinese during the COVID-19 pandemic (33). The cut-off score for clinical insomnia is greater or equal to 15.The Cronbach's alpha reliability of the Chinese version ISI was 0.83 and the 2-week test–retest reliability was 0.79 (34). For this study, the Cronbach's alpha reliability of ISI is 0.92.

For the entire survey, the Cronbach's alpha reliability, Split-half reliability, Content Validity Index, and Kappa values were 0.967, 0.783, 0.967, and 0.967, respectively, reflecting excellent internal consistency, good reliability, and strong content validity. The Content Validity Index and Kappa values were evaluated by seven external experts who were not members of the study team, including two psychologists, four psychiatrists, and one epidemiologist (see Supplementary Table S1).

Statistical analysis

Descriptive statistics were calculated for sociodemographic characteristics, physical health status, views toward measures adopted by the dynamic zero-COVID policy, and the perceived impact of the dynamic zero-COVID policy. Percentages of responses were calculated according to the number of respondents per response with respect to the number of total responses to a question. The total scores of the Y-BOCS, IAS, IES-R, DASS-21 and ISI. Their respective subscales were expressed as mean and standard deviation. The number and percentage of respondents above the cut-off scores for different scales, respondents reporting 5 or more COVID-19-related symptoms and hoarding 5 or more COVID-19-related precautionary items, were calculated. Linear regression was used to calculate the univariate associations between sociodemographic characteristics, physical health status, views toward measures adopted by the dynamic zero-COVID policy, and the perceived impact of the dynamic zero-COVID policy, against the total scores of Y-BOCS, illness attitude scale, IES-R, DASS-21, and ISI. The Variance Inflation Factor (VIF) was used to detect multicollinearity among the predictor variables. If the VIF is more than 5, the regression analysis is said to be highly correlated. Multivariate linear regression was then performed using significant variables from the previous regressions as independent variables, against presence of COVID-19 over-concern as the dependent variable with adjustment of potential confounding demographic factors. Zero-order and partial correlation were also calculated from the multivariate regression. Breusch-Pagan test was used to test each regression model for heteroskedasticity of residuals. If heteroskedasticity exists, the regression contains unequal variance and the analysis results may be invalid. All tests were two-tailed, with a significance level of $p < 0.05$. Statistical analysis was done using SPSS Statistic 28.0.

Results

Demographics of respondents

We received responses from 1,526 respondents, and 175 did not complete the questionnaires. Eventually, we included 1,332

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TABLE 1 Demographic data characteristics ($N = 1,332$).

Demographic data	Number (%)
Age	
18–21 years	169 (12.6)
22–30 years	296 (22.2)
31–40 years	442 (33.2)
41–49 years	274 (20.6)
50–59 years	114 (8.6)
Above 60 years	37 (2.8)
Gender	
Male	575 (43.2)
Female	757 (56.8)
Highest education level	
None/Kindergarten	4 (0.3)
Primary school	8 (0.6)
Junior high school	31 (2.3)
Senior high school	88 (6.6)
Junior college	258 (19.4)
University: Bachelor	665 (49.9)
University: Master	232 (17.4)
University: PhD	46 (3.5)
Marital status	
Single or not married	473 (35.5)
Married	785 (58.9)
Divorce or Separated	65 (4.9)
Widowed	9 (0.7)
Household size	
Living alone	139 (10.4)
2 people	331 (24.8)
3 to 5 people	806 (60.5)
6 or more people	56 (4.2)
Do you live with the following family members (Multiple choice)	
Living with a child under 16 years old	540
Living with a child over 16 years old	160
Living with two or more children	191
Living with a healthy older adult	444
Living witan a older adult with poor health	102
Do not live with children or older adult	382
Employment status	
Unemployed or waiting for work	54 (4.1)
Retired	74 (5.6)
Freelancer	137 (10.3)
Managers of government agencies and public institutions	220 (16.5)
Professional and technical personnel	228 (17.1)
Clerical and related personnel	64 (4.8)
Commercial and service personnel	102 (7.7)
Production personnel in agriculture, forestry and fishery	7 (0.5)
Production, transportation and equipment operators	21 (1.6)
Soldier	1 (0.1)
Student	195 (14.6)
Housewife	30 (2.3)
Medical worker, doctor, nurse, examiner, therapist, others	70 (5.3)
Workers related to epidemic prevention, nucleic acid monitoring	3 (0.2)
Self-employed	31 (2.3)
Others	92 (7.1)
Work/study condition	
I am working in the office	587 (44.1)
I am working in a factory	50 (3.8)
I am working from home	226 (17.0)
I do not have a fixed place to work	51 (3.8)
I am working on vacation	46 (3.5)
I am studying from home	128 (9.6)
I am studying in school	23 (1.7)
I am on study leave or vacation	46 (3.5)
Others	175 (13.1)

respondents (completion rate: 87.29%) from 22 provinces, four municipalities and five autonomous regions in China. The five areas with the largest number of respondents were Beijing ($N = 235$, 17.64%), Sichuan Province ($N = 205$, 15.39%), Guangdong Province ($N = 145$, 10.89%), Chongqing ($N = 105$, 7.88%) and Hubei Province ($N = 73$, 5.48%). Table 1 summarizes the demographics of the participants. Sixty-eight percent of participants were 40 years and below. The majority of participants were women (56.8%), had a university education with at least a bachelor degree and above (70.8%), married (58.9%) and living with 3 to 5 people (60.5%). Only 4.1% of respondents were unemployed, and the three most frequent occupations were professional and technical personnel (17.1%), managers of government agencies and public institutions (16.5%) and students (14.6%). The majority of respondents (44%) worked in the office, while 17 and 9.6% worked and studied from home, respectively.

Frequencies of responses to health status and questions related to COVID-19 pandemic and dynamic zero-COVID policy

The most common physical symptoms experienced by respondents in the past 14 days were cough (740 respondents), stuffy nose (598 respondents) and coughing up phlegm (594 respondents; see Supplementary Table S2). About 63.3% of respondents related their health status as healthy and relatively healthy. About 72.1% of respondents had at least one episode of COVID-19 infection. About

58.4% were fully vaccinated with no booster shot and one booster shot. The most common items hoarded by respondents were fever medicine (1,041 respondents), cold medicine (980 respondents) and thermometer (866 respondents). About 1% of respondents were admitted to Fangcang hospital due to COVID-19 infection. About 2.9% of respondents had a family or friend who died from COVID-19 infection. About 70.3% of respondents experienced at least one lockdown in their residential areas. About 63.9% of respondents experienced at least 7 days of lockdown in 2022. About 79.5% of respondents were slightly and very worried about their family members getting COVID-19 infection. The measures associated with dynamic zero-COVID policy had the highest percentage of strong agreement of beneficences were home quarantine for people infection with COVID-19 infection (31%), receiving COVID-19 infection and booster shots (25.9%) and close management of small district with infected COVID-19 cases (23.2%; see Supplementary Table S3). About 95.3% of respondents rated mild to very severe impact due to the COVID-19 pandemic and dynamic zero-COVID policy (see Supplementary Table S4).

Prevalence of COVID-19 over-concern

Table 2 shows the number of participants who scored above the cut-off scores for the Y-BOCS, Illness Anxiety Scale, DASS-21 Scale, IES-R Scale and Insomnia Severity Index. About 27.2% of respondents exhibited significant obsessive-compulsive symptoms, 37.6% demonstrated significant illness anxiety, 20.5% reported significant PTSD symptoms, 27.8% reported significant depressive symptoms, 35.4% reported significant anxiety symptoms, 10.3% reported

TABLE 2 Summary of yale-brown, illness anxiety, DASS-21, IES-R, and insomnia severity index scores among participants ($N = 1,332$).

Psychosocial profile	Mean ± SD [Number (%)]
Yale-Brown total score	**11.84 ± 5.71**
Number of participants above YBOCS [a] cut-off score	362 (27.2)
Illness anxiety total score	**38.81 ± 16.10**
IAS[b]-1: Worry about illness	4.77 ± 2.66
IAS-2: Concerns about pain	5.64 ± 2.82
IAS-3: Health habits	6.42 ± 2.92
IAS-4: Hypochondriacal beliefs	3.44 ± 2.33
IAS-5: Thanatophobia	3.90 ± 3.13
IAS-6: Disease phobia	3.90 ± 3.13
IAS-7: Bodily preoccupation	3.98 ± 2.78
IAS-8: Treatment experience	4.10 ± 2.61
IAS-9: Effects of symptoms	3.73 ± 2.56
Number of participants above IAS cut-off score	501 (37.6)
IES-R[c]total score	**20.30 ± 14.59**
Avoidance Intrusion Hyperarousal	7.38 ± 5.71 7.43 ± 5.59 5.44 ± 4.36
The number of participants above the IES-R cut-off score	273 (20.5)
DASS-21[c]score	**23.30 ± 22.91**
Depression Anxiety Stress	7.81 ± 8.10 7.31 ± 7.59 8.19 ± 8.15
Number of participants above the Depression cut-off score	370 (27.8)
Number of participants above the Anxiety cut-off score	471 (35.4)
Number of participants above the Stress cut-off score	137 (10.3)
Insomnia severity index total score	**6.49 ± 5.48**
Number of participants above ISI[e] cut-off score	105 (7.9)
Participants who experienced five or more COVID-19-related symptoms in the past 14 days	**725 (54.4)**
Participants who hoarded five or more COVID-19-related prevention and control items in the past 14 days	**913 (68.5)**

[a]YBOCS, Yale-Brown Obsessive-compulsive scale. [b]IAS, Illness Anxiety Scale. [c]IES-R, Impact of Event Scale-Revised. [d]DASS-21, Depression, Anxiety, Stress Scale. [e]ISI, Insomnia Severity Index.

significant stress symptoms and 7.9% reported clinically significant insomnia. About 54.4% of respondents experienced five or more COVID-19-related symptoms in the past 14 days, and 68.5% of respondents hoarded 5 or more COVID-19-related precautionary items in the past 14 days. Two hundred eighty-three respondents (21.2%) who fulfilled the diagnostic criteria for COVID-19 over-concern by meeting the cut-off for at least 5 of the above symptoms.

Regression analysis

Table 3 shows the linear regression analysis using psychological outcomes as dependent variables and demographic data as independent variables. Younger age was significantly associated with higher mean scores in obsessive-compulsive symptoms ($p < 0.05$), post-traumatic stress ($p < 0.01$), depression, anxiety and stress ($p < 0.001$). Male gender ($p < 0.01$) and education ($p < 0.001$) were significantly associated with higher mean scores of illness anxiety. Employment was significantly associated with lower mean scores in obsessive-compulsive symptoms ($p < 0.05$), illness anxiety ($p < 0.05$), depression, anxiety and stress ($p < 0.05$) and insomnia ($p < 0.05$). Marital status and household size were not associated with psychological outcomes ($p > 0.05$). Breusch-Pagan test showed the presence of heteroskedasticity in the regression model using DASS-21 as dependent variable ($p < 0.05$; see Supplementary Table S5).

Table 4 shows the linear regression analysis using psychological outcomes as dependent variables and physical health status as independent variables. The presence of 5 or more physical symptoms was significantly associated with higher mean scores in illness anxiety ($p < 0.001$), post-traumatic stress ($p < 0.01$), depression, anxiety and stress ($p < 0.001$) and insomnia ($p < 0.001$). Poor self-health status was significantly associated with higher mean scores in obsessive-compulsive symptoms ($p < 0.001$), illness anxiety ($p < 0.001$), post-traumatic stress symptoms ($p < 0.001$), DASS-21 ($p < 0.001$) and insomnia ($p < 0.001$). Hoarding of 5 or more COVID-19-related precautionary items was associated with higher mean scores in

TABLE 3 The linear regression analysis using psychological outcomes as dependent variables and demographic data as independent variables ($N = 1,332$).

Demographic data	YBOCS[a]	IAS[b]	IES-R[c]	DASS-21[d]	ISI[e]	Collinearity
	B[f] (SE)	B (SE)	B (SE)	B (SE)	B (SE)	VIF[g]
Age	−0.043 (0.018)*	−0.083 (0.051)	−0.127 (0.047)**	−0.347 (0.073)***	0.000 (0.018)	1.729
Gender (Female)	0.295 (0.316)	−2.429 (0.886)**	−0.034 (0.809)	0.855 (1.259)	0.176 (0.304)	1.007
Education level	0.269 (0.154)	1.663 (0.431)***	0.135 (0.393)	0.405 (0.612)	−0.028 (0.148)	1.080
Marital status	0.586 (0.339)	1.322 (0.951)	1.107 (0.868)	1.760 (1.352)	−0.162 (0.326)	1.632
Household size	0.334 (0.216)	0.717 (0.606)	0.518 (0.553)	1.330 (0.862)	0.154 (0.208)	1.029
Employment status	−0.780 (0.371)*	−1.516 (1.040)	−1.530 (0.950)	−3.569 (1.479)*	−0.872 (0.357)*	1.127

[a]YBOCS, Yale-Brown Obsessive-compulsive scale. [b]IAS, Illness Anxiety Scale. [c]IES-R, Impact of Event Scale-Revised. [d]DASS-21, Depression, Anxiety, Stress Scale. [e]ISI, Insomnia Severity Index. [f]B, regression coefficient; SE, standard error. [g]VIF, variance inflation factor. *$p < 0.05$. **$p < 0.01$. ***$p < 0.001$.

TABLE 4 The linear regression analysis using psychological outcomes as dependent variables and physical health factors as independent variables ($N = 1,332$).

Physical health status	YBOCS[a]	IAS[b]	IES-R[c]	DASS-21[d]	ISI[e]	Collinearity
	B[f] (SE)	B (SE)	B (SE)	B (SE)	B (SE)	VIF[g]
5 or more physical symptoms	0.494 (0.308)	4.263 (0.813)***	2.063 (0.772)**	6.561 (1.221)***	1.066 (0.296)***	1.050
Self-rated health status	0.954 (0.236)***	4.242 (0.622)***	2.439 (0.591)***	3.558 (0.934)***	1.174 (0.226)***	1.013
Number of past COVID-19 infections	−0.083 (0.104)	−0.401 (0.274)	−0.289 (0.260)	−0.432 (0.412)	−0.174 (0.100)	1.017
COVID-19 vaccination status	0.206 (0.141)	0.205 (0.372)	−0.213 (0.353)	−0.662 (0.558)	−0.124 (0.135)	1.003
5 or more items hoarded	−0.083 (0.328)	1.168 (0.867)	−2.809 (0.824)***	−5.113 (1.302)***	−0.361 (0.316)	1.038
Admission to Fangcang Hospital	0.135 (1.538)	3.258 (4.061)	2.891 (3.857)	3.095 (6.100)	1.401 (1.479)	1.021
Family or friend died from COVID-19	1.405 (0.913)	1.529 (2.410)	3.580 (2.289)	6.718 (3.620)	1.190 (0.878)	1.031
Number to times residential area been locked down	0.409 (0.123)***	0.518 (0.326)	0.454 (0.309)	1.074 (0.489)*	0.236 (0.119)*	1.403
Number of days being lockdown in 2022	0.307 (0.131)*	0.762 (0.345)*	1.111 (0.328)***	1.033 (0.518)*	0.251 (0.126)*	1.399
Concerned about family members getting COVID-19	1.298 (0.174)***	6.460 (0.460)***	4.488 (0.437)***	5.706 (0.691)***	1.129 (0.168)***	1.029

[a]YBOCS, Yale-Brown Obsessive-compulsive scale. [b]IAS, Illness Anxiety Scale. [c]IES-R, Impact of Event Scale-Revised. [d]DASS-21, Depression, Anxiety, Stress Scale. [e]ISI, Insomnia Severity Index. [f]B, regression coefficient; SE, standard error. [g]VIF, variance inflation factor. *$p < 0.05$. **$p < 0.01$. ***$p < 0.001$.

post-traumatic stress symptoms ($p < 0.001$), depression, anxiety and stress ($p < 0.001$). The higher number of days under lockdown was significantly associated with higher mean scores for obsessive-compulsive symptoms ($p < 0.05$), illness anxiety ($p < 0.05$), post-traumatic stress ($p < 0.001$), depression, anxiety and stress ($p < 0.05$) and insomnia ($p < 0.05$). More concern about family members getting COVID-19 infection was significantly associated with higher mean scores in obsessive-compulsive symptoms ($p < 0.001$), illness anxiety ($p < 0.001$), post-traumatic stress symptoms ($p < 0.001$), depression, anxiety and stress ($p < 0.001$) and insomnia ($p < 0.001$). The number of past COVID-19 infections, COVID-19 vaccination status, previous admission to Fangcang Hospitaland death of a family member or friend due to COVID-19 were not associated with any psychological outcome ($p > 0.05$). Breusch-Pagan test showed absence of heteroskedasticity for all regression models below ($p > 0.05$; see Supplementary Table S5).

Table 5 shows the linear regression analysis using psychological outcomes as dependent variables and views toward dynamic zero-COVID policy as independent variables. Respondents who viewed COVID vaccination as beneficial were significantly associated with higher mean scores in obsessive-compulsive symptoms ($p < 0.01$), illness anxiety ($p < 0.01$), post-traumatic stress ($p < 0.001$), depression, anxiety and stress ($p < 0.001$) and insomnia ($p < 0.001$). In contrast, respondents who viewed working from home as beneficial were significantly associated with lower illness anxiety ($p < 0.01$) but higher insomnia ($p < 0.05$). Respondents who viewed the limitation on sales of antipyretics and other medications as non-beneficial were significantly associated with a higher level of illness anxiety ($p < 0.01$) and insomnia ($p < 0.05$). Respondents who viewed limiting people in public dining areas as beneficial were significantly associated with lower mean scores in obsessive-compulsive symptoms ($p < 0.05$), illness anxiety ($p < 0.001$) and post-traumatic stress ($p < 0.01$). Respondents who viewed wearing face mask all the time as beneficial was significantly associated with a lower mean score in insomnia ($p < 0.01$). Views toward massive nucleic acid testing, home quarantine, close management of the small district, electronic health pass, travel restriction, avoidance of face-to-face contact and closure of indoor leisure facilities were not associated with any psychological outcome ($p > 0.05$). Breusch-Pagan test showed the presence of heteroskedasticity in the regression

TABLE 5 The linear regression analysis using psychological outcomes as dependent variables and views toward the dynamic zero-COVID policy as independent variables ($N = 1,332$).

Opinions	YBOCS[a]	IAS[b]	IES-R[c]	DASS-21[d]	ISI[e]	Collinearity
	B[f] (SE)	B (SE)	B (SE)	B (SE)	B (SE)	VIF[g]
Massive nucleic acid testing is beneficial	−0.261 (0.227)	−1.094 (0.630)	−0.082 (0.578)	−0.223 (0.915)	0.016 (0.216)	2.263
Home quarantine for people with COVID-19 is beneficial	0.053 (0.224)	0.280 (0.621)	−0.033 (0.570)	0.047 (0.902)	0.182 (0.213)	1.478
Home quarantine for people with close contact but no COVID-19 is beneficial	0.244 (0.185)	0.567 (0.512)	−0.149 (0.470)	−0.127 (0.744)	0.259 (0.176)	1.685
Close management of a small district with COVID-19 cases is beneficial	0.302 (0.250)	−0.953 (0.693)	−1.054 (0.636)	−0.760 (1.006)	−0.069 (0.238)	2.384
Receiving COVID-19 vaccination and booster shots is beneficial	0.647 (0.197)**	1.416 (0.546)**	2.013 (0.501)***	2.859 (0.793)***	0.882 (0.187)***	1.350
The use of electronic health pass is beneficial	0.243 (0.255)	−0.215 (0.709)	0.461 (0.650)	0.736 (1.030)	−0.321 (0.243)	2.862
Travel restriction is beneficial	0.004 (0.211)	0.665 (0.584)	−0.325 (0.536)	0.015 (0.849)	−0.294 (0.200)	2.307
Attending online classes and avoid face-to-face classes is beneficial	0.167 (0.194)	0.623 (0.540)	0.553 (0.495)	−0.410 (0.784)	−0.188 (0.185)	1.902
Working from home is beneficial	0.013 (0.215)	−1.650 (0.598)**	0.047 (0.548)	0.116 (0.868)	0.479 (0.205)*	1.725
Limitation on the sale of antipyretics and medication to treat influenzas over the counter is beneficial	0.281 (0.156)	1.211 (0.433)**	0.052 (0.397)	−0.990 (0.629)	0.327 (0.148)*	1.364
Closure of indoor public spaces such as bars, KTV, and swimming pools is beneficial	−0.134 (0.234)	−0.111 (0.650)	−0.476 (0.597)	−0.180 (0.945)	−0.161 (0.223)	2.520
Limiting people in dining areas and encouraging customers to take away is beneficial	−0.590 (0.260)*	−2.514 (0.723)***	−1.767 (0.663)**	−1.049 (1.050)	−0.153 (0.248)	2.481
Wearing face mask all the time is beneficial	−0.354 (0.245)	−0.912 (0.680)	−0.347 (0.624)	−1.159 (0.988)	−0.644 (0.233)**	2.210

[a]YBOCS, Yale-Brown Obsessive-compulsive scale. [b]IAS, Illness Anxiety Scale. [c]IES-R, Impact of Event Scale-Revised. [d]DASS-21, Depression, Anxiety, Stress Scale. [e]ISI, Insomnia Severity Index. [f]B, regression coefficient; SE, standard error. [g]VIF, variance inflation factor. *$p < 0.05$. **$p < 0.01$. ***$p < 0.001$.

models using DASS-21 and ISI as dependent variables ($p < 0.05$; see Supplementary Table S5).

Table 6 shows the linear regression analysis using psychological outcomes as dependent variables and the perceived impact of measures associated with dynamic zero-COVID policy as independent variables. The greater perceived impact on lives was significantly associated with higher mean scores in obsessive-compulsive symptoms ($p < 0.001$), illness anxiety ($p < 0.001$), post-traumatic stress symptoms ($p < 0.001$), DASS-21 ($p < 0.01$) and insomnia ($p < 0.001$). The greater perceived impact on income, employment and studies was significantly associated with obsessive-compulsive symptoms ($p < 0.001$), post-traumatic symptoms ($p < 0.01$), depression, anxiety and stress ($p < 0.001$). The perceived impact on the family was significantly associated with higher mean scores in obsessive-compulsive symptoms ($p < 0.001$), illness anxiety ($p < 0.001$), post-traumatic stress symptoms ($p < 0.01$), depression, anxiety and stress ($p < 0.01$) and insomnia ($p < 0.05$). The perceived impact of traveling was significantly associated with obsessive-compulsive symptoms ($p < 0.001$) and illness anxiety ($p < 0.05$). Breusch-Pagan test showed the presence of heteroskedasticity for all regression models below ($p < 0.05$; see Supplementary Table S5).

Table 7 shows the linear regression analysis between COVID-19 over-concern and significant independent variables identified by previous regression analysis after adjustment for age, gender, education level and employment status. Poor self-rated health status ($p < 0.001$), number of days under lockdown in 2022 ($p < 0.01$), concerns about family members contracting COVID-19 infection ($p < 0.001$), perceived usefulness of receiving COVID-19 vaccine and booster shot ($p = 0.011$) were significantly associated with the development of COVID-19 over-concern. In contrast, views on working from home, views on the limitation on sales of antipyretics and medication, and views on limitations on public dining were not associated with the developing of COVID-19 over-concern ($p > 0.05$). Breusch-Pagan test showed absence of heteroskedasticity in the regression model ($p > 0.05$).

Discussion

This study was conducted to explore COVID-19 over-concern following the removal of stringent restrictive measures in a country implementing the dynamic zero-COVID policy. Data collection occurred during a critical window from December 25 to 27, 2022,

TABLE 6 The linear regression analysis using psychological outcomes as dependent variables and the perceived impact of measures associated with dynamic zero-COVID policy as independent variables ($N = 1,332$).

Perceived impact of measures	YBOCS[a]	IAS[b]	IES-R[c]	DASS-21[d]	ISI[e]	Collinearity
	B[f](SE)	B (SE)	B (SE)	B (SE)	B (SE)	VIF[g]
Impact on lives	1.398 (0.197)***	3.184 (0.601)***	2.003 (0.554)***	2.514 (0.872)**	0.946 (0.209)***	1.861
Impact on incomes, employment, and studies	0.696 (0.159)***	0.282 (0.484)	1.459 (0.446)**	2.579 (0.703)***	0.234 (0.169)	1.667
Impact on families	0.632 (0.154)***	1.571 (0.471)***	1.329 (0.433)**	2.125 (0.683)**	0.398 (0.164)*	1.629
Impact on leisure and business trips	0.507 (0.149)***	0.980 (0.454)*	−0.135 (0.418)	−0.344 (0.659)	−0.055 (0.158)	1.637
The latest health information related to COVID-19 are clear and correct	0.315 (0.150)*	0.961 (0.457)*	0.563 (0.421)	1.068 (0.663)	0.428 (0.159)**	1.006

[a]YBOCS, Yale-Brown Obsessive-compulsive scale. [b]IAS, Illness Anxiety Scale. [c]IES-R, Impact of Event Scale-Revised. [d]DASS-21, Depression, Anxiety, Stress Scale. [e]ISI, Insomnia Severity Index. [f]B, regression coefficient; SE, standard error. [g]VIF, variance inflation factor. *$p < 0.05$. **$p < 0.01$. ***$p < 0.001$.

TABLE 7 Linear regression analysis between COVID-19 over-concern and independent variables ($N = 1,332$) after adjustment of confounding demographic factors.

Independent variables	COVID-19 over-concern[a]				
	B[a](SE)	Zero-order correlation	Partial correlation	*p*-value	VIF[b]
Poor self-rated health status	0.077 (0.017)	0.129	0.123	<0.001***	1.004
Number of days under lockdown in 2022	0.025 (0.008)	0.098	0.083	0.002**	1.007
Concerned about family members getting COVID-19	0.081 (0.013)	0.178	0.167	<0.001***	1.088
Receiving COVID-19 vaccination and booster shots is beneficial	0.033 (0.013)	0.037	0.070	0.011*	1.200
Working from home is not beneficial	0.006 (0.013)	0.040	0.012	0.661	1.246
Limitation on the sale of antipyretics and medication to treat influenzas over the counter is not beneficial	0.004 (0.010)	0.012	0.012	0.672	1.194
Limiting people in public dining areas and encouraging customers to take away is not beneficial	0.009 (0.014)	0.054	0.019	0.498	1.405

Adjusted with confounding factors: Age, Gender, Education level, Employment status. [a]B, regression coefficient; SE, standard error. [b]VIF, variance inflation factor. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

which followed closely after the peak of COVID-19 infections in China on 22 December 2022, when the Chinese Center for Disease Control and Prevention reported a peak of 6.94 million positive cases, which subsequently began to decline (35). COVID-19 over-concern could be considered a new type of hypochondriasis during this period (36). Our study featured 1,332 respondents from 31 regions in China, boasting a robust 87.29% response rate. This diverse sample, comprising individuals of different ages, genders, educational backgrounds, marital statuses, and living arrangements, contributes to the depth and breadth of our research findings. According to this study, after the cancelation of the measures adopted by the dynamic zero-COVID policy in China, there were 283 respondents (21.2%) who fulfilled at least five of the diagnostic criteria for COVID-19 over-concern. This finding supports hypotheses 1 (The COVID-19 over-concern was a common condition and the prevalence would be higher than 10% when the dynamic zero-COVID measures were lifted). This study identified that poor self-rated health status, concerns about family members contracting COVID-19 infection, perceived usefulness of receiving COVID-19 vaccine and booster shot, negative impact on incomes, employment and studies and negative impact on families were significantly associated with the development of COVID-19 over-concern after adjustment of confounding demographic factors and these associations warranted further discussion.

Young age was associated with the development of COVID-19 over-concern after the cancelation of measures associated with the dynamic zero-COVID policy. In this study, young age was specifically associated with more severe obsessive-compulsive symptoms and post-traumatic stress, after the cancelation of measures associated with the dynamic zero- COVID policy. This finding was not surprising as the academic and social lives of young Chinese were more affected by the COVID-19 pandemic due to the prolonged closure of school and cancelation of extra-curricular activies (37), long periods of online learning (38, 39), disruption of public examinations (11), suspension of cross border education between territories (40), not being able to return to hometown or village during holidays (37), poor social support from peers (39), and social isolation due to quarantine of self, friends and family members (39, 41). Because of the above school arrangement and lifestyle changes, young Chinese were deprived of the opportunities to develop social and interpersonal skills during the pandemic. Consequently, they might experience the greatest psychological impact following the cancelation of measures associated with the dynamic zero-COVID policy, as they foresaw challenges in readjusting to their previous lifestyles with more face-to-face contact and concerns about the potential risk of contracting COVID-19 without restrictive measures.

The most common physical symptoms experienced by respondents in the past 14 days were cough, stuffy nose and coughing up phlegm. It is not surprising that poor self-rated health status and concerns about family members contracting COVID-19 infection were associated with the development of COVID-19 over-concern after the cancelation of measures associated with the dynamic zero COVID policy. This finding supported hypothesis 2 (Higher severity of physical symptoms would be associated with higher severity of psychological symptoms, including obsessive-compulsive symptoms, illness anxiety, depression, anxiety, stress, PTSD symptoms and insomnia). This study found that poor self-rated health status and more concern about family members getting COVID-19 were significantly associated with higher mean scores in obsessive-compulsive symptoms, illness anxiety, post-traumatic stress symptoms, depression, anxiety and stress and insomnia. While most of the research focuses on mental health status, there is a paucity of research data on the Chinese population about the impact of poor self-rated physical status and concerns about family members during the COVID-19 pandemic. A previous global research found that poor self-rated physical health status is a mediator between the COVID-10 pandemic and adverse mental health status (10). After the cancelation of the dynamic zero-COVID measures, people with poor self-rated health status and concerns about family members faced challenges in two folds: (1) an increased risk of contracting COVID-19 infection; (2) a reduction in healthcare system resources available to manage non-COVID-19 diseases due to the strain imposed by an overload of COVID-19 cases.

It was unexpected that the perceived usefulness of receiving the COVID-19 vaccine and booster shot was significantly associated with the development of COVID-19 over-concern after the cancelation of measures associated with the dynamic zero-COVID policy. This finding suggests that people might perceive the COVID-19 vaccine and booster as useful but still lack confidence that the vaccine could prevent future strains of COVID-19 infection. Global acceptance of COVID-19 vaccines depends on several factors related to psychology, society, and the vaccines themselves. A previous study found that low confidence in the COVID-19 vaccine might negatively influence people's health behaviors during the COVID-19 pandemic (42). Since China did not have an mRNA vaccine available at the time of the study, participants may have had unmet expectations regarding the vaccine's effectiveness (43), particularly against future strains and mutations of coronavirus. The confidence might improve as the Chinese-made mRNA vaccine against Omicron strains started production in 2023 (44).

Finally, negative impacts on incomes, employment, studies and families were significantly associated with COVID-19 over-concern after the cancelation of measures associated with the dynamic zero-COVID policy. This finding partially supports hypothesis 3 (The severity of COVID-19 over-concern among individuals was positively associated with how much they perceive various aspects of their lives being affected). In this study, most respondents rated mild to very severe impact due to the COVID-19 pandemic and dynamic zero-COVID policy. Unlike citizens in other countries who sought to lift COVID-19 restrictions to facilitate the return of their incomes, jobs, educational pursuits, and family life to pre-pandemic standards, our findings suggest that the Chinese individuals were worried about the further negative impact on the economy, work, study and family if the COVID-19 outbreak was out of control and further prolonged their suffering. These findings align with the outcomes of a previous multinational study, highlighting differences between Chinese citizens and their counterparts from other countries in this regard (45).

After the dynamic zero-COVID policy was lifted, there was a significant increase in COVID-19 cases (896%, from 21.54 to 49.01 per million people) and deaths (127%, an absolute change of 27.46 per million people) in the following 6 weeks (46, 47). The notable rise in infections and deaths coincided with the public's overconcern, suggesting that the COVID-19 over-concern was not just a psychopathological phenomenon but also a realistic reaction to the rapidly changing situation.

Implications for policy changes

The findings of this study have the following implications for policy changes and preparator work for resuming pre-pandemic life. First, around one-fifth of the population developed COVID-19 over-concern when there was a sudden change in the dynamic zero-COVID policy. Health authorities should form a task force to roll out targeted online interventions, like cognitive behavioral therapy (48), for COVID-19 over-concern, along with monitoring their effectiveness. Second, the Ministry of education, schools and local psychological services should offer group social and interpersonal skill training for young Chinese. These programs should be tailored to help young people adapt to increased face-to-face interactions, reflecting the shift from virtual to in-person communication in the post-pandemic era. Third, a rapid response from the public health system targets people with poor health status. This includes ensuring equitable access to medical services for both COVID-19-related and unrelated health issues, with an emphasis on vulnerable populations (49). Fourth, health authorities could adopt the enhancing Confidence in vaccines, reducing Complacency to health risks of COVID-19 infection, enhancing Convenience to receiving vaccines and accurate COVID-19 Communications (4C) model to enhance confidence in future COVID-19 vaccines (43). A clear communication strategy and community involvement are key to building trust in these programs. Fifth, the government should reduce the impact on income, employment, studies and families in future pandemics. Policies should be developed to provide support and resources to minimize lifestyle disruptions, including policies for financial and mental health support and flexible work and education arrangements. Additionally, it would be crucial to conduct these psychological interventions ethically, respecting individual rights and privacy and adhering to ethical standards.

Limitations of this study

This study has several limitations. First, adopting the snowball sampling strategy due to the urgency following the cancelation of the dynamic zero-COVID policy introduced a key limitation of potential selection bias, as respondent recruitment was not random. To mitigate this, we initiated recruitment from multiple, diverse recruitment sites, but the possibility of bias still persists. Consequently, the study population might not fully represent the broader population, including those without digital access. Additionally, reliance on participant honesty for exclusion criteria, without the ability to verify their medical and psychiatric history, further limit the findings of this study.

Second, the study identifies associations but does not establish causality. The cross-sectional nature of this study limits our ability to establish causality between the observed factors and COVID-19 over-concern. These findings are useful for hypothesis formation, but longitudinal studies are needed to establish causality. The sudden cancelation of the zero-COVID policy restricted our ability to gather pre-cancelation data or conduct a long-term comparison. Also, due to the anonymity of respondents, we could not collect personal details for future follow-up studies.

Third, this study used self-reports to assess psychological symptoms like anxiety, depression, stress, and COVID-19 over-concern. Self-reported data can be less reliable than clinical assessments, as participants might give biased answers or lack self-awareness regarding their mental health. Future research should include clinical evaluations to collect more accurate data.

Fourth, despite COVID-19 overconcern being a new research area without established criteria, we rigorously evaluated our proposed criteria. We assessed the Cronbach's alpha reliability, Split-half reliability, CVI, and Kappa values for our survey, yielding high scores that indicate strong reliability and validity. These results suggest the robustness of our criteria, though future research might refine them further. Despite the above limitations, our study offers unique insights into COVID-19 over-concern prevalence and its associated factors, contributing significantly to global data during the pandemic.

Conclusion

After canceling measures associated with the dynamic zero-COVID policy in China, around 21.2% of respondents fulfilled the diagnostic criteria for COVID-19 over-concern. This study identified that poor self-rated health status, concerns about family members contracting COVID-19 infection, perceived usefulness of receiving COVID-19 vaccine and booster shot, negative impact on incomes, employment and studies and negative impact on families were significantly associated with the development of COVID-19 over-concern after adjustment of confounding demographic factors. Our findings will help health authorities formulate future policies to prepare the public to cope with the transition between different phases during a pandemic.

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 humans were approved by Institutional Review Board (IRB) of the Huaibei Normal University, China (HBS-FDX-2022-012). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

FH: Conceptualization, Data curation, Investigation, Methodology, Resources, Writing – original draft, Writing – review & editing. ZZ: Conceptualization, Methodology, Writing – review & editing. SL: Conceptualization, Methodology, Writing – review & editing. S-KC: Data curation, Formal analysis, Writing – original draft. DZ: Data curation, Writing – review & editing. WT: Data curation, Writing – review & editing. XT: Funding–acquisition, Project administration,

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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.2023.1319906/full#supplementary-material

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Circadian light therapy and light dose for depressed young people: a systematic review and meta-analysis

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Background: Empirical evidence has shown that light therapy (LT) can reduce depression symptoms by stimulating circadian rhythms. However, there is skepticism and inconclusive results, along with confusion regarding dosing. The purpose of this study is to quantify light as a stimulus for the circadian system and create a dose-response relationship that can help reduce maladies among adolescents and young adults (AYAs). This will provide a reference for light exposure and neural response, which are crucial in the neuropsychological mechanism of light intervention. The study also aims to provide guidance for clinical application.

Methods: The latest quantitative model of CL_A (circadian light) and $CS_{t,f}$ (circadian stimulus) was adopted to quantify light dose for circadian phototransduction in youth depression-related light therapy. Articles published up to 2023 through Web of Science, Cochrane Library, Medline (OVID), CINAHL, APA PsycINFO, Embase, and Scholars were retrieved. A meta-analysis of 31 articles (1,031 subjects) was performed using Stata17.0, CMA3.0 (comprehensive meta-analysis version 3.0) software, and Python 3.9 platform for light therapy efficacy comparison and dose-response quantification.

Results: Under various circadian stimulus conditions ($0.1 < CS_{t,f} < 0.7$) of light therapy (LT), malady reductions among AYAs were observed (pooled SMD = −1.59, 95%CI = −1.86 to −1.32; $z = -11.654$, $p = 0.000$; $I^2 = 92.8\%$), with temporal pattern ($p = 0.044$) and co-medication ($p = 0.000$) suggested as main heterogeneity sources. For the efficacy advantage of LT with a higher circadian stimulus that is assumed to be influenced by visualization, co-medication, disease severity, and time pattern, sets of meta-analysis among random-controlled trials (RCTs) found evidence for significant efficacy of circadian-active bright light therapy (BLT) over circadian-inactive dim red light (SMD = −0.65, 95% CI = −0.96 to −0.34; $z = -4.101$, $p = 0.000$; $I^2 = 84.9\%$) or circadian-active dimmer white light (SMD = −0.37, 95% CI = −0.68 to −0.06; $z = -2.318$, $p = 0.02$; $I^2 = 33.8\%$), whereas green-blue, circadian-active BLT showed no significant superiority over circadian-inactive red/amber light controls (SMD = −0.21, 95% CI = −0.45 to 0.04; $z = -2.318$, $p = 0.099$; $I^2 = 0\%$). Overall, circadian-active BLT showed a greater likelihood of clinical response than dim light controls, with increased superiority observed with co-medication. For pre-to-post-treatment amelioration and corresponding dose-response relationship, cumulative duration was found more influential than other categorical (co-medication, severity, study design) or continuous ($CS_{t,f}$) variables. Dose-response fitting indicated that the therapeutic effect would reach saturation among co-medicated patients at 32–42 days (900–1,000 min) and

58–59 days (1,100–1,500 min) among non-medicated AYAs. When exerting high circadian stimulus of light therapy ($0.6 < CS_{t,f} < 0.7$), there was a significantly greater effect size in 1,000–1,500 min of accumulative duration than <1,000 or >1,500 min of duration, indicating a threshold for practical guidance.

Limitations: The results have been based on limited samples and influenced by a small sample effect. The placebo effect could not be ignored.

Conclusions: Although the superiority of LT with higher circadian stimulus over dimmer light controls remains unproven, greater response potentials of circadian-active BLT have been noticed among AYAs, taking co-medication, disease severity, time pattern, and visual characteristics into consideration. The dose-response relationship with quantified circadian stimulus and temporal pattern had been elaborated under various conditions to support clinical depression treatment and LT device application in the post-pandemic era.

KEYWORDS

light therapy, circadian light, circadian stimulus, youth, meta-analysis, dose response

1 Introduction

The circadian stimulus of light therapy (1), also known as bright light therapy (BLT), has been found to have positive clinical outcomes in reducing symptoms of depression. Since the dysfunction of the circadian system has been strongly linked to psychological disorders, light therapy has been particularly successful in treating such conditions (2). However, skeptics contend that light therapy's efficacy may be little better than a placebo under great varieties of light administration protocols (e.g., white light or monochromatic light, various intensities) (3), as well as malady conditions. The skepticism surrounding the efficacy of light therapy for treating a wide range of maladies is rooted in the uncertainty of light dosing (2), whether in monotherapy studies or combination cases (4). Therefore, quantifying the amount of light can help establish a reliable and predictable relationship between light therapy and reductions in relevant disorders. This study aims to verify the efficacy of light therapy by quantifying the circadian stimulus and duration time as vital parameters of light dose for the circadian system among adolescents and young adults (AYAs).

1.1 Youth depression and circadian dysrhythmias

There is substantial evidence that links circadian misalignment with depression among young people (5, 6), e.g., major depressive disorder (7), bipolar disorder (8), unipolar depressive disorders (9), delayed sleep phase (DSP), attention deficit hyperactive disorder (ADHD) (10), and "circadian" depression clinical phenotype (11). Besides classical diagnostic depressive subtypes, other primary (e.g., post-natal, peri-menopausal, late-onset) and secondary (e.g., post-infective, comorbid pain syndromes) depressive subtypes may also be linked with underlying circadian dysfunction (12, 13). Circadian responses to bright light therapy are mainly based on the circadian phototransduction mechanism, which is considered beneficial for the treatment of SAD (seasonal affective disorder) (14, 15), NSD (non-seasonal affective disorder) (16), BD (bipolar disorder) (17), MDD (major depressive disorder) (18), ADHD (attention deficit hyperactivity disorder) (19), Parkinson (20), Alzheimer's disease (21), antepartum depression (22), and CRSWDs (circadian rhythm sleep-wake disorders) (23)-related circadian rhythm disturbances, depression, and sleeping problems. Furthermore, there is empirical evidence that depressed youth have been prescribed not only light therapy but also chronotherapy (which is a combination of light therapy and sleep deprivation—wake therapy) for greater circadian adjustment and anti-depressive effect stabilization in seasonal affective disorders and non-seasonal unipolar and bipolar depression (24). Though overall treatment effectiveness may be inconclusive (25), the dose effect and dose response of light therapy have been hypothesized and explored in numerous protocols, e.g., dose equivalence assumption on a duration× light intensity basis (4, 26). Additionally, the temporal pattern has also been found to be related to dose-dependent efficacy and has been studied (27); for instance, depression severity has been found (22) or presumed (28) altering along with varied duration or total treatment period (29–31). Overall, the lack of an accepted standard definition of adequate dosing for experimental light treatment, along with controversial presumptions and results, has made it challenging to assess the effectiveness of such treatment.

1.2 Circadian phototransduction and current quantifying model

Human circadian phototransduction, which is closely related to the non-visual effects of light, should be distinguished from visual effects. Multiple neural channels emanate from the retina, each with different spectral sensitivities that convert optical radiation into neural signals. Yet, the quantitative photopic luminous efficiency function $V(\lambda)$ defined by CIE (Commission Internationale de l'Eclairage) and the photometric illuminance (lux) (for quantifying light therapy devices) is not relevant to all of these neural channels (32). Circadian phototransduction is a non-visual effect of light primarily based on photoreceptor-like intrinsically photosensitive retinal ganglion cells (ipRGCs) that send light information

to the biological clock in the hypothalamic suprachiasmatic nucleus (SCN), which then synchronizes biological rhythms and projects signals to (including but not limited to) the ventrolateral preoptic (VLPO) nucleus, extended amygdala (33), pineal body, etc. The synthesis of melatonin in the pineal gland and core body temperature rhythmically rise and fall over a 24-h period and are used experimentally as markers of the endogenous rhythm (34); mood oscillates in parallel to core body temperature and is strongly influenced by the circadian process (35). Besides, other chronobiological effects of light are based on SCN-related physiological mechanisms (36). The human retina has five photoreceptors that contribute to the circadian system phototransduction (37). These include rods, cones, and ipRGCs, along with their respective photopigments, retinal opsin proteins such as melanopsin, rhodopsin, S-, M-, and L-cone opsin. Among these photoreceptors, ipRGCs, and melanopsin are mostly involved in the process, and they are more sensitive to "blue" wavelength at around 480 nm (38). S-cone-opic also plays a role in the circadian system phototransduction (39, 40). Therefore, the relative potency of light sources for light therapy would be more influenced by the amount of short-wavelength light mediated by the melanopsin system than the illuminance (lux) at eye level (41). Short-wavelength enriched light with lower intensity may have a stronger effect on the circadian system than visually stronger light.

The circadian light (CL_A) model, which has been undergoing retinal neurophysiology and psychophysics experiments (42, 43), can be explained as a spectral weighting function suitable for SCN-oriented circadian responses. The CL_A model can quantify a functional relationship between optical radiation incident on the retina and the spectral, temporal, and absolute responses of the SCN. The circadian stimulus (CS) was developed as the operating range of the circadian system from threshold to saturation, taking nocturnal melatonin suppression as the outcome measure (42). These models have photoreceptors (cones, rods, ipRGCs) and retina amacrines and their neuroanatomical and neurophysiological interactions (43) and have shown a response magnitude characteristic of different amounts of spectrally weighted optical radiation of the single circadian phototransduction circuit (42). Moreover, the latest models of circadian stimulus (CS) and circadian light (CL_A) have reduced discrepancy in response to "warm" and "cold" light sources, optimized duration, and light exposure distribution; therefore, in this study, they were adopted to quantify circadian phototransduction.

It has also been proven that besides the SCN-dependent circadian phototransduction circuit, separate non-circadian (34) or SCN-independent pathways exist with light effects on mood that may be direct, immediate, and sustained. For instance, the simultaneous inhibition of the sleep-inducing ventrolateral preoptic (VLPO) and the activation of the monoaminergic (44), thalamic, and hypothalamic regions (45) are involved in the control of mood and alertness. Likewise, the orexinergic and monoamine-dependent pathways impact mood. Moreover, there are also emotional processing pathways (light-sensitive circuits) in the cortical system, frontal cortex, and limbic system that ameliorate depressive symptoms (46). For example, the ipRGCs-vLGN/IGL (thalamic region)-LHb (lateral habenula) pathway may be the crucial sluice through which light ameliorates depression-like behaviors (47). However, for this study, we did not adopt indicators besides CS because light dose-related experiments are limited or have merely been verified in animal models (48), and there are huge differences in the efficacious light dose between humans and other species (49).

1.3 Scoping "circadian" treatment for young people

Depressive disorders are among the most prominent health problems among young people. Extensive research efforts have reported unsatisfactory outcomes among AYAs who have undergone prescribed medication side-effects, treatment resistance, breakthrough depressive symptoms, much lower response rates under combined medication and psychotherapy compared with adults (50), or deficient evidence for pharmaxgical treatments on comorbidity of depression (51), or potential recurrence risk (52). However, light therapy has shown potential for AYAs suffering from these issues. Additionally, depression and sleep disorders exhibit high comorbidity among youth (53); all these have urged light as a zeitgeber for synchronization, as well as a non-invasive treatment for depression. Current evidence has shown BLT is likely well-tolerated in adolescents but pointed out that the highly variable selection of light dosing presents a challenge in comparing treatment response and tolerability (54).

It is noteworthy that age exerts influence on light therapy in both visual and non-visual ways. Older people normally receive decreased retinal illumination due to reduced pupil size, increased ocular lens absorption (55), and other substantial changes in visual organs. Correspondingly, young people obtain higher lens transmittance, especially for short-wavelength light that peaks non-visual sensitivity, which is shifted to longer wavelengths in older people (56). CIE has also outlined the sensitivity variation of light-sensitive photoreceptors (38); compared to 32-year-old reference observers, populations aged 22 and 42 expressed weighted, fluctuated sensitivity, which may influence synchronizing input and melatonin suppression (57). Phase and amplitude of circadian functions are also related to age, such as alterations in SCN-related molecular and neuronal factors (58) and output levels [e.g., VLPO and pineal gland (59)]. Therefore, this study focuses on the current circadian aspect of light therapy in the depression treatment of the young population.

In this study, the therapeutic effect of circadian light therapy among AYAs will be quantitatively explored between circadian stimulus (defined by certain spectrum, illuminance, exposure duration time, and lighting distribution factor) and reductions in relevant maladies, using mainly the SMD values of clinical depression measurement scales as outcomes.

2 Materials and methods

2.1 Literature research

This systematic review study was registered with PROSPERO under code number CRD42022375211 and was conducted

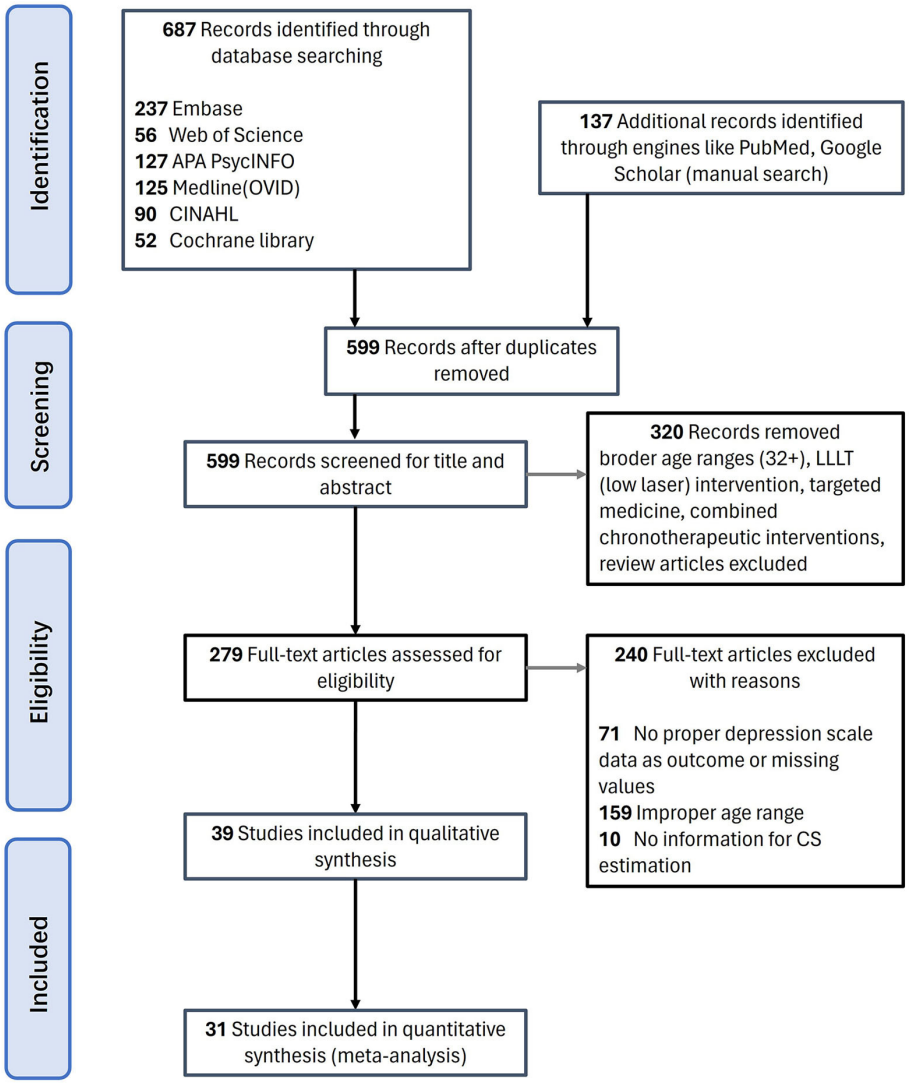

FIGURE 1
Literature search results following PRISMA flow.

following Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (60). Articles published up to 2023 were searched through Web of Science, Embase, CINAHL, Cochrane Library, Medline (OVID), APA PsycINFO databases, as well as websites of the National Library of Medicine, ClinicalTrials.gov and Scholars. Multiple databases were also searched simultaneously using PubMed. Advanced searches with MeSH (medical subject heading) terms were included when available. The search strategy contained the following terms: (light therapy OR light treatment OR bright light therapy OR BLT OR chronotherapy OR phototherapy OR wake and light therapy) AND (youth OR adolescent OR students OR young adults OR teens OR teenagers) AND (depression OR depressive OR mood disorder). The detailed strategies can be checked in Supplementary Table S1. Full text was required but not restricted to English. The preliminary screening results were 90 in CINAHL, 52 in Cochrane Library, 237 in Embase, 125 in Medline (OVID), 127 in APA PsycINFO, and 56 in Web of Science. Additional studies that had not been captured by the original database search were retrieved mainly through Google Scholar. After removing duplication, 599 articles were left (Figure 1).

2.2 Inclusion criteria

Studies that met the following criteria were included: (A) The subjects are youth or young adults who averagely aged < 32 years—the age considered responding consistently to light stimulus in circadian phototransduction progress as addressed; (B) Must have bright light therapy as primary independent intervention, no sleep deprivation combined, since potential therapeutic effect may be disturbed by sleep deprivation; (C) Only difference between experiment and control groups should be BLT treatment, that when combined with antidepressants, it must be equally administered in both intervention and control to rule out the effect of the adjunct treatment; (D) Details of BLT included (e.g., specific

device, light sources, illumination, correlated color temperature, continuous duration) for $CS_{t,f}$ calculation; (E) Outcomes reported in standardized depression scales, e.g., Hamilton Depression Scale HAMD, HIGH-SAD, Hospital Anxiety and Depression Scale (HADS), Beck Depression Inventory BDI-II, Montgomery Asberg Depression Rating Scale (MADRS), Center for Epidemiologic Studies Depression Scale (CES-D) or other scales with similar structures proved reliable and validate among worldwide AYA (61).

Studies that met the following criteria were excluded: (1) Broader age groups (average age >32); (2) LLLT (low-level laser therapy) treatment studies; (3) Abstracts, case reports, case series, or literature reviews excluded.

2.3 Data extraction

Among the 599 articles excluding duplication (Figure 1), the research team reviewed the titles and abstracts of all downloaded literature for initial screening. The articles were further filtered based on the relevancy of contents, and 279 were left. After thorough screening for relevancy and eligibility through a full-text review, we finalized 31 pieces of literature that met the criteria. Then, two dependent reviewers, R.P. and X.C., extracted the main information shown in Table 1: (A) Subject information, including age and gender; (B) Experimental design. BLT period, duration (weeks, times, exposure minutes); (C) Sample size of experiment group, control group; (D) Light therapy devices, spectra, illumination at eye level, lighting details, and distribution, which are parameters needed for $CS_{t,f}$ calculation; (E) Pre-to-post-treatment quantitative outcomes of measurement scales (detailed information can be checked in Supplementary Table S2).

2.4 Data analysis

Although the literature included patients with various pathologic features and was not limited to randomized controlled trials (RCT), the continuous outcomes variables of clinical depression measurement were recorded and analyzed. The mean (standard deviation) was derived as the main outcome at the starting point before intervention and the endpoint after intervention. The changes in scores were converted into the starting point and endpoint values. Heterogeneity among included studies was analyzed using $\chi 2$ tests ($\alpha = 0.05$), and the magnitude was quantified in conjunction with Cochran's Q statistics and I^2. The primary outcome was an improvement in depressive symptoms on a clinician-rated depression rating scale, including differences in endpoint scores on the scale between active and control conditions with intent-to-treat samples, analyzed using standardized mean differences (SMD). If the secondary outcomes were available (clinical response defined a priori as a 50% reduction on a clinician-rated depression rating scale, assumed more reported by RCTs), we calculated risk ratios and odds ratios for the categorical data. Correspondingly, the included studies were preliminarily categorized with additional consideration of co-medication× study design (Table 1). Besides, as light dose quantification had barely been reported in previous BLT-oriented reviews, the dose-response analysis was drawn from neighboring methodologies.

3 Results

3.1 Study characteristics

The selected 31 articles were mainly small-sample clinical trials (<30 subjects). Only four studies involved larger samples (31, 62–64). Twenty-two studies were randomized controlled trials (RCTs), three of which adopted intervention beyond light therapy: e,g., CBT (cognitive–behavioral psychotherapy) (29), LT + CBT (65), and wake therapy + LT (66) as control to testify whether BLT acted as an effective adjunctive intervention. Nine were non-randomized controlled experiments (quasi-experimental studies) that may have been launched because lighting properties (colors, levels) are intuitively recognized by the human eye (1); therefore, true blindness for light treatment studies is difficult to achieve.

Depression was mainly screened by the Diagnostic and Statistical Manual of Mental Disorders (DSM) criteria; similarly maladies, where depression was a frequent co-morbid condition. One article studied depressed adolescents with anorexia nervosa (29), one study focused on depression in co-morbidity with cystic fibrosis (67), one for cancer-related fatigue (CRF)/depression (68), one for Tourette's disorder/depression (69), two for bulimia nervosa/winter binge/depression (70, 71), one for borderline personality disorder (BPD) (72), four for perinatal/postpartum depression (22, 30, 73, 74), one for non-seasonal subthreshold depression (31). Besides, non-specific depressed non-depressed were also included, especially those accompanied by sleep disturbances. Three studies targeted people with Delayed Sleep-Wake Phase Disorder (DSWPD) (65, 75, 76). One article studied burnout (77), one was on insomnia/shift work disorder (63), and one focused on mild traumatic brain injury (mTBIs) that excluded Axis I mental disorders (78). One study was on healthy first-time mothers with low-birth-weight (LBW) infants (79). One study aimed to investigate the alerting effect of BLT; thus, only healthy people were included (80). The majority of participants in two studies were mainly healthy college students (81, 82), but depressed individuals constituted a certain proportion and were balanced among groups. In a few co-medication studies, BLT was accompanied by antidepressants or other treatments, but it could be guaranteed that BLT was the only variable.

In terms of intervention time, one study (83) carried out both morning and night BLT, two studies carried out BLT in the early evening (71, 81) and two experimented in late night (63, 80), and in the rest, BLT were all morning interventions. In terms of a consecutive duration time, 16 studies were carried out daily for consecutive 30–45 min of exposure, seven studies for 45–60 min, four studies for 50–60 min, one study for 90 min, one for daily 120 min, and one for 150 min. In terms of BLT devices, all but seven studies used light boxes or lamps, where light visors (six studies) and light masks (one study) were employed. As for active bright white light, treatment illuminance varied between 3,000 and 10,000 lux, and only a few adopted 2,500 lux (71). The glasses mainly emitted blue or green light at a much lower intensity, and the intervention $CS_{t,f}$ (circadian stimulus) ranged from <0.1–0.7 (Supplementary Table S2). A CS = 0.3 in the original metric of CS for at least 1 h in the morning has been shown to improve sleep and reduce depression empirically (84, 85), while CS < 0.3 was not expected to considerably suppress nocturnal melatonin. However, these conclusions may be less convincing for depression

TABLE 1 Characteristics of the included trials ($n = 31$).

Subgroup/ Study/ Country	Diagnosis	Duration	Accumulative duration day-minutes	Treatment condition; wavelength; intensity	Control condition; wavelength; intensity	$CS_{t,f}$	Mean age (years ± SD)	Sample size (n)	Sex: male/female (n/n)	Mood measure	Antidepressant medication
Random-controlled trials											
Diagnosed with depression and medicated											
Bogen et al. (87), Germany	MDD (BDI-II), 6 in each group with SAD pattern	2 weeks, daily morning 45 min	10 days; 450 min	white light fluorescent box (Davita), 10,000 lux	wake therapy + LT	Tx: $CS_{t0.75} = 0.665$	Tx: 15.75 ± 1.017; Control: 16.16 ± 1.275	Tx: $n = 37$; Control: $n = 25$	Tx: 2/35; Control: 3/22	BDI-II	Partial co-medication
Youngstedt et al. (90), USA	Anxiety (DSM-IV), MDD, PTSD, GAD balanced	4 weeks, daily morning 45min	7 days; 315 min 14 days; 630 min 21 days; 945 min 28 day; 1260 min	Blue-enriched white light LED; 460 nm (Litebook); 3,000 lux	Inactivated negative ion generator (INIG)	Tx: $CS_{t0.75} = 0.652$	Tx: 22.0 ± 1.0; Control: 21.4±0.6	Tx: $n = 17$; Control: $n = 16$	Tx: 5/12; Control: 3/13	BDI	Partial co-medication
Goel et al. (81), USA (81)	29.7% depressed	3 days, daily evening 30 min	3 days; 90 min	white light fluorescent lamps, 10,000 lux (3,000 K)	Negative ion generator, sound	Tx: $CS_{t0.5} = 0.635$	Overall: 19.4 ± 1.7	BLT: $n = 29$; sound stimulus: $n = 30$; High-density air flow rate: $n = 29$; low-density air flow rate: $n = 30$	Overall: 49/69	POMS	Partial co-medication
Richardson and Gradisar (76), Australia*	30 self-reported MDD	3 weeks, daily morning 30–60 min, 3 times per week	3 days; 150 min 6 days; 300 min 9 days; 450 min	Green light LED (Re-timer); 507 nm; 112 lux	Amber light LED (Re-timer); 643 nm; 112 lux	Tx: $CS_{t0.78} = 0.242$; Control: $CS_{t0.8} < 0.1$	Tx: 16.07 ± 2.4; Control: 15.6 ± 2.2	Tx: $n = 30$; Control: $n = 30$	Tx: 11/19; Control: 11/19	SMFQ	Partial co-medication
Flory et al. (97), USA*[a]	MDD with seasonal pattern (SIGH-SAD-SR, DSM-IV)	12 days, daily morning 30 min	12 days; 360 min	White light fluorescent boxes, 10,000 lux (4,100 K)	Red light fluorescent box; 300 lux	Tx: $CS_{t0.5} = 0.642$–0.663; Control-DRL: $CS_{t0.5} = 0.129$	Overall: 20.8 ± 5.69	BLT: $n = 19$; DRL: $n = 16$; high-density negative ions (HDNI): $n = 18$; low-density negative ions (LDNI): $n = 20$	All females	SIGH-SAD-SR, HAM-D, BDI-II	All co-medication
LaRosa et al. (68), USA	Cancer-related fatigue	8 weeks, 30 min within 1 h of waking	8 weeks; 1,680 min	Blue-enriched white light LED; 460 nm (Litebook); 3,000–10,000 lux	red Light LED; 680 nm (The Litebook;50 lux	Tx: $CS_{t0.5} = 0.64$ (0.549–0.679); Control: $CS_{t0.5} < 0.1$	Overall: 15.96 ± 2.41	Tx: $n = 21$[c]; Control: $n = 23$	Tx: 8/13; Control: 11/12	CDI-II	co-medication

(Continued)

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TABLE 1 (Continued)

Subgroup/ Study/ Country	Diagnosis	Duration	Accumulative duration day-minutes	Treatment condition; wavelength; intensity	Control condition; wavelength; intensity	$CS_{t,f}$	Mean age (years ± SD)	Sample size (*n*)	Sex: male/female (*n*/*n*)	Mood measure	Antidepressant medication
Spezzano (88), USA*	SAD	3 weeks, daily morning 30 min	7 days; 210 min 14 days; 420 min 21 days; 630 min	White light fluorescent box (SunBox) 10,000 lux	Inactivated ion generator	Tx: $CS_{t0.5}$ = 0.658	Tx: 19.75 ± 1.4; Control: 19.7 ± 1.2	Tx: n = 20; Control: n = 20	Tx: 9/11; Control: 7/13	SIGH-SAD, BDI-II	co-medication
Blouin et al. (71), Canada*	Bulimia nervosa (DSM-III-R), 13 MDD, 10 SAD (SPAQ)	1 week, daily 2 h in the early evening, 17:00–19:00 p.m.	7 days; 840 min	White light fluorescent box (Duratest); 2,500 lux	White light fluorescent box (Duratest); 500 lux	Tx-2 500 lux: $CS_{t2.0}$ = 0.669; Control-500 lux: $CS_{t2.0}$ = 0.552	Overall: 27.9 ± 8.0	Tx: n = 9; Control: n = 9	Tx: 0/9; Control: 0/9	SIGH-SAD, BDI,	Partial co-medication
Braun et al. (70), USA	Bulimia nervosa (SCID), some MDD (SCID)	3 weeks, daily morning 90 min	21 days; 1,890 min	White light fluorescent box (Apollo), 10,000 lux	Red fluorescent light; 50 lux	Tx: $CS_{t1.5}$ = 0.690; Control: $CS_{t1.5}$ <0.01	Tx: 30.50 ± 7.3; Control: 30.50 ± 8.6	Tx: n = 15; Control: n = 16	Tx:0/15; Control: 0/16	SIGH-SAD, BDI,	Co-medication
Bais et al. (73), the Netherlands*[b]	MDD (SCID, DSM-5)	6 weeks, daily morning 30 min	7 days; 210 min 14 days; 420 min 21 days; 630 min 28 days; 840 min 35 days; 1050 min 42 days; 1260 min	White light LED (EnergyUp HF3419/01, Philip); 9,000 lux (5,000 K)	Red LED light; 100 lux (2,700 K)	Tx: $CS_{t0.5}$ = 0.657; Control: $CSt_{0.5}$ <0.1	Tx: 31.9 ± 4.4; Control: 31.9 ± 5.3	Tx: n = 33; Control: n = 34	Tx: 0/33; Control: 0/34	SIGH-SAD, HAMD-17, EPDS	Partial co-medication
Randomized controlled trials											
Depressed but non-medicated											
Bogen et al. (87), Germany*	MDD (ICD-10), ≥20 points (BDI-II)	2 weeks, 45 min of morning BLT, 5 times a week	2 weeks; 450 min	White light fluorescent box (Davita), 10,000 lux	White light LED box (Davita Luxor), 100–150 lux	Tx: $CS_{t0.75}$ = 0.665; Control: $CS_{t0.75}$ <0.1	Tx: 15.4 ± 1.6; Control: 15.3 ± 1.5	Tx: n = 30; Control: n = 27	Tx: 11/19; Control: 4/23	BDI-II	No co-medication
Jiang et al. (31), China*	Non-seasonal subthreshold depression (HAMD-24).	8 weeks, daily morning 30 min	28 days; 840 min 56 day; 1,680 mi	white cold LED, 5,000 lux (5,000K)	A:500 lux white cold LED B: Waiting list	Tx- 5,000 lux: $CS_{t0.5}$ = 0.639 (0.622-0.648); Tx−500 lux: $CS_{t0.5}$ = 0.277(0.272–0.30)	Tx-5,000 lux: 21.18 ± 2.31; Tx-500 lux: 21.49 ± 2.35; Control: 21.38 ± 2.22	Tx- 5,000 lux: n = 51; Tx−500 lux: n = 51; Control: n = 42	Tx- 5,000 lux: 16/35; Tx−500 lux :13/38; Control: 15/27	BDI-II, HAMD-24, SAI	No

(Continued)

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TABLE 1 (Continued)

Subgroup/ Study/ Country	Diagnosis	Duration	Accumulative duration day-minutes	Treatment condition; wavelength; intensity	Control condition; wavelength; intensity	$CS_{t,f}$	Mean age (years ± SD)	Sample size (*n*)	Sex: male/female (*n*/*n*)	Mood measure	Antidepressant medication
Janas-Kozik et al. (29), Polland*	Anorexia nervosa (AN-R) (DSM-IV), ≥17 points (21-item HDRS)	6 weeks, 30 min daily morning	7 days; 210 min 14 days; 420 min 21 days; 630 min 28 days; 840 min 35 days; 1,050 min 42 days; 1,260 min	White light fluorescent box; 10,000 lux	no LT + CBT	Tx: $CS_{t0.5}$ = 0.60–0.69	Tx: 17.8 ± 1.34; Control: 17.0 ± 1.34	Tx: $n = 12$; Control: $n = 12$	Tx:0/12; Control: 0/12	HDRS	No co-medication
Donmezt al. (30), Turkey*	MDD (DSM-5 criteria), ≥12 points (EPDS)	3 weeks, daily morning 45 min	7 days; 315 min 14 days; 630 min 21 days; 945 min	White light LED lamp (Beurer), 10,000 lux (2,500 lux at eye, 5,000 K)	White light LED lamp (Beurer), 500 lux (125 lux at the eye)	Tx: $CS_{t0.75}$ = 0.59; Control: $CS_{t0.75} \approx 0.12$	Tx: 29.73 ± 6.57; Control: 28.0 ± 3.8	Tx: $n = 15$; Control: $n = 15$	Tx:0/15; Control: 0/15	MADRS, HAM-D, EPDS	No
Epperson et al. (22), USA	MDD (DSM-IV), 1 with seasonal pattern (DSM-IV)	5 weeks, daily 60 min,	35 days; 2,100 min	White light fluorescent box (HealthLight, SphereOne); 7,000 lux	White light fluorescent box; 500 lux	Tx: $CS_{t1.0}$ = 0.678–0.682; Control: $CS_{t1.0}$ = 0.497	Overall: 32.10 ± 3.9	Tx: $n = 4$; Control: $n = 5$	Tx: 0/4; Control: 0/5	SIGH-SAD	No
Grandner (82), USA*	some with minimal to mild depression	12 days, 150 min prior to usual wake time (30 min intensity 0–100%)	Tx: 10.7 days-1,605; Control: 11.3 days-1,695	Green light LED; 500 nm; 10,000 lux	red light LED; 0.5 lux	Tx: $CS_{t2.5}$ = 0.692–0.694; Control: $CS_{t2.5} < 0.1$	Tx: 23.13; Control: 22.13	Tx: $n = 15$; Control: $n = 15$	Tx: 15/0; Control: 15/0	QIDS-SR	No
Quasi-experimental trials											
Depressed and medicated											
Swanson et al. (74), USA	MDD (DSM-V), ≥20 points (SIGH-SAD)	5 weeks, daily morning 60 min	35 day-1,050–2,100	Green light LED (Re-timer); 507 nm; 506 lux	—	Tx: $CS_{t0.5}$ = 0.451; $CS_{t1.0}$ = 0.557	Tx: 32.30 ± 3.27	Tx: $n = 10$	0/10	SIGH-SAD	Partial co-medication
Kirschbaum-Lesch et al. (64), Germany	MDD (BDI-II)	4 weeks, weekdays daily morning 30 min	10 day-600 20 day−1,200	Blue-enriched white light LED (Luminette®); 468 nm; 10,000 lux	—	Tx: $CS_{t0.5}$ = 0.686	Tx: 15.74 ± 1.14	Tx: $n = 39$	7/32	BDI-II	Partial co-medication
House et al. (62), USA	MDD, SAD	4 weeks, 15mins for 1st week, weekday morning 30 min next 3 weeks	20 day-525	White light fluorescent box (NorthStar); 10,000 lux (4,100 K)	—	$CS_{t0.5}$ = 0.667–0.668	Tx: 19–21	Tx: $n = 79$	18/61	BDI-II	Partial co-medication

(Continued)

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TABLE 1 (Continued)

Subgroup/ Study/ Country	Diagnosis	Duration	Accumulative duration day-minutes	Treatment condition; wavelength; intensity	Control condition; wavelength; intensity	$CS_{t,f}$	Mean age (years ± SD)	Sample size (*n*)	Sex: male/female (*n*/*n*)	Mood measure	Antidepressant medication
Papatheodorou and Kutcher (83), Canada	Bipolar disorder (DSM-III-R)	1 week, 7:00–9:00 a.m. +19:00–21:00 p.m., daily 45–60 min	7 days-650	Cool-white fluorescent box; 10,000 lux	—	Tx: $CS_{t0.75}$ = 0.679 (0.663–0.683); $CS_{t1.0}$ = 0.685 (0.682–0.692)	Tx:19.4 ± 2	Tx: *n* = 7	2/5	BDI-II	All co-medication
Nixon et al. (92), Canada	At least mild symptoms on QIDS-SR16 or QIDS-A17	4 weeks, daily morning 45–60 min	10 day-735 (630–840) 21 days-(620–1,240 min)	Green light LED (Re-timer); 507 nm; 112 lux	—	Tx: $CS_{t0.78}$ = 0.242; $CS_{t1.0}$ = 0.287	Tx: 21.2 ± 1.0	Tx: *n* = 24[d]	4/20	BDI-II	Partial co-medication
Kopp et al. (67), USA	80% at least mild MDD	1 week, daily morning 30 min	7 days-210	White light fluorescent box Sun Touch Plus Light ©; 10,000 lux (17,000 K)	—	Tx: $CS_{t0.5}$ = 0.669–0.684	Tx: 27.7 ± 8.5	Tx: *n* = 30	17/13	QIDS-C	Partial co-medication
Ricketts et al. (69), USA	85.7% TD (tic disorder), 57.1% MDD	2 weeks, daily morning 60 min	14 day-840	Re-Timer Light Therapy Glasses, 112 lux, peak 507 nm	Healthy controls	Tx: $CS_{t0.75}$ = 0.235	Tx: 27.86 ± 5.20; Control: 31.75 ± 8.49	Tx: *n* = 14; Control: *n* = 20	Tx:10/4	DASS	Partial co-medication
Bromundt et al. (72), Switzerland	BPD (DSM-IV), 7 (50%) SAD, 2 (14%) subsyndromal form	3 weeks, daily morning 30–40 min	18 day-630	white light fluorescent lamp (Daylight®); 8,000 lux	healthy females + oLT	Tx: $CS_{t0.5}$ = 0.647–0.669	Tx: 30.1 ± 6.0; Control: 25.7 ± 4.8	Tx: *n* = 14; Control: *n* = 10	Tx: 0/14; Control: 0/10	SIGH-ADS-SR, BDI-II	Partial co-medication
Non-depressed and non-medicated											
Lee et al. (79), USA	healthy first-time mothers	3 weeks, daily morning 30 min	18 day-550	Blue–green light LED; 500 nm; 3,000–8,000 lux	Dim red light	Tx: $CS_{t0.5}$ = 0.663–0.688	Tx: 24.4 ± 5.4; Control:29.1 ± 6.7	Tx: *n* = 16; Control: *n* = 14	Tx: 0/16; Control: 0/14	EPDS	None
Sasseville et al. (80), Canada	healthy	30 min at 3:00 am	1 day-30	Blue-enriched white light LED (Litebook®); 1,420 lux	Amber light LED (blue-blocking), 580 nm; 1,150 lux	Tx: $CS_{t0.5}$ = 0.556; Control: $CS_{t0.5}$ <0.1	Tx: 24.5 ± 1.5 (21–26 years); Control: 27.4 ± 1.8 (25–30 years)	Tx: *n* = 10; Control: *n* = 10	Tx: 5/5; Control: 4/6	VAS	None

(Continued)

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TABLE 1 (Continued)

Subgroup/ Study/ Country	Diagnosis	Duration	Accumulative duration day-minutes	Treatment condition; wavelength; intensity	Control condition; wavelength; intensity	$CS_{t,f}$	Mean age (years ± SD)	Sample size (*n*)	Sex: male/female (*n*/*n*)	Mood measure	Antidepressant medication
Raikes et al. (78), USA	Mild traumatic brain injuries, no Axis I disorders (DSM-IV)	6 weeks, daily morning 30 min	42 day-1,260	blue light LED (Philips goLITE BLU); 469–480 nm; 214 lux	amber light LED box; 578 nm, 188 lux	Tx: $CS_{t0.5}$ = 0.580–0.585; Control: $CS_{t0.5}$ < 0.1–0.135	Tx: 25.53 ± 8.65; Control: 26.63 ± 7.62	Tx: *n* = 17; Control: *n* = 18	Tx: 5/12; Control: 8/10	BDI-II	None
Huang et al. (63), China	Insomnia (ISI score > 14)	10 days, daily >30 min, evening shift exposure 19:30–20:30 p.m., night shift exposure 23:00–24:00 p.m.	10 days-300	White light LED (Apollo briteLITE 6); 5,000–6,000 lux	A sham lightbox of much lower intensity or dim red light; also wore dark sunglasses	Tx: $CS_{t0.5}$ = 0.651 (0.638–0.656)	Tx: 30.2 ± 4.5; Control: 30.3 ± 4.7	Tx: *n* = 46; Control: *n* = 46	Tx: 0/46; Control: 0/46	HADS, HADS-D,	Partial co-medication
Li et al. (75), China	DSWPD	1 week, daily morning 60 min	7 days-420	Green-blue light LED (PEGASI®); 470 nm; 20–1,200 lux	—	Tx: $CS_{t1.0}$ = 0.302–0.507	Tx: 29.73 ± 8.98; Control: 34.9 ± 10.80	Tx: *n* = 15; Control: *n* = 15	Tx: 4/11	HAMD-24	None
van Kol (77), the Netherlands	Burnout	2 weeks, weekdays day morning 20–30 min	10 day-300	White light LED (EnergyUp HF3419/01, Philips); 984–1,088 lux (4,590 K)	Red light LED (Philips-7001831PH); 205 lux	Tx: $CS_{t0.5}$ = 0.401–0.420; Control: $CS_{t0.5}$ <0.1	Overall: 28.28 ± 14.10	Tx: *n* = 29;	Tx:10/19	BDI-II-NL (Dutch),	None
Danielsson et al. (65), USA	DSPD	2 weeks, daily morning 30–45 min	14 day-420	White light fluorescent lamp (Brite LITE 6, Philips)	LT+CBT	Tx: $CS_{t0.5}$ = 0.675 (0.656–0.673); $CSt_{0.75}$ = 0.684 (0.671–0.683)	Tx: 22 ± 3; Control: 22 ± 2	Tx: *n* = 19; Control: *n* = 17	Tx:9/10; Control:10/7	HADS-D	Partial co-medication

*Studies included in between-group comparison with identical baseline or response details.

[a]11 remained on prescribed medications other than psychotropic drugs, eight remained on a psychotropic medication regimen of either an SSRI (six subjects) or a norepinephrine/dopamine reuptake inhibitor (two subjects).

[b]11 started an SSRI, 1 woman in the postpartum period (both sertraline), one with an antipsychotic (quetiapine), and one with a benzodiazepine (temazepam) postpartum. The escitalopram dose increased in the postpartum period of one participant.

[c]Although 26 patients in the BWL group and 25 patients in the DRL group were randomized, data were available only for 21 in the BWL group and 23 patients in the DRL group.

[d]31 participants were recruited, but only 24 completed at least 2 weeks of the intervention and were included in the analyses: adherence data was missing for 1 participant. During the 4 weeks (28 days) of intervention, 12 participants (50%) reported using the light therapy glasses in the morning for 30–60 min between 22 and 29 days, six participants (25%) reported using them between 14 and 21 days, and 5 participants (21%) reported using on <14 days.

MDD, Major Depressive Disorder; OCD, Obsessive–Compulsive Disorder; PTSD, Post-traumatic Stress Disorder; SP, Social Phobia; ADA, Alcohol/Drug abuse; GAD, Generalized Anxiety Disorder; DSPD, delayed sleep phase disorder; DSWPD, Delayed Sleep-Wake Phase Disorder; CF, Cystic fibrosis; SCID, Structured Clinical Interview for DSM-IV Axis I Disorders; CGI, Clinical Global Impression of Severity scale; STAI, State–Trait Anxiety Inventory (Form Y2); QIDS, The Quick Inventory of Depressive Symptomatology self-report; LOS, length of stay; TD, Tourette's disorder; LT, light therapy; BWL, bright white light; CBT, cognitive– behavioral psychotherapy; EPDS, Edinburgh Postnatal Depression Scale; DSM, Diagnostic and Statistical Manual of Mental Disorders; HDRS, 21-item Hamilton Depression Rating Scale; HADS, Hospital Anxiety and Depression Scale; ISI, Insomnia Severity Index; HADS-A, anxiety subscale of the Hospital Anxiety and Depression Scale; HADS-D, depression subscale of the Hospital Anxiety and Depression Scale; SIGH-SAD, Structured Interview Guide for the Hamilton Depression Rating Scale-Seasonal Affective Disorder; SIGH-SAD-SR, Structured Interview Guide for the Hamilton Depression Rating Scale–Seasonal Affective Disorder Version–Self Rating; SDQ, The Strength and Difficulties Questionnaire (SDQ- emotional problems, hyperactivity, behavioral problems with peers and ability to socialize in 25 items); SAI, state anxiety inventory; HAMD-24, Hamilton Depression Rating Scale; HAM-A, Hamilton Anxiety Scale; ICD-10, International Statistical Classification of Diseases and Related Health Problems; SPAQ, Seasonal Pattern Assessment Questionnaire; BMI, body mass index; BDI-II, Beck Depression Inventory Second Edition; MAVS, mood visual analog scale; ESS, Epworth Sleepiness Scale; DASS, Depression Anxiety Stress Scale; KSS, Karolinska Sleepiness Scale; POMS, The Profile of Mood States Questionnaire; PSQI, Pittsburgh Sleep Quality Index; MBI, the Maslach Burnout Inventory; UBOS, Utrechtse Burnout Schaal; FAS, Fatigue Assessment Scale; BO-NKS, Burnout- Neurasthenia Complaints Scale; RPCSQ, the Rivermead Post-concussion Symptoms Questionnaire-The Functional; YBC-EDS, Yale-Brown-Cornell Eating Disorder Scale; LFS, Lee's Fatigue scale; CDI-II, Children's Depression Inventory, 2nd Edition; BSL-95, Borderline Symptom List; VAS, visual analog scales; SSS, Stanford Sleepiness Scale; NIMH-DIS-R, National Institute of Mental Health Diagnostic Interview Schedule-Revised; SMFQ, Short Mood and Feelings Questionnaire; SSRI, selective serotonin reuptake inhibitor; Tx, treatment condition; LED, light emitting diode.

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amelioration since this value was merely hypothesized for group comparisons. The analogic CS_t metric also indicated no strict definition for high or low CS_t threshold (32). As the $CS_{t,f}$ metric represents the instantaneous luminous stimulus for the circadian system (42), the vast majority of included studies considered responding to applied light intervention from circadian ways.

3.2 Risk-of-bias assessment

For randomized controlled trials (RCTs), the quality of evidence was evaluated with the revised Cochrane Risk of Bias Tool (86) (Supplementary Figure 1). One study adopted a randomizer box (87), six studies adopted computer software (31, 65, 68, 73, 76, 88), two studies adopted a random-number table (30, 81), one study adopted a random digit table (63), and one study adopted numbered, sequential, sealed envelopes (82). The remaining RCTs that indicated randomization sequence generation were also considered to be low risk in selection bias. Most studies owned moderate risk in allocation concealment since it was not reported (89). As for performance bias, seven studies showed moderate risk when participants were possibly non-blinded while specific examiners were blinded (29, 31, 65, 87, 90) or vice versa (22, 82). For attrition bias assessment, statistical approaches like LOCF (last observation carried forward) (87), BOCF (baseline observation carried forward) (78), and multiple imputations (66) were adopted, whereas bias still existed among dropouts. Linear Mixed Modeling (LLM) (69, 73, 76), General Linear Model (GLM) (66), and Hierarchical Linear Modeling (HLM) (77) were optimal, accounting for missing data, small sample size, and non-parametric distributions (91); thus, six studies were considered as at low risk. As for detection bias, seven studies where participants were informed of comparing different types of light therapy (30, 31, 66, 77, 78, 82, 87) were regarded as moderate risk since the blinding of outcome assessment remained unclear. For nine quasi-experimental/non-randomized controlled studies, the quality of evidence was evaluated using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Quasi-Experimental studies (Supplementary Table S3). In two studies (83, 92), other measures remained unclear, and in two studies (69, 75), the baseline conditions could not be totally balanced, but the overall quality was eligible.

3.3 Circadian stimulus models and deduction

The evolving CLA and CS model and calculation formula had been optimized by Rea et al. (42) as follows (Eqs. 1, 2):

$$CLA = \begin{cases} 1548 \left\{ \begin{array}{c} \int Mc_\lambda E_\lambda d\lambda - a_{rod1}\left(\frac{\int V'_\lambda E_\lambda d\lambda}{\int V_{c\lambda} E_\lambda d\lambda + g_1 \int S_{c\lambda} E_\lambda d\lambda}\right)\left(1 - e^{\frac{-\int V'_\lambda E_\lambda d\lambda}{RodSat}}\right) \\ + a_{b-y}\left(\int S_{c\lambda} E_\lambda d\lambda - k \int V_{c\lambda} E_\lambda d\lambda\right) \\ - a_{rod2}\left(\frac{\int V'_\lambda E_\lambda d\lambda}{\int V_{c\lambda} E_\lambda d\lambda + g_2 \int S_{c\lambda} E_\lambda d\lambda}\right)\left(1 - e^{\frac{-\int V'_\lambda E_\lambda d\lambda}{RodSat}}\right) \end{array} \right\} & b - y \succ 0 \\ 1548\left(\int Mc_\lambda E_\lambda d\lambda - a_{rod1}\left(\frac{\int V'_\lambda E_\lambda d\lambda}{\int V_{c\lambda} E_\lambda d\lambda + g_1 \int S_{c\lambda} E_\lambda d\lambda}\right)\left(1 - e^{\frac{-\int V'_\lambda E_\lambda d\lambda}{RodSat}}\right)\right) & b - y \prec 0 \end{cases} \quad (1)$$

Where, $b - y = \int S_{c\lambda} E_\lambda d\lambda - k \int V_{c\lambda} E_\lambda d\lambda$

$k = 0.2616$;

$a_{b-y} = 0.21$;

$a_{rod1} = 2.30$;

$a_{rod2} = 1.60$;

$g_1 = 1.00$;

$g_2 = 0.16$;

$RodSat = 6.5\ \mathrm{W/m^2}$, representing the half-saturation constant of bleached rod cells;

$V_{c\lambda} = \frac{\frac{V_\lambda}{mp_\lambda}}{\max\left(\frac{V_\lambda}{mp_\lambda}\right)}$, $S_{c\lambda} = \frac{\frac{S_\lambda}{mp_\lambda}}{\max\left(\frac{S_\lambda}{mp_\lambda}\right)}$

E_λ: light source spectral irradiance

Mc_λ: melanopsin sensitivity (corrected for crystalline lens transmittance) (93)

S_λ: S-cone fundamental (94)

mp_λ: macular pigment transmittance (95)

V_λ: photopic luminous efficiency function (96)

V'_λ: scotopic luminous efficiency function (96)

And,

$$\mathbf{CS_{t,f} = 0.7 \times \left[1 - \frac{1}{1 + \left(\frac{t \times f \times CLA}{355.7}\right)^{1.1026}}\right]} \quad (2)$$

where t represents the exposure duration time and has been fitted by a duration of consecutive 0.5–3 h in previous studies (56). f represents the spatial distribution of circadian light exposure. As most of the related studies used light boxes, lamps, or light visors/glasses with less visual field covering than Ganzfeld, f was all valued as 1.0. CL_A, representing circadian light illumination (circadian lux), was determined by the physiological properties of human eyes and light sources. As some spectral information of the devices was unavailable, similar CIE standard light sources or devices have been substituted for $CS_{t,f}$ calculation (Table 1). Besides, we deduced that the accumulative light dose was also important and would contribute significantly to therapeutic efficacy. So that relationship was presumed as (Eq. 3):

$$\mathbf{P_{(u)} = \left[T_{(u,)}\ CS_{t,f_{(u)}}\right]} \quad (3)$$

where $P(u)$ means the function of effect size, $T(u)$ represents the function of accumulative exposure time, and $CS_{t,f}$ represents a continuous circadian stimulus. However, whether T stands for min or days was not yet known and was verified through meta-analysis and dose-response fitting.

4 Clinical efficacy of circadian lighting

The clinical efficacy of circadian lighting was elaborated through between-group efficacy comparison, pre-to-post-treatment evaluation, dose-response, and saturation deduction. We anticipated heterogeneity of study methodologies with variability in diagnosis (depression or not), co-medication, lighting administration, duration, and so on and hence planned several exploratory subgroup analyses (protocol/flow can be checked in Supplementary Figure 2).

TABLE 2 Pre- to-post-treatment outcome sub grouped by study design, co-medication, and disease severity.

Subgroup (study *n*)	Pooled SMD, random, 95% CI	*z* test (p_1)	I^2 (p_2)	p^3	p^4	p^5	p^6
Subgroup A (31)							
Medicated (18)	−2.10 (−2.50, −1.68)	−9.991(<0.01)	94.8% (<0.01)	0.01	0.05		
RCTs	−2.321 (−2.798, −1.845)	−9.543 (<0.01)	94.8% (<0.01)			0.000	0.000
Quasi experimental	−1.102 (−1.895, −0.310)	−2.726 (<0.01)	94.7% (<0.01)				
Non-medicated (13)	−0.799 (−1.010. −0.587)	−7.411 (<0.01)	70.6% (<0.01)	0.001	0.002		
RCTs (6)	−1.03 (−1.27, −0.78)	−8.283 (<0.01)	64.5% (<0.01)				
Non-depressed (7)	−0.398 (−0.700, −0.095)	−2.574 (<0.01)	60.9% (<0.01)				
Subgroup B (24)							
Medicated (18)	−2.10 (−2.50, −1.68)	−9.991(<0.01)	94.8% (<0.01)	0.135	0.29	0.000	0.009
Moderate to severe (13)	−2.215 (−2.683, −1.747)	−9.282 (<0.01)	95.5% (<0.01)				
Mild to moderate (5)	−1.536 (−2.293, −0.779)	−3.975 (<0.01)	87.2% (<0.01)				
Non-medicated (6)	−1.03 (−1.27, −0.78)	−8.283 (<0.01)	64.5% (<0.01)	0.502	0.45		
Moderate to severe (4)	−0.917 (−1.099, −0.734)	−9.833 (<0.01)	0.0% (0.597)				
Mild to moderate (2)	−1.137 (−1.752, −0.521)	−3.620 (<0.01)	88.1% (<0.01)				

Pre-to-post outcomes extracted at various time points within 24 depression-related studies; $p1$ is the p-value of the overall effect size test; $p2$ is the p-value within the subgroup referring to heterogeneity using Cochran's Q statistic; $p3$ is the p-value between severity subgroups using Q-statistic; $p4$ is the p-value between severity subgroups using F-statistic; $p5$ is the p-value between medication subgroups using Q-statistic; and $p6$ is the p-value between medication subgroups using F-statistic.

4.1 Main heterogeneity sources

Pre- to-post-treatment outcomes were sub grouped based on study characteristics, based on which preliminary meta-regression was stratified separately by categorical covariates: (a) co-medication, (b) disease severity, (c) light intensity, (d) light color, (e) accumulative duration of exposure to light during intervention, (f) circadian stimulus of light, (g) intervention period and follow-up, and (h) whether study designed as RCT (Supplementary Table S4). The p-values of meta-regression had implied co-medication ($p = 0.01$) and temporal pattern ($p = 0.000$) as main sources of heterogeneity. Subgroup meta-analysis was further adopted to quantify the between-study differences, with I^2 values of 25, 50, and 75% reflecting a small, medium, and large degree of heterogeneity, and H values of 1, <1.2, 1.2–1.5, >1.5 indicating non, small, substantial, and considerable heterogeneity.

Subgroup meta-analysis subdivided by co-medication × depression (shown in Tables 1, 2 Subgroup A) yielded a significant effect of this covariate on the outcome ($p = 0.000$), suggesting significant difference existed between studies with co-medication, without co-medication, and non-depressed (non-medicated) groups. Significant differences also existed between temporal pattern subgroups during the intervention ($p = 0.044$). None of the other tests showed a statistically significant influence of the moderator variable: light intensity ($p = 0.208$), light color ($p = 0.241$), $CS_{t,f}$ division ($p = 0.543$), intervention period/follow-up ($p = 0.361$) or study design ($p = 0.105$), whereas disease severity ($p = 0.085$) may be slightly more influencing (Supplementary Table S5). Notably, whether these factors yield a significant effect on the primary and secondary outcomes or not (see discussion in Section 4.2) could be dose-response confounding variables (see discussion in Section 4.3).

With co-medication suggested as a confounding factor, outcome data were further extracted within both co-medicated and non-medicated studies with only depressed participants. The meta-analysis (Table 2, Subgroup B) showed that 18 studies with co-medication (575 participants) obtained higher pre-to-post effect size (SMD = −2.1, 95% CI = −2.5 to −1.68; $z = -9.991$, $p = 0.000$; $I^2 = 94.8\%$) than those non-medicated (231 participants) (SMD = −1.03, 95% CI = −1.27 to −0.78; $z = -8.283$, $p = 0.000$, $I^2 = 64.5\%$), and the effect of this variable showed significant between-group heterogeneity [$\chi^2_{(1,85)} = 19.14$, $p = 0.000$]. The outcome was simultaneously confirmed in conjunction with the F statistic [$F_{(1,83)} = 7.08$, $p = 0.009$].

To confirm the disease severity factor, a further subgroup meta-analysis of severity was undertaken. There was no significant between-group heterogeneity both with [$\chi^2_{(1,n=60)} = 2.24$, $p = 0.135$] and without [$\chi^2_{(1,n=23)} = 0.45$, $p = 0.502$] co-medication. Some inconsistency was observed in the subgroup with more severity—it yielded a numerically higher effect size (SMD = −2.215, 95% CI = −2.68 to −1.75; $z = -9.282$, $p = 0.000$; $I^2 = 95.5\%$) than a presumed milder subgroup (SMD = −1.53, 95% CI = −2.29 to −0.77; $z = -3.975$, $p = 0.000$; $I^2 = 87.2\%$) under co-medication conditions, whereas the reverse was observed in non-medicated studies.

4.2 Between-group efficacy comparison

Between-group efficacy comparison of circadian-active BLT vs. dim light control among RCTs was also studied with possible confounding factors such as visualization, co-medication, disease severity, as well as

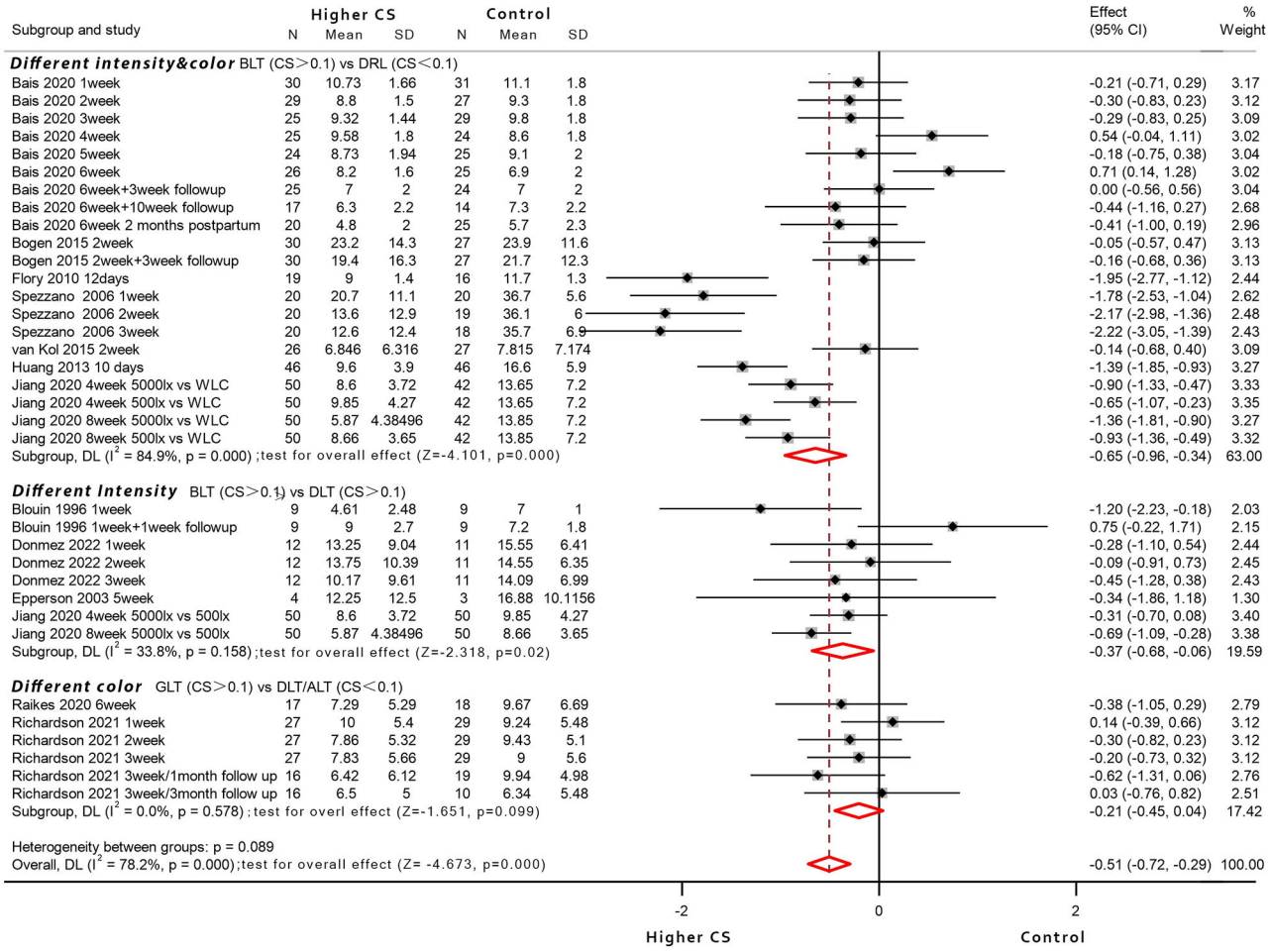

FIGURE 2
Forest plot displaying between-group meta-analysis of bright light therapy (higher circadian stimulus) vs. the control group (n = 12 articles; RCTs without identical baseline were excluded).

time pattern, which were all reported in the primary and secondary results.

4.2.1 Visualization factors

Assuming light intensity and light color across RCTs may exert visualization influence, they were examined as weighted random-effects meta-analyses (Figure 2), undertaking for each of the comparisons that were eligible for analysis, i.e., higher $CS_{t,f}$ of BLT vs. lower $CS_{t,f}$ of DLT- dim light therapy (four studies); higher $CS_{t,f}$ of BLT vs. non-circadian dim red light-DRL (seven studies); and higher $CS_{t,f}$ of GLT (green light therapy) vs. non-circadian DLT/amber light therapy-ALT (two studies). The intervention/control conditions were compared after parameter conversion ($CS_{t,f}$ in the intervention group > $CS_{t,f}$ in the control group).

Eleven studies had <100 lux dim-light control (light box or light visor), four studies utilized a sham negative ion generator with working lights and sound (81, 88, 90, 97), four studies adopted 500 lux light to eliminate placebo effect as much as possible (22, 30, 31, 71), and one study employed an untreated control arm (31). To conclude, ten studies where intervention could be visually distinguished among different arms were included as a subgroup, and so were the two RCT studies that adopted similar devices with identical photopic lux (76, 78). The participants were reported keeping as naive as possible regarding the existence and effects of LT (70, 71, 77, 81), or they held identical expectations for different interventions (70, 78, 88, 90, 97), or the light devices were identical in shape and appearance among double-blind studies (30, 78). However, the placebo effect could hardly be ruled out—it was proposed that the circadian stimulus from a non-visual perspective would exert additional influence; thus, the between-group comparison was based on higher/lower $CS_{t,f}$ variation. Apart from exclusionary RCTs with unequal baseline [or not reported identical (68, 70, 79, 80, 82)], all others reported no statistically significant baseline difference and identical expectation of treatment response.

For the higher $CS_{t,f}$ of GLT vs. non-circadian DLT/ALT (different color, two studies) subgroup, where LT devices shared similar appearance with equal photon densities of blue-green light vs. amber/red light, the results for a total of 91 participants were evaluated, of which 44 patients received blue-green light ($CS_{t,f}$ >

0.1) and 47 patients received a placebo control light therapy ($CS_{t,f} < 0.1$). The meta-analysis with random-effects models found no evidence for the significant efficacy of GLT compared to amber/red light conditions (SMD = −0.21, 95% CI = −0.45 to 0.04; $z = -1.651$, $p = 0.099$; $I^2 = 0\%$).

For the higher $CS_{t,f}$ of BLT vs. lower $CS_{t,f}$ of DLT (different intensity of white light, four studies) subgroup where bright white light ($N = 75$ participants) compared with mainly 500 lux white light ($N = 73$ participants), the former yielded significant efficacy with pooled effect size of −0.37 (95% CI = −0.68 to −0.06; $z = -2.318$, $p = 0.02$; $I^2 = 33.8\%$) compared to controls ($CS_{t,f} > 0.1$ in both groups).

For higher $CS_{t,f}$ of BLT vs. circadian-inactive DRL (different intensity and color, seven studies), the results for a total of 430 participants were evaluated, of which 221 patients received BLT ($CS_{t,f} > 0.1$), and 209 patients received a placebo control, presumably circadian-inactive ($CS_{t,f} < 0.1$). The results showed an overall high heterogeneity with a significant heterogeneity index when included trials were pooled ($I^2 = 84.9\%$) and revealed the bright light superiority in depressive symptoms reduction compared to the control group (pooled SMD = −0.65, 95% CI = −0.96 to −0.34; $z = -4.101$, $p = 0.000$).

The secondary outcome was also pooled on the random-effects inverse-variance model. Relative risk and 95% CIs were calculated for the subset of nine RCT studies of which the number of subjects who experienced response was known (Supplementary Figures 3A, B). The pooled estimate RR of BLT over no light placebo was 2.39 (95% CI = 1.54–3.73; $z = 3.856$, $p = 0.000$; $I^2 = 28.4\%$; three studies). For comparison over DLT and DRL controls, a revealed RR of 1.33 (95% CI = 0.98–1.80; $z = 1.823$, $p = 0.068$; $I^2 = 0.0\%$; four studies) and 1.53 (95% CI = 0.71–3.29; $z = 1.085$, $p = 0.278$; $I^2 = 0.0\%$; three studies) showed no significant superiority. Similarly, calculated odds ratios (95% CI) showed a significant advantage over no light control (OR = 9.59, 95% CI = 3.7–24.88; $z = 4.648$, $p = 0.000$; $I^2 = 70.3\%$) and DLT control (OR = 9.59, 95% CI = 3.7–24.88; $z = 3.370$, $p = 0.001$; $I^2 = 0.0\%$), but no significant difference of response rates between BLT and DRL control was found (pooled OR = 2.13, 95% CI = 0.76–5.99; $Z = 1.434$, $p = 0.152$; $I^2 = 12.3\%$). Overall, there was no significant difference between the three subgroups subdivided by visual characteristics [SMD: $\chi^2_{(2,35)} = 4.83$, $p = 0.09$; RR: $\chi^2_{(2,13)} = 2.78$, $p = 0.25$; OR: $\chi^2_{(2,13)} = 0.50$, $p = 0.78$].

4.2.2 Co-medication and disease severity factors

Since co-medication was largely a main heterogeneity source, in addition to the fact that response outcomes were barely reported by quasi-experimental trials, a subgroup meta-analysis was further carried out but focused on depression-oriented RCTs accompanied with or without co-medication (Supplementary Figures 3C, E). Where primary results indicated circadian-active BLT, the analysis showed significant efficacy compared to dimmer light controls under both co-medicated (pooled SMD = −0.47, 95% CI = −0.80 to −0.13; $z = -2.749$, $p = 0.006$; $I^2 = 82.0\%$; five studies) and non-medicated conditions (pooled SMD = −0.57, 95% CI = −0.81 to −0.33; $z = -4.67$, $p = 0.000$; $I^2 = 58.0\%$; four studies). There was no significant between-group heterogeneity caused by co-medication [$\chi^2_{(1,32)} = 0.24$, $p = 0.62$].

Secondary outcomes indicated that circadian-active bright light showed significantly greater response likelihood than controls among both medicated (pooled RR = 1.56, 95% CI = 1.24–1.95; $z = 3.869$, $p = 0.000$; three studies) and non-medicated individuals (pooled RR = 6.31, 95% CI = 2.34–16.99; $z = 3.645$, $p = 0.000$; five studies). Both subgroups showed non-significant heterogeneity ($I^2 = 0.0\%$), indicating significant between-group heterogeneity caused by co-medication [$\chi^2_{(1,15)} = 8.45$, $p = 0.007$]. Similar results of superiority could be drawn on a pooled estimate OR of 5.01 (95% CI = 2.79–8.99; $z = 5.934$, $p = 0.000$; eight studies) over controls. The noticeable superiority of response possibility may be due to co-medication that caused significant between-group heterogeneity [$\chi^2_{(1,15)} = 5.23$, $p = 0.004$]. Both outcomes were further confirmed [co-medication RR: $F_{(1,13)} = 8.24$, $p = 0.01$; OR: $F_{(1,13)} = 7.75$, $p = 0.01$].

Response data was further extracted and subdivided by disease severity as a secondary subgroup. On the whole, consistent conclusions could be drawn from secondary outcomes among non-medicated studies (Supplementary Figure 3F), with a pooled RR value indicating circadian-active bright light showing overall superior response rate compared to controls, whether not significant under more severe conditions (pooled RR = 2.20, 95% CI = 0.86–5.63; $z = 1.648$, $p = 0.099$; $I^2 = 0.0\%$; three studies) or significant under milder conditions (pooled RR = 1.53, 95% CI = 1.21–1.92; $z = 3.578$, $p = 0.000$; $I^2 = 0.0\%$; two studies). Similar results were shown among co-medication studies (Supplementary Figure 3G), which showed significant superiority under more severe conditions (pooled RR = 6.29, 95% CI = 2.18–18.14; $z = 3.405$, $p = 0.001$; $I^2 = 0.0\%$; two studies) or non-significant under milder conditions (pooled RR = 6.43, 95% CI = 0.39–106.44; $z = 1.299$, $p = 0.194$; $I^2 = 0.0\%$; one study). There was no significant between-group heterogeneity among severity subgroups regarding response rates both with [$\chi^2_{(1,5)} = 0.01$, $p = 0.457$] and without [$\chi^2_{(1,10)} = 0.42$, $p = 0.989$] co-medication, confirming "co-medication" rather than "disease severity" was an efficacy comparison influential factor.

4.2.3 Time pattern factors

The time factor (cumulative duration) that was implied as a heterogeneity source was further elaborated among depression-related RCTs. Primary results indicated circadian-active BLT showing significant or non-significant efficacy compared to dimmer light controls under various duration conditions (Supplementary Figure 3H), with combined results significantly indicating superior efficacy than the control group (pooled SMD = −0.49, 95% CI = −0.71 to −0.27; $z = -4.34$, $p = 0.000$; $I^2 = 77.7\%$; nine studies). There was no significant between-group heterogeneity caused by time pattern factor [$\chi^2_{(4,32)} = 9.03$, $p = 0.06$].

Similar secondary pooled RR and OR estimates of eight RCTs indicated that the circadian-active bright light showed overall greater response likelihood than controls. There was no significant between-group heterogeneity caused by time [RR: $\chi^2_{(4,15)} = 6.72$, p

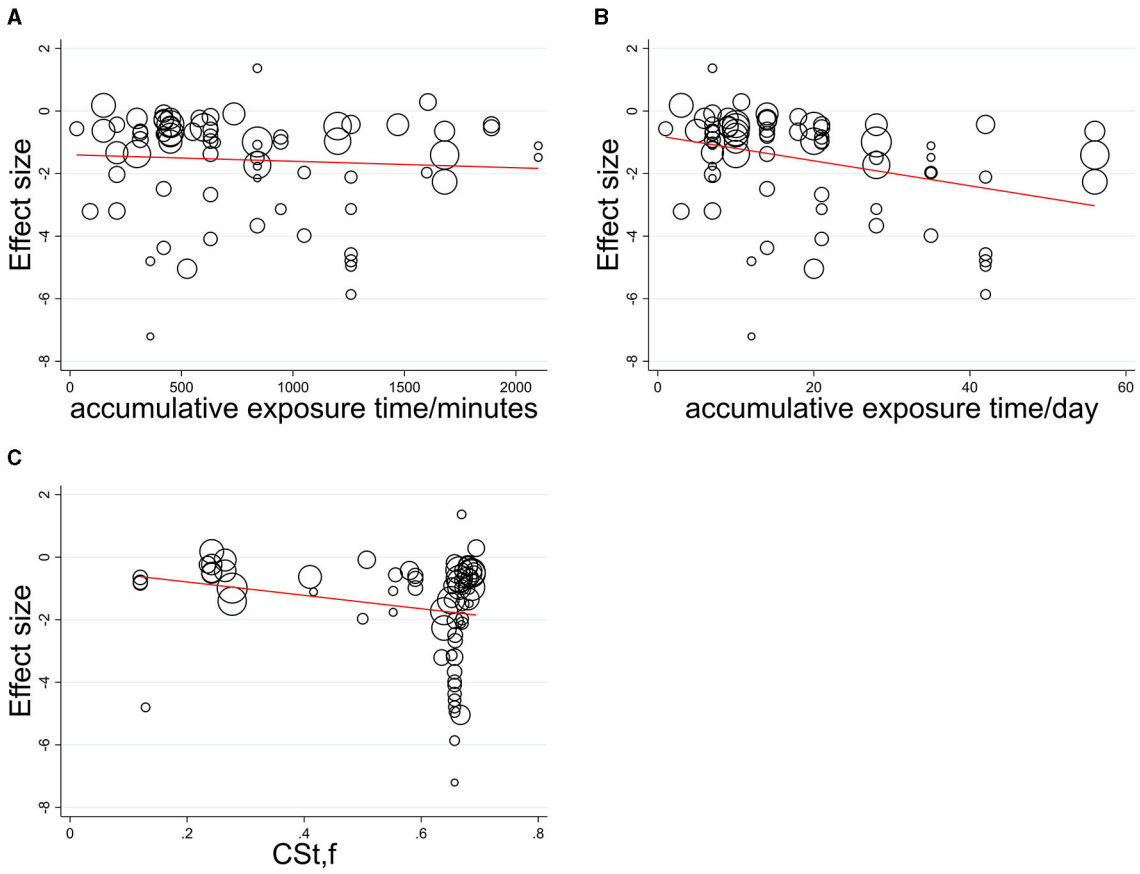

FIGURE 3
Meta-regression relationship between effect size and its standard error with **(A)** accumulative exposure min/h, **(B)** accumulative exposure days, **(C)** $CS_{t,f}$ as a covariate.

$= 0.235$; OR: $\chi^2_{(4,15)} = 7.88$, $p = 0.146$], whether significant or not (Supplementary Figures 3I, J).

In conclusion, due to the non-ignoring visual distinction and the placebo effect, the efficacy of the bright light intervention compared to both circadian-inactive and active control conditions cannot be simply elucidated from the "circadian" perspective. Nevertheless, it seemed not all observed treatment responses were related to the non-specific effects since some cases had reported no relationship between expectation and improvement (88). On the whole, circadian-active BLT, whether significant or not, showed a greater possibility of response than active/inactive placebo, regardless of visualization, co-medication, disease severity, or cumulative duration that were assumed as confounding factors; co-medication alone showed more likelihood.

4.3 Dose-response relationship and influencing factors

A dose-response relationship was quantified with only vital continuous parameters such as $CS_{t,f}$, and accumulative exposure time and was explored among the circadian studies ($CS_{t,f} > 0.1$; 31 studies, $N = 813$ participants). The single covariate was carried out in meta-regression to show the statistically significant influence of the moderator variable (Figure 3), indicating accumulative exposure min/h as irrelevant explanatory covariate (no explanation, $R^2 = 1.01\%$, $p = 0.582$) and relevant covariate as accumulative exposure days (some explanation, $R^2 = 12.43\%$, $p = 0.003 < 0.05$) and $CS_{t,f}$ value (weak explanation, $R^2 = 5.71\%$, $p = 0.041 < 0.05$).

Fitting was further carried out by two independent variables ($CS_{t,f}$, time) among the sub grouped medicated and non-medicated studies to show their contribution to therapeutic effect size, utilizing the Levenberg Marquardt algorithm. The 3D fitting outcomes among medicated patients (Figures 4–6) offer a glimpse of the relationship between accumulative circadian stimulus and malady reduction. Based on current data, the fitting adaptability of accumulative exposure days ($R^2 = 17.0$–33.7%) was overall better than minutes ($R^2 = 4.59$–12.62%). Meanwhile, accumulative circadian stimulus, i.e., $P(u)$ illustrated by $T_{(u)}$ and $CS_{t,f}$ may largely be explained by polynomial models with better goodness of fit that shown in Equations 4 and 5:

$$\mathbf{P}\ (\mathbf{u}) = \mathbf{a} + \mathbf{b} \times \mathbf{T} + \mathbf{c} \times \mathbf{T}^2 + \mathbf{d} \times \mathbf{T}^3 + \mathbf{e} \times \mathbf{CS_{t,f}} + \mathbf{f} \times \mathbf{CS_{t,f}}^2 \quad (4)$$

or

$$\mathbf{P}\ (\mathbf{u}) = \mathbf{a} + \mathbf{b} \times \mathbf{T} + \mathbf{c} \times \mathbf{T}^2 + \mathbf{d} \times \mathbf{CS_{t,f}} + \mathbf{e} \times \mathbf{CS_{t,f}}^2 + \mathbf{f} \times \mathbf{CS_{t,f}}^3 \quad (5)$$

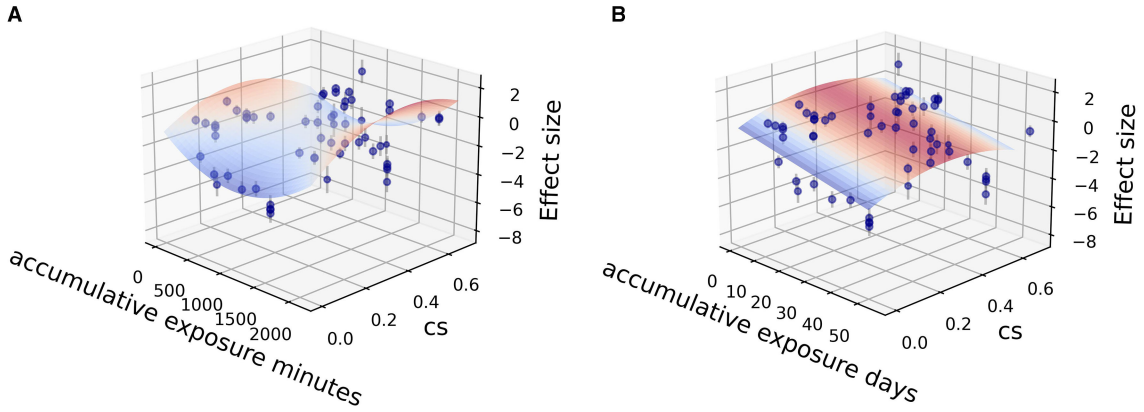

FIGURE 4
Fitting for data points clusters of 18 co-medication studies on poly 2D fitting models. **(A)** Poly 2D model fitted with accumulative exposure minutes, $z = 1.0178 - 0.004x - 10.544y + 0.000002x^2 - 15.33y^2 + 0.00156xy$ ($R^2 = 6.07\%$). **(B)** Poly 2D model fitted with accumulative exposure days, $z = -0.488 - 0.153x + 6.999y + 0.002x^2 - 9.358y^2 + 0.004xy$ ($R^2 = 17.0\%$).

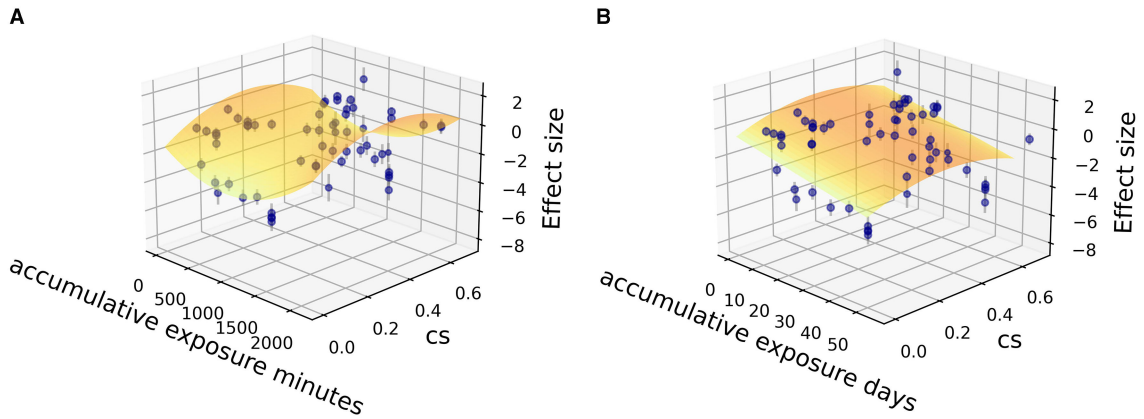

FIGURE 5
Fitting for data points clusters of 18 co-medication studies on parabola 2D fitting models. **(A)** Parabola 2D model fitted with accumulative exposure minutes, $z = -1.50 - 0.00368x + 11.78y + 0.00000195\ x^2 - 15.31y^2$ ($R^2 = 4.59\%$). **(B)** Parabola 2D model fitted with accumulative exposure days, $z = -0.52 - 0.15x + 7.127y + 0.0021\ x^2 - 9.421\ y^2$ ($R^2 = 17.0\%$).

where a, b, c, d, e, f are all parameters working on the slope and direction of the curve. T represents accumulative exposure time. And the models implied that the therapeutic effect may reach saturation.

The overall dose-response relationship among depressed, co-medicated patients (18 studies) implied saturation would reach at about 36 days (1,000 min) modeled on both poly 2D parabora2D equations and 34.4 days modeled on polynormal 2D models.

Figures 7, 8 show that the dose-response relationship between therapeutic effect size (SMD value) and its standard error with accumulative exposure time as an independent variable in various $CS_{t,f}$ ranges fit well with the exponent function or polynomial function. Among medicated individuals, The effect size would reach saturation in about 1,000 min/36–38 days in $CS_{t,f} < 0.1$–0.4 range ($n = 7$ studies, 26 items), 900–1,000 min/32–33 days in 0.6–0.665 range ($n = 7$ studies, 20 items), and 40 days in 0.665–0.7 ($n = 7$ studies, 13 items) ranges (780–850 min/37–38 days in 0.6–0.7 range, 970–1,000 min/41–42 days in 0.2–0.7 range). On the whole, in most "circadian" conditions ($0.2 < CS_{t,f} < 0.7$), polynomial models implied the saturation would reach 900–1,000 min (32–42 days) as temporal saturation for medicated AYAs.

Similar quantification outcomes were checked in non-medicated and non-depressed people (Supplementary Figures 5, 6) and severity × co-medication interaction tests (Supplementary Figures 7, 8). For non-medicated, depressed people (six studies), it was found that saturation would reach in ∼1,350 min (accumulative) fitted by the poly 2D model and 1,450 min (58.9 days) by the parabora2D equations. The polynomial models implied 1,100–1,500 min as temporal saturation for non-medicated AYAs. Similar outcomes were verified among those who suffered at least moderate disease severity, where 700–1,000 min (22–41 days) saturation was implied with co-medication and 700–1,500 min for the non-medicated subgroup, indicating the dominant synergistic effect of medication. In contrast, among those with mainly mild depression (seven studies) or non-depressed (seven studies), the saturation seemed

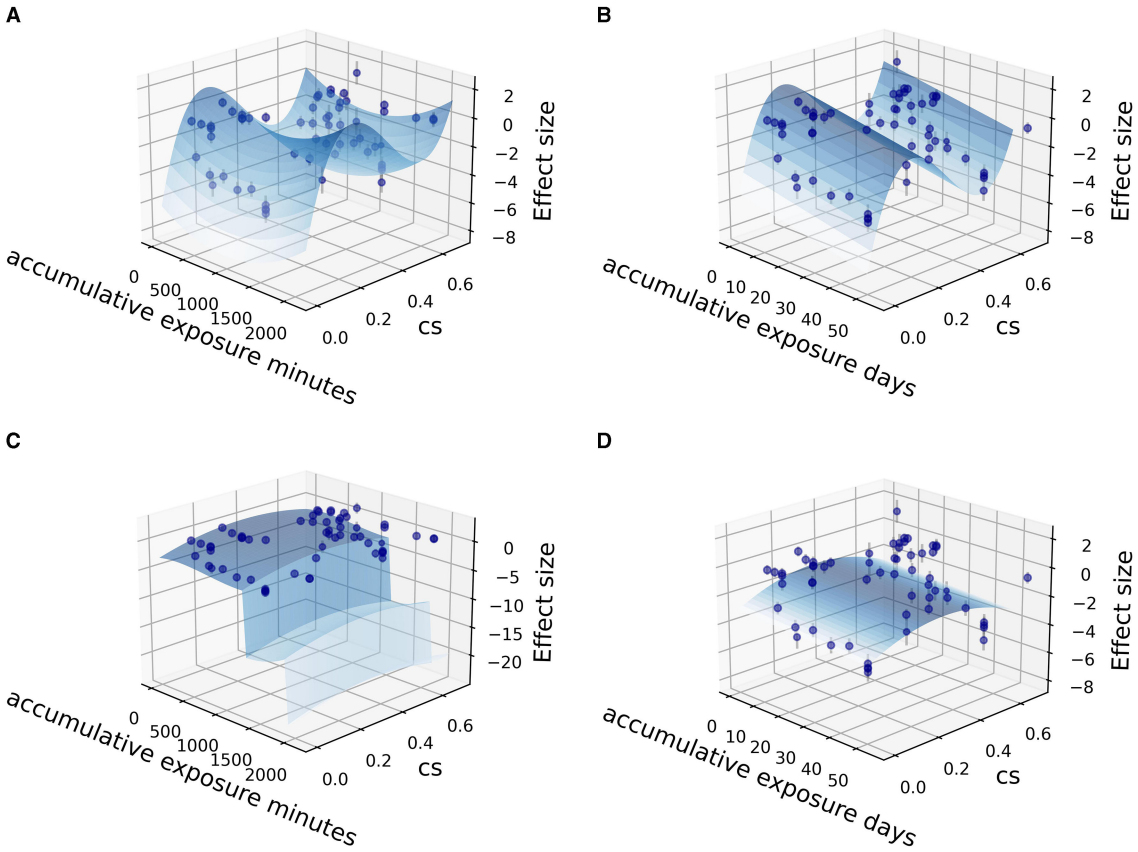

FIGURE 6
Fitting for data points clusters of 18 co-medication studies on polynormal 2D fitting models. **(A)** Polynormal 2D model fitted with accumulative exposure minutes, $z = 6.211 - 0.0037x + 0.000975x^2 + 80.506y + 0.00000188x^2 - 265.733y^2 + 236.39y^3$ ($R^2 = 15.62\%$). **(B)** Polynormal 2D model fitted with accumulative exposure days, $z = -5.349 - 0.1556x + 0.002x^2 + 75.99y + 0.00000188x^2 - 258.30y^2 + 233.96y^3$ ($R^2 = 28.0\%$). **(C)** Polynormal 2D model fitted with accumulative exposure minutes (–). **(D)** Polynormal 2D model fitted with accumulative exposure days, $z = 2.933 + 0.306x - 0.0185x^2 + 0.000243x^3 + 8.649y - 11.993y^2$ ($R^2 = 33.76\%$).

indistinct. The confounding effect of disease severity was not qualified due to limited samples.

For circadian RCT studies ($CS_{t,f} > 0.1$), the implied saturation reached about 1,000 min (46 days) based on the poly2D model, 1,145 min (44 days) on the parabora2D model, and 1,230 min (44 days) modeled on the polynormal 2D equation. No quantitative conclusions were derived among quasi-experimental studies. Whether the study design was influencing remains ambiguous (Supplementary Figure 9).

On the whole, $CS_{t,f}$, duration, and co-medication proved to be dose-response influencing factors, whereas the potential confounding effects of disease severity, study design, and lighting administration are yet to be fully explicated (Supplementary Figures 4, 10). Overall, 1,000–1,500 min (~30–60 days) of accumulative duration can be inferred as saturation, as fully discussed with certain factors. Meanwhile, it is concluded that accumulative duration $T_{(u)}$ suitably fitted into the polynomial model within various $CS_{t,f}$ intervals, and the relationship did not change significantly after adjusting for various confounding factors (equation 6), that:

$$\mathbf{P_{(u)} = a + b \times T + c \times T^2} \quad (6)$$

4.4 Saturation of light therapy

Since continuous dose-response analysis showed a non-linear relationship between temporal pattern and depression reduction, subgroup meta-analysis of temporal pattern within $CS_{t,f}$ variation was further specified, considering co-medication as a covariate. Depression reduction showed in pooled estimates of SMD was associated with cumulative duration intervals (subdivided by 5, 35, 65, 95%, i.e., dose division). The categorical dose-response analysis was undertaken by comparing 0–300 min/300–500 min/500–1,000 min/1,000–1,500 min/>1,500 min subgroups with each other, using random-effects modeling techniques, and p-values < 0.05 were considered statistically significant with all double-sided testing (Table 3).

In the $CS_{t,f} < 0.1$–0.2 range that is barely considered as "circadian" condition, there was significant pre- to post-treatment difference between 1,000–1,500 min/>1,500 min ($p = 0.0018$), 1,000–1,500 min/0–300 min ($p = 0.004$), 1,000–1,500 min/300–500 min ($p = 0.008$), and 500–1,000 min/0–300 min ($p = 0.03$), 500–1,000 min/>1,500 min ($p = 0.01$) subgroups among depressed and medicated AYAs, indicating time as a confounding factor [$F_{(4,12)} = 6.06$, $p = 0.006$]. There was no significant between-group heterogeneity among depressed but non-medicated persons

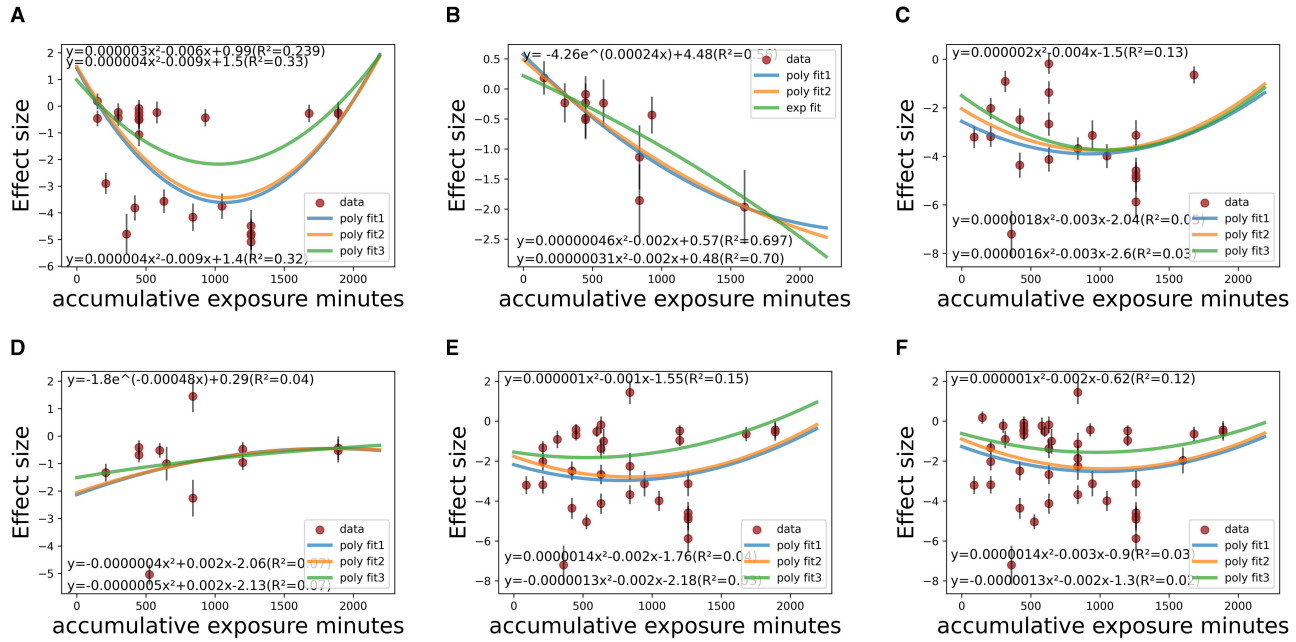

FIGURE 7
Temporal fitting (accumulative exposure minutes) among co-medicated studies within various $CS_{t,f}$ ranges. **(A)** $CS_{t,f}$ range < 0.1–0.4 (R^2 = 23.9–33.0%). **(B)** $CS_{t,f}$ range 0.40–0.60 (R^2 = 28.2–30.8%). **(C)** $CS_{t,f}$ range 0.60–0.665 (R^2 = 1.0–13%). **(D)** $CS_{t,f}$ range 0.665–0.7 (R^2 = 4.0–7.0%). **(E)** $CS_{t,f}$ range 0.60–0.70 (R^2 = 3.0–15.0%). **(F)** $CS_{t,f}$ range 0.20–0.70 (R^2 = 2.0–12.0%).

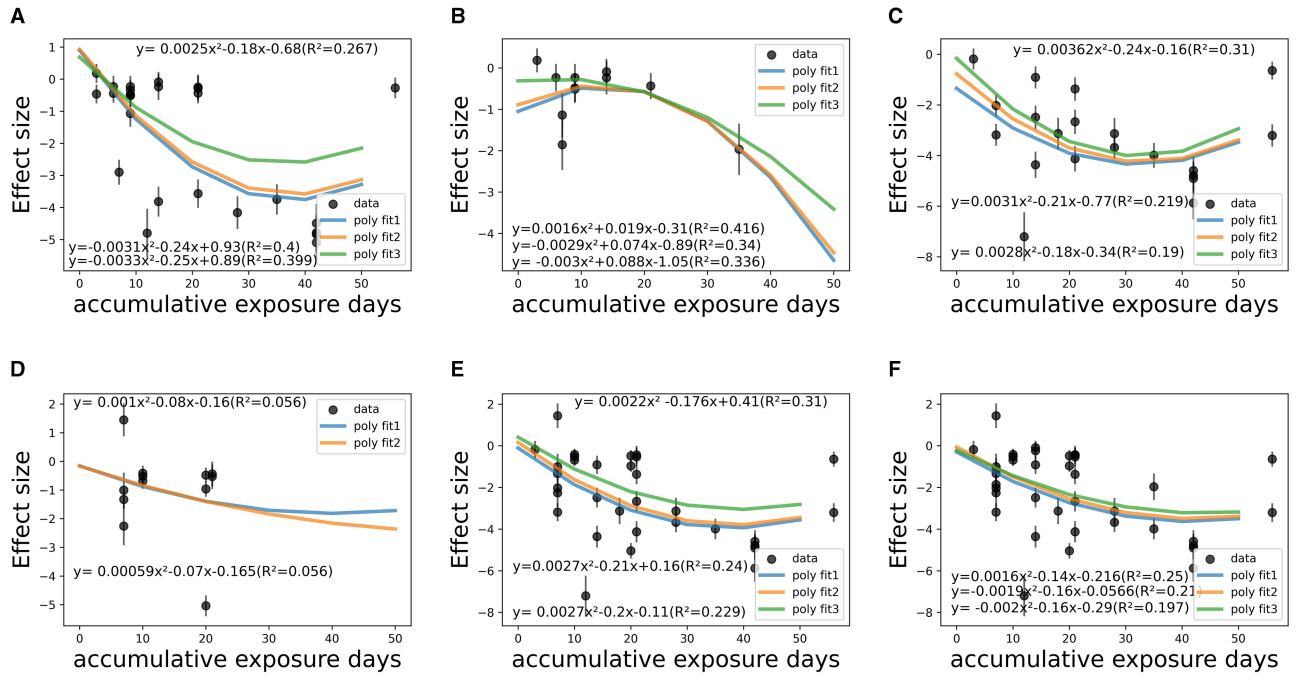

FIGURE 8
Temporal fitting (accumulative exposure days) among co-medicated studies within various $CS_{t,f}$ ranges. **(A)** $CS_{t,f}$ range <0.1–0.40 (R^2 = 26.7–40.0%). **(B)** $CS_{t,f}$ range 0.40–0.60 (R^2 = 33.6–41.6%). **(C)** $CS_{t,f}$ range 0.60–0.665 (R^2 = 19.0–31.0%). **(D)** $CS_{t,f}$ range 0.665–0.70 (R^2 = 5.6%). **(E)** $CS_{t,f}$ range 0.60–0.70 (R^2 = 22.9–31.0%). **(F)** $CS_{t,f}$ range 0.20–0.70 (R^2 = 19.7–25.0%).

($p = 0.922$), nor among non-depressed, non-medicated people ($p = 0.688$). In contrast, there was a significant difference between the three subgroups [$F_{(2,24)} = 5.99$, $p = 0.007$].

In the $CS_{t,f}$ 0.2–0.4 range, there was no significant between-group heterogeneity of time pattern among depressed and medicated patients ($p = 0.729$) or non-medicated people ($p = 0.175$). No significant pre- to post-treatment difference was observed between various duration subgroups [$F_{(2,5)} = 0.33$, $p = 0.73$]. In contrast, a significant difference existed between with/without co-medication subgroups [$F_{(2,8)} = 15.01$, $p = 0.002$].

In the $CS_{t,f}$ 0.4–0.6 range, there was no significant between-group heterogeneity of time pattern among medicated patients ($p = 0.473$), depressed but non-medicated patients ($p = 0.904$), and non-depressed, non-medicated people ($p = 0.475$). In contrast, a significant difference existed between these three groups [$F_{(2,8)} = 4.55$, $p = 0.04$].

In the $CS_{t,f}$ 0.6–0.7 range among the depressed but non-medicated people, there was significant between-group heterogeneity ($p = 0.004 < 0.5$), but it could not be explained by between-group differentiation due to high heterogeneity within subgroups. No significant difference was found between temporal pattern groups [$F_{(4,7)} = 0.87$, $p = 0.53$]. In the $CS_{t,f}$ 0.6–0.7 range among depressed, medicated people, no significant pre to post-treatment difference was found between time pattern differentiation [$F_{(4,29)} = 1.39$, $p = 0.26$]. However, there was a significant difference between 1,000 and 1,500 min/>1,500 min subgroups ($p = 0.03 < 0.05$). Similarly, a significant difference was observed between the three groups [$F_{(2,45)} = 3.52$, $p = 0.037$].

In conclusion, 1,000–1,500 min of accumulative exposure duration is suggested as a threshold, especially on a higher $CS_{t,f}$ basis, and co-medication was verified as the main heterogeneity source, corresponding with previous outcomes.

4.5 Publication bias

Using Egger's linear regression test, we found there existed publication bias and small study effects (Supplementary Figure 11) with all outcomes (97 items, intercept = −6.25, 95% CI = −8.52 to −3.99, $t = 5.48$, $p = 0.000 < 0.05$), only "circadian" studies (73 items, intercept = −4.82, 95% CI = −7.23 to −2.41, $t = 3.98$, $p = 0.000 < 0.05$), only "depression" studies (85 items, intercept = −7.27, 95% CI = −9.69 to −4.86, $t = 5.99$, $p = 0.000 < 0.05$), only co-medicated studies (61 items, intercept = −10.75, 95% CI = −13.62 to −7.88, $t = 7.49$, $p = 0.000<0.05$), as well as only RCT studies (85 items, intercept = −7.20, 95% CI = −9.61 to −4.78, $t = 5.94$, $p = 0.000 < 0.05$), respectively. However, for the purpose of dose-response quantification, the more data was included, the better.

5 Discussion

5.1 Efficacy of specified, quantified circadian light therapy

To our knowledge, the study may not be the first systematic review of BLT on youth, but it is the first meta-analysis of lighting therapy focusing on circadian stimulus and its accumulative dose-response on depression-related illnesses for AYAs. On the whole, bright light therapy for depressed AYA with higher $CS_{t,f}$ cannot be proved significantly efficacious over lower $CS_{t,f}$ light interventions since symptom reduction was seen in both groups. It was largely influenced by both circadian ways and visual ways, accompanied by the fact that strong circadian evidence has not been found in young individuals with severe visual impairment or blindness (capacity for photoentrainment may be sustained) since empirical evidence was only derived from certain adults (98). However, measuring circadian timing in future trials would allow for a more rigorous examination of mechanisms (and possibly different pathways) linking circadian misfunction with depressive symptomology.

To explore circadian stimulus connection with therapeutic efficacy, $CS_{t,f}$ can indeed be used as a metric quantification method for its accuracy in circadian phototransduction process in AYA depression-oriented clinical trials and theoretical studies. The conclusion was supported and validates previous conclusions quantitatively in the following ways. (1) It can be conservatively concluded that when exerting light exposure with certain circadian stimulus ($CS_{t,f}$ = <0.1–0.7), 30–2,100 min of accumulative time (roughly within 8 weeks) is efficacious for disease amelioration. Despite the value of I^2 ($I^2 = 92.8\%$) indicating a high degree of heterogeneity, the pooled SMD values of the vast majority of studies indicated at least small (>0.2) to large (>2.0) change of effect size. The result has supported a broader range of $CS_{t,f}$ of light therapy compared to previous conclusions where $CS_{t,f}$ ranged from 0.57 to 0.7 (1).

(2) The therapeutic effect has shown a positive relationship with increasing light dose in both within-group and crossover changes. For young people primarily aged <32 (approximate mean age 22.3 ± 7.4), temporal duration of exposure contributed up to about 20–30% (or much higher) to within-group effect size variation (fitted by various models), while the therapeutic effect size was less be explained by $CS_{t,f}$ ($R^2 = 5.71\%$), co-medication ($R^2 = 6.94\%$) or hardly by other confounding factors, indicating that overall temporal pattern was the most crucial. These quantified conclusions have been drawn from regression models performed by Statas 17.0, CMA 3.0, and Python 3.9 that polynomial 2D models can better illustrate quantification correlation between therapeutic effect and accumulative circadian stimulus, despite fitting models showing imperfection statistically (much-oscillated R^2).

(3) Dose-response saturation. From the dose-response fitting and subgroup meta-analysis of temporal patterns, accumulative 900–1,000 min (32–42 days) of duration may be the saturation for depressed and medicated AYAs and 1,100–1,500 min (58–59 days) for non-medicated patients. Albeit, 1,000–1,500 min (5–7 weeks) of accumulative exposure duration showed more efficacy in symptom reduction than <1,000 min (3–4 weeks) or >1,500 min (7+ weeks) subgroups within high circadian stimulus ($0.6 < CS_{t,f} < 0.7$). For $CS_{t,f} < 0.2$ intervals that are barely considered as "circadian" conditions, accumulative 500–1,000 min duration may be the most efficacious among depressed and medicated AYAs. Meanwhile, for non-depressed individuals, the temporal pattern could not be verified due to limited samples. The results suggest that for common LT devices (LT-box, lamps, glasses), 1,000–1,500 min (5–7 weeks) of the threshold may be saturation combined with medication, regardless of their lighting features (e.g., light levels, spectra, light distribution). This conclusion endorses and expands previous conclusions, suggesting 2–5 weeks of exposure (16).

(4) Possible polynomial models on accumulative circadian stimulus and therapeutic effect have been quantified beyond consecutive light dose ($CS_{t,f}$ value), which has not been illustrated in previous studies.

TABLE 3 Significant between-group differences are sub grouped by main heterogeneity sources ($CS_{t,f}$, co-medication, and temporal pattern).

Subgroup (study *n*)	Temporal pattern/mins	Pooled SMD, random, 95% CI	*z* test (p_1)	I^2 (p_2)	p^3	p^4	p^5
$CS_{t,f} < 0.2$							
Medicated (4)	0–300	−1.25 (−2.66, 0.16)	−5.869 (<0.01)	94.5% (<0.01)	<0.01	0.006	0.007
	300–500	−2.01 (−3.43, −0.59)		94.7% (<0.01)			
	500–1,000	−3.80 (−4.30, −3.29)		0% (0.639)			
	1,000–1,500	−4.81 (−5.34, −4.27)		0% (0.902)			
	>1,500	−0.26 (−0.77, 0.24)		0% (0.943)			
Non-medicated (2)	0–300	−0.65 (−1.51, 0.22)	−5.190 (<0.01)	0 (1.0)	0.922	NA	
	300–500	−0.84 (−1.23, −0.44)		0% (0.66)			
	500–1,000	−0.81 (−1.43, −0.19)		0% 0.966)			
	>1,500	−0.48 (−1.20, 0.25)		0 (1.0)			
Non-depressed, non-medicated (4)	0–300	0.15 (−1.15, 1.44)	−0.173 (0.863)	83.1% (0.015)	0.688	NA	
	500–1,000	−0.34 (−1.08, 0.41)		0 (1.0)			
	1,000–1,500	0.06 (−0.59, 0.71)		0 (1.0)			
$0.2 < CS_{t,f} < 0.4$							
Medicated (4)	0–300	0.15 (−1.15, 1.44)	−2.253 (0.024)	0% (0.424)	0.729	NA	0.02
	500–1,000	−0.34 (−1.08, 0.41)		0% (0.759)			
	1,000–1,500	0.06 (−0.59, 0.71)		0 (1.0)			
Non-medicated (1)	500–1,000	−0.99 (−1.40, −0.57)	−5.709 (<0.01)	0 (1.0)	0.175	NA	
	>1,500	−1.40 (−1.84, −0.97)		0 (1.0)			
$0.4 < CS_{t,f} < 0.6$							
Medicated (2)	500–1,000	−1.45 (−2.21, −0.69)	−4.911 (<0.01)	0% (0.358)	0.473	NA	0.04
	>1,500	−1.97 (−3.15, −0.79)		0 (1.0)			
Non-medicated (2)	300–500	−2.01 (−3.43, −0.59)	−3.311 (<0.01)	0 (1.0)	0.904	NA	
	500–1,000	−3.80 (−4.30, −3.29)		0% (0.519)			
	>1,500	−0.48 (−1.20, 0.25)		0 (1.0)			
Non-depressed, non-medicated (4)	0–300	−0.61 (−1.08, −0.15)	−2.590 (0.01)	0% (0.901)	0.475	NA	
	300–500	−0.08 (−0.80, 0.64)		0 (1.0)			
	1,000–1,500	-−0.43 (−1.11, 0.25)		0 (1.0)			
$0.6 < CS_{t,f} < 0.7$							
Medicated (15)	0–300	−2,12 (−3.03, −1.21)	−7.945 (<0.01)	87.2% (<0.01)	<0.01	0.26	0.037
	300–500	−2.01 (−4.98, −0.97)		97.0% (<0.01)			
	500–1,000	−2.23 (−3.29, −1.18)		95.3% (<0.01)			
	1,000–1,500	−3.48 (−5.10, −1.87)		96.6% (<0.01)			
	>1,500	−0.55 (−0.97, −0.14)		0% (0.918)			
Non-medicated (5)	0–300	−1.25 (−2.66, 0.16)	−5.209 (<0.01)	0 (1.0)	<0.01	0.53	
	300–500	−2.01 (−3.43, −0.59)		0% (0.824)			
	500–1,000	−3.80 (−4.30, −3.29)		0.5% (0.389)			

(Continued)

TABLE 3 (Continued)

Subgroup (study *n*)	Temporal pattern/mins	Pooled SMD, random, 95% CI	*z* test (p_1)	I^2 (p_2)	p^3	p^4	p^5
	1,000–1,500	−4.81 (−5.34, −4.27)		0 (1.0)			
	>1,500	−0.26 (−0.77, 0.24)		93.5% (<0.01)			
Non-depressed, non-medicated (3)	300–500	−0.67 (−1.45, 0.11)	−2.264 (0.024)	82.1% (<0.01)	0.986	NA	
	500–1,000	−0.66 (−1.38, 0.05)		0 (1.0)			

*p*1 is the *p*-value of the overall effect size test; *p*2 is the *p*-value within the subgroup referring to heterogeneity using Cochran's *Q*-statistic; *p*3 is the *p*-value between temporal subgroups referring to heterogeneity using *Q*-statistic; *p*4 is the *p*-value between time pattern groups using *F*-statistic; and *p*5 is the *p*-value between medication-depression groups using *F*-statistic.

5.2 Heterogeneity and clinical efficacy discussion

Discussion on clinical efficacy with regard to PICO principles: (1) Participants. Although the subjects discussed were all adolescents and youth, their depression episodes, phenotype, severity, light exposure history, and co-medication status may have caused differentiation and heterogeneity. From another perspective, there is preliminary evidence with regard to various circadian-related illnesses where light therapy has shown improvement [e.g., bipolar depression (99), atypical depression (100), melancholic depression (100), unipolar depression (101), light therapy with more accumulated circadian stimulus may be an efficacious treatment for "circadian" depression (102)], where conventional pharmacological intervention had poor responses. Indeed, AYAs have benefited from light therapy as an adjunctive, additive, and non-invasive treatment to their continued treatment modalities despite uncertainties and difficulties. In this study, the discrepancy may partially be explained by demonstrated resistance to pharmacotherapy (83) or depression severity [mild depression might coexist (62, 67, 76, 81, 82, 92)], whilst compliance and adverse side effect did not appear to be the confounding factors.

As indicated, bipolar depression, major depressive disorder, postpartum depression, subthreshold depression, and dysthymia may share and respond to similar lighting therapeutic mechanisms. However, as not yet extensively investigated, the presence of certain comorbid disorders may compromise treatment efficacy, e.g., whether seasonality or comorbid SAD increases the likelihood of positive response to light (103) as reported included (22, 71, 72, 74, 88, 97), or Axis *I* anxiety disorders (90) and Axis II personality disorders vice versa (72). For most non-comorbid cases, a reduction in disease severity had been observed (30, 31, 70, 78). On one hand, it is necessary to identify homogenous patient groups. On the other hand, we still emphasize the vital role of dosing. As had been implied, emerging hypomanic symptoms may be relieved after a small increment in exposure duration (22), but qualitative discussion on comorbidity alone may be far from sufficient.

(2) Intervention perspective. Only three studies excluded any form of intervention (medication, psychotherapy, etc.) within at least the past 6 months (30, 31, 75). Three studies reported no medication (22, 82, 87). A few studies reported no recently initiated antidepressants or the use of psychotropic medication had remained stable (68, 70–72, 74, 88). Several studies excluded light-sensitizing medication that may act as photosensitizers and increase the risk of eye/skin damage (62, 74). Additional interventions were generally balanced between experiment vs. control groups, and participants from both groups had received identical medication/psychotherapy, if applicable (64). A few studies reported medication had little or no effect on the overall result (66, 97). However, it is scarcely possible that the evaluation of light therapy on mood eliminated a potentially confounding variable of medication. Light therapy has been reported with a clear synergistic effect when combined with SSRIs (selective serotonin reuptake inhibitors) during a moderate to severe major depressive episode (4). Though medication components were barely reported by included studies, significant differences between with and without co-medication were seen not only in between-group comparison but also in pre-to-post-effect size and dose-response relationship, although it was impossible to completely separate the effects of co-medication from depression severity. Additionally, it is less possible that medication masks the effects of light therapy since the outcomes of LT monotherapy were found to be equivalent or superior to that of the medicated group on a lower $CS_{t,f}$ basis (Table 3).

(3) Experimental design. In this study, both RCTs and non-randomized experimental studies were included for therapeutic efficacy evaluation, while few previous studies have discussed the aspect by merely including RCT studies (3) since total blindness for RCTs is quite hard to achieve, as mentioned. Since intuitive, neurophysiological, and chronobiological light therapies are distinct from pharmaceutical interventions, we deduced less differentiation caused by design methodology and combined overall outcomes by fully discussing between-group differences and comparing dose-response saturation. Moreover, the heterogeneity could be influenced by in-, out- patients or whether they adopted home-based protocol, since those administered in laboratory or hospital treatment rooms where the protocol may largely be correctly followed had implied more eligibility than those less-supervised home-based evidence.

(4) Statistics. Although SMD effect size and random-effect model were applied for collected data, depression measurement outcomes with different scales may have led to certain heterogeneity.

6 Limitation

The study has several limitations. On the whole, there were limited samples since only a few studies focused on AYA-oriented depression light therapy with mainly small samples. In order to elaborate on accumulative light stimulus and reductions in

relevant maladies, 31 articles (N = 1,031) included not only diagnosed depressed individuals but also healthy participants for circadian improvement intentions. Since the adopted outcomes were SMD mean values rather than individual results, the meta-regression may result in aggregation bias. The outcomes of fitting accumulative exposure time and $CS_{t,f}$ as two independent variables indicated imperfection in mathematics. However, the results had been adjusted and intercalibrated with subgroup meta-analysis and have implied trend and saturation of accumulative light dose.

The limitations based on $CS_{t,f}$ model, are as follows: (1) Despite that $CS_{t,f}$ values ranged from <0.1–0.7, it is scarcely possible that continuous $CS_{t,f}$ values can be acquired. Subgroup meta-analysis and meta-regression have been carried out on this basis, by which the accuracy of the fitting models was also influenced by restricted $CS_{t,f}$ values. (2) Spatial distribution. The circadian light spatial distribution factor f and intensity have not been totally validated. Parameters like the distance, the angle between the lighting device and human eyes, light source positions (104), and background reflection factors were not provided. Therefore, $CS_{t,f}$ factor was not well-discussed without details. (3) Intervention moment factor may also be influential. Some studies (105, 106) have quantified light moments in circadian phase shift and DLMO calculation. However, since only one included study (83) carried out morning and night BLT, four studies carried out nocturnal BLT (63, 71, 80, 81). In some studies, subjects were relatively flexible in receiving BLT at home; further validation is needed for the quantification. The quantified model could be explored in future studies with larger samples and specific individual results.

At present, there is only a $CS_{t,f}$ model in discussion; other light dose-related responses through light-sensitive circuits have not yet been explored. More targeted phototherapy studies on depression-related light-sensitive circuits on patients with different depression phenotypes, severity, light exposure history, physiological characteristics, gender as well and exposure duration are necessary for therapeutic efficacy validation. Moreover, light therapies and correspondent circadian stimulus for combined treatment (e.g., antidepressants, chronotherapy) should be explored with consistent clinical trials and follow-ups. In addition to larger, all-around samples and precise experimental design for heterogeneity reduction, more objective parameters and indicators are necessary for efficacy evaluation beyond standardized depression measurement outcomes. Objective evaluation methods and approaches like neuron-related blood inflammatory markers (107), cerebrospinal fluid (CSF) analysis (108), or brain physiological examinations electroencephalogram/EEG (109) can also be adopted as evaluation tools when possible.

7 Conclusion

The significant efficacy of a higher circadian stimulus of light therapy over a lower circadian stimulus of light intervention among AYAs remains unproven. Yet, factors such as co-medication, disease severity, time pattern, visual characteristics, etc., are considered sources of heterogeneity that affect the response potential. Conservatively, light therapy with certain circadian stimuli has indicated significant reductions in relevant maladies both among medicated (pooled SMD = −2.1, 95% CI = −2.51 to −1.68; $z = -9.979$, $p = 0.000$; $I^2 = 94.8\%$) as well as non-medicated persons (pooled SMD = −1.03, 95% CI = −1.27 to −0.78; $z = -8.283$, $p = 0.000$; $I^2 = 64.5\%$), with enhanced response superiority through co-medication. The dose-response relationship between accumulative circadian stimulus (considered as light dose for the circadian system) and disease reduction has been specified by meta-regression and dose-response quantification based on CL_A and $CS_{t,f}$ models, indicating accumulative 32–58 days (1,000–1,500 min) as saturation, considering co-medication, severity, study design, etc., are all dose-response influencing factors. It is advised that for the treatment of depression in adolescents and young adults, using current common light therapy devices for "circadian" light therapy ($0.1 < CS_{t,f} < 0.7$), an accumulative duration of 1,000–1,500 min (5–7 weeks/32–58 days) may be effective. However, for co-medicated patients, the effect size may reach saturation in about 900–1,000 min (32–42 days), while for non-medicated, depressed individuals, it may take 1,100–1,500 min (48–58 days) to reach saturation. It is also possible that an accumulative duration of more than 1,500 min may not be as efficacious on a high $CS_{t,f}$ basis. Overall, the study has provided quantified references for light patterns and neural responses that are vital in the neuropsychological mechanism of light intervention, as well as guidance for clinical application.

Author contributions

RC: Conceptualization, Data curation, Methodology, Software, Writing – original draft, Writing – review & editing. YY: Conceptualization, Supervision, Writing – original draft, Writing – review & editing. XC: Data curation, Writing – original draft, Writing – review & editing.

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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.2023.1257093/full#supplementary-material

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Smartphone-delivered multicomponent lifestyle medicine intervention for improving mental health in a nonclinical population: a randomized controlled trial

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Objective: To prevent the exacerbation of mental health burdens, a growing body of research has recommended a balanced approach that emphasizes both the delivery of mental health treatments to individuals with common mental disorders (CMDs) and the strengthening of protective factors for CMDs among nonclinical populations. This randomized controlled trial (RCT) evaluated the efficacy of a smartphone-delivered multicomponent lifestyle medicine (LM) intervention, Lifestyle Hub, for improving mental health among a nonclinical population of Chinese adults.

Methods: A total of 106 participants with Patient Health Questionnaire-9 total score < 10 and Generalized Anxiety Disorder 7-Item Scale <8 were randomly assigned to either the Lifestyle Hub intervention group (LH, $n = 53$) or the waitlist control group (WL, $n = 53$). Lifestyle Hub is an 8-week smartphone-delivered multicomponent LM intervention developed based on the transtheoretical model. The intervention components included lifestyle psychoeducation, physical activity, diet and nutrition, stress management, sleep management, and motivation and goal-setting techniques. Assessments were conducted at baseline, immediate post-intervention, and 1-month follow-up (LH only).

Results: The linear mixed effect model based on the intention-to-treat principle indicated that Lifestyle Hub significantly improved overall mental health, depressive symptoms, anxiety symptoms, stress, insomnia severity, overall health-promoting behaviors, dietary quality, and stress management compared to the WL group at immediate post-intervention ($d = 0.13–0.56$). No significant between-group differences were observed in terms of functional impairment, health-related quality of life, health responsibility, physical activity level, spiritual growth, and interpersonal relations. The intervention gains in the LH group were maintained at 1-month follow-up. The LH participants indicated that Lifestyle Hub was an acceptable intervention for improving mental health, although a significantly higher level of study attrition was observed in the LH group (20.8%) relative to the WL group (5.7%).

Conclusion: Lifestyle Hub may serve as an efficacious and acceptable intervention for improving mental health in nonclinical adult populations. To extend the benefits of LM interventions at the population level, future studies are warranted to examine a stepped-care approach to delivering LM interventions.

Trial registration: This randomized controlled trial was pre-registered with ClinicalTrials.gov (NCT04295369).

KEYWORDS

lifestyle, mood, mental health, self-help, smartphone-based intervention, randomized controlled trial

Introduction

Common mental disorders (CMDs), such as depression and anxiety, are significant public health concerns worldwide. Recent studies indicated that the prevalence of depression and anxiety among the general population ranged between 32% and 38% across the globe (1, 2). The impacts of CMDs extend beyond the individual level and can have profound adverse effects on society. It was estimated that CMDs accounted for more than 60% of disability-adjusted life-years among mental disorders and were ranked among the top 10 leading causes of years lived with disability (3). Additionally, the economic burden of CMDs is significant, with estimated costs exceeding US$1 trillion globally each year (4). The growing prevalence of CMDs reflected the inadequacy of existing strategies in addressing the ongoing mental health crisis and strengthening mental health at the population level (5). To prevent the exacerbation of mental health burdens, a growing body of research has recommended a paradigm shift in managing CMDs. Specifically, this paradigm shift advocates a balanced approach that emphasizes both the delivery of mental health treatments to individuals with CMDs and the strengthening of protective factors for CMDs among nonclinical populations (6–9).

Considering the sound evidentiary support for the relationship between lifestyles and the onset and development of CMDs, there has been a growing interest in the lifestyle medicine (LM) approach as one of the potential options for managing CMD symptoms in clinical populations and promoting mental health in nonclinical populations (10–14). The LM approach is grounded in evidence-based principles and utilizes multicomponent LM interventions to mitigate the risk of mental and physical health with a lifestyle etiology (14–17). The intervention content encompasses a range of components, including lifestyle psychoeducation and fundamental pillars such as physical activity, diet and nutrition, sleep management, stress management, and motivational elements that encourage sustained participation and engagement (12). The LM approach endeavors to empower individuals to proactively manage their own health; hence, the principal responsibility of disease management lies primarily with the individuals themselves (15).

Recent meta-analytic reviews revealed that multicomponent LM interventions comprising exercise, diet and nutrition, sleep management, and/or stress management were efficacious for improving depressive ($d = 0.20$–0.22) and anxiety symptoms ($d = 0.19$) compared to inactive control groups at immediate post-intervention (14, 16). While these meta-analyses have revealed only modest clinical effects, recent randomized controlled trials (RCTs) targeting individuals with significant depressive and anxiety symptoms have demonstrated moderate to large effect sizes for improving depressive and anxiety symptoms at immediate post-intervention assessment ($d = 0.66$–0.93) (18–21). Furthermore, multicomponent LM interventions have a robust safety profile, with recent clinical guidelines recognizing lifestyle-based interventions as a foundational component for the prevention, treatment, and recovery of CMDs (11, 22–24). Although the efficacy of multicomponent LM interventions for improving CMD symptoms in the nonclinical population has been demonstrated, such interventions were predominantly delivered face-to-face by health professionals, which restricted access in larger population groups (11, 14, 16, 17). Therefore, novel and scalable modes of delivery are required to meet the vast mental health needs of the population.

The utilization of smartphones has emerged as a promising approach for augmenting the dissemination and reach of LM interventions. With an estimated 80% of the world population being smartphone users (13), this ubiquitous technology represents an accessible medium to facilitate population-level mental health promotion. Additionally, smartphone-delivered interventions can overcome geographical and time constraints and are more affordable compared to face-to-face interventions (25). Furthermore, smartphone-delivered interventions can provide a level of anonymity and privacy, which is crucial for individuals who are concerned with mental health-related stigma (26). Sound evidence from meta-analyses suggested that smartphone-delivered mental health interventions were promising for improving depressive symptoms ($g = 0.24$), anxiety symptoms ($g = 0.24$–0.28), and stress ($g = 0.36$) relative to active and inactive control groups among nonclinical populations at immediate post-intervention assessment (27, 28).

Given the potential merit of smartphone-delivered interventions in managing CMDs, a pioneering smartphone-delivered LM intervention, Lifestyle Hub, was developed (21). The efficacy of Lifestyle Hub in ameliorating depressive symptoms has previously been evaluated in a Chinese adult population with at least moderate

Abbreviations: CMD, Common Mental Disorder; CEQ, Credibility-Expectancy Questionnaire; DASS-21, Depression Anxiety Stress Scales-21; GAD-7, Generalized Anxiety Disorder 7-Item Scale; HPBs, Health-Promoting Behaviors; HRQOL, Health-Related Quality of Life; ISI, Insomnia Severity Index; LMM, Linear Mixed-Effects Model; LM, Lifestyle Medicine; PHQ-9, Patient Health Questionnaire-9; RCT, Randomized Controlled Trial; SDS, Sheehan Disability Scale; WL, Waitlist.

levels of depressive symptoms (21). The results suggested that Lifestyle Hub was efficacious in improving depressive and anxiety symptoms with moderate to large effect sizes compared to a waitlist (WL) control group at immediate post-intervention assessment ($d = 0.66–0.93$). Moreover, participants who used the intervention for 8 weeks generally considered Lifestyle Hub as acceptable and creditable for improving depressive symptoms. Building upon the positive findings and recognizing the dearth of literature on the efficacy of smartphone-delivered multicomponent LM for improving mental health among nonclinical populations, we conducted the first RCT to evaluate a smartphone-delivered, 8-week multicomponent LM intervention, Lifestyle Hub, for improving mental health among a Chinese nonclinical population. We hypothesized that Lifestyle Hub would result in significant improvements in overall mental health conditions (including depressive symptoms, anxiety symptoms, stress, and perceived insomnia severity), functional impairment, health-related quality of life (HRQOL), and overall health-promoting behaviors (HPBs) relative to a WL control group at immediate post-intervention (Week 9). In addition, we hypothesized that these intervention gains would be maintained at the 1-month follow-up assessment (Week 13).

Methods

Study design

To assess the efficacy of Lifestyle Hub in improving mental health, a two-arm RCT was conducted between February and May 2020. A total of 106 eligible participants were randomly assigned to either the intervention group receiving the 8-week smartphone-delivered multicomponent LM intervention (Lifestyle Hub; LH) or the WL control group. This study was approved by the Survey and Behavioral Research Ethics Committee (Reference no. SBRE-19-303), The Chinese University of Hong Kong. The trial was registered with ClinicalTrials.gov (NCT04295369).

Eligibility criteria

Participants were eligible if they (1) were Hong Kong residents; (2) aged 18 years or older; (3) were able to read Chinese and type in Chinese or English; (4) had an internet-enabled mobile device (iOS or Android operating system); and (5) were willing to provide informed consent and comply with the trial protocol. Participants were excluded if they (1) had a Patient Health Questionnaire-9 (PHQ-9) total score ≥ 10, indicating the presence of at least a moderate level of depressive symptoms (29, 30); (2) had a Generalized Anxiety Disorder 7-Item Scale (GAD-7) total score ≥ 8, indicating the presence of at least a mild level of anxiety symptoms (29, 31); (3) were receiving psychotherapy and/or unstable medication for depression and/or anxiety disorders in the past 2 months; (4) had a PHQ-9 Item 9 score > 2, indicating current suicidality that might require active crisis management (24-h suicide prevention hotlines and details of accessing public professional mental health services were offered); (5) had an unstable medical condition or were not recommended for lifestyle modifications by health professionals (e.g., physician, dietitian); or (6) were having major psychiatric, medical or neurocognitive disorders that made intervention involvement difficult or might interfere with participation in the intervention or adherence to lifestyle modification.

Recruitment and study procedure

Participants were recruited via the university mass mailing system, social networking websites (i.e., Facebook and Instagram), and print media. Prospective participants were required to complete a set of online questionnaires for screening purposes, which included (1) the PHQ-9 measuring depressive symptoms and current suicidality; (2) the GAD-7 measuring anxiety symptoms, (3) a self-report checklist on eligibility criteria, and (4) a demographics questionnaire. Eligible participants were invited to participate in this study via text messaging or telephone calls by a research assistant. Besides, they were instructed to download an in-house smartphone application (*Longitudinax*) for online informed consent and data collection. Participants who signed the online consent form and completed the baseline questionnaire were randomly assigned to either the LH or WL group in a 1:1 ratio by an independent statistician using a computer-generated list of numbers.

Given the nature of the study design, blinding of participants and research personnel was not possible. However, the data analyst was blinded to the group assignment. The research assistant instructed the participants in the LH group to download Lifestyle Hub, and each LH participant was provided with a unique account via text messages. The LH participants were informed that Lifestyle Hub is a self-help intervention such that no therapeutic support would be provided throughout the trial period. However, they could contact the research assistant for technical assistance (e.g., log-in problems). Participants assigned to the WL group were informed that they would be given access to Lifestyle Hub upon the completion of the immediate post-intervention assessment at Week 9. A research compensation of HK$100 (approximately USD12.8) was offered to the participants in both groups after they completed all the required assessments.

The LH intervention group

The detailed intervention content has been published elsewhere (21) and summarized in Table 1. Lifestyle Hub is an 8-week smartphone-delivered multicomponent LM intervention developed based on the transtheoretical model (32). The intervention components included (1) lifestyle psychoeducation; (2) physical activity; (3) nutrition; (4) stress management; (5) sleep management; and (6) motivation and goal-setting techniques. Specifically, Sessions 1 and 2 were designed to enhance participants' perception of their current lifestyle and raise doubts about problematic lifestyle behavior(s). Sessions 3 and 4 aimed to facilitate the identification of the pros and cons of unhealthy lifestyle habits and the development of personal motivations for lifestyle modifications. Sessions 5 and 6 focused on preparing and establishing a practical action plan for lifestyle modifications. Session 7 aims to strengthen participants' self-efficacy in overcoming obstacles and reaffirm the long-term benefits of lifestyle modifications. The last session was intended to consolidate the implemented lifestyle modifications and prevent relapse in the long term.

TABLE 1 Overview of the intervention structure and content of Lifestyle Hub.

Session	Content	Homework activity
1–2	- Overview of *Lifestyle Hub* - Introduction to lifestyle medicine - A brief assessment of physical activity - Introduction to low-intensity exercise with demonstration videos - Explain the association between physical activity and mental health - Introduction to calories (with gamified tests) - Tips for healthy eating - Explain the relationship between food micronutrients and mental health - SMART goal-setting	- Setting up mid-term and short-term goals - Daily lifestyle tasks (physical activity and diet)
3–4	- Introduction to low-intensity exercise with demonstration videos (i.e., flexibility and balancing exercise) - Introduction to food nutrition labels - Introduction to progressive muscle relaxation - Explain the association between sleep and mental health	- Setting up short-term goals - Daily lifestyle tasks (physical activity and diet) - Progressive muscle relaxation
5–6	- Introduction to moderate-intensity exercise with demonstration videos (i.e., cardiovascular and muscle training) - Wake-up and wind-down routine - Sleep hygiene and sleep–wake regularity - Stimulus control - Worry time - Problem-solving strategies	- Setting up short-term goals - Daily lifestyle tasks (physical activity and diet) - Wake-up and wind-down routine practice - Worry time and problem-solving practice
7	- Introduction to yoga and abdominal breathing exercise - Explain the association between mindfulness and mental health - Introduction to positive psychology	- Setting up short-term goals - Daily lifestyle tasks (physical activity and diet) - Mindfulness and abdominal breathing practice - Gratitude journal
8	- Revision of all session content - Review of *Lifestyle Hub* - Review self-setting goals and lifestyle modification progress - Setting long-term goals	- Setting up long-term goals - Daily practice of lifestyle modifications

To facilitate intervention delivery and participant understanding, the eight 60-min weekly sessions were divided into 45 submodules (i.e., 5–6 submodules per session), and the content was structured to progress from low to high intensity. Each weekly session began with a review of the previous session to consolidate participant learning outcomes (except for Session 1). Subsequently, new intervention content was introduced through animated videos (8–15 min each with video scripts supplemented), gamified mini quizzes, texts, audios, and/or infographics. Each weekly session was concluded with a smart goal-setting submodule to facilitate short/long-term lifestyle modifications and self-monitoring of intervention progress. The motivational interviewing approach was adopted to promote lifestyle modifications and guide participants to accomplish their lifestyle goals (33). To encourage self-monitoring of lifestyle behaviors and facilitate long-term lifestyle modifications, daily homework activities (10–20 min per day) were pre-assigned, and a daily challenge (e.g., walking 8,000 steps a day) was automatically sent to participants every morning to promote adherence to the intervention. Besides, a wide variety of extra materials regarding exercise (e.g., low-intensity exercise demonstrations and yoga), diet (recipes with cooking demonstrations), sleep management, and stress management (e.g., video demonstrations of progressive muscle relaxation and diaphragmatic breathing) were continuously provided in the Explore page of Lifestyle Hub. Moreover, participants were able to set personalized short-term and long-term lifestyle goals using the "Goal Setting" function.

The WL control group

Participants allocated to the WL control group were advised to maintain their usual lifestyle routines and were given access to Lifestyle Hub upon the completion of the immediate post-intervention assessment at Week 9.

Outcome measures

Self-report outcome measures were collected at baseline (Week 0), immediate post-intervention (Week 9), and 1-month post-intervention (LH only; Week 13). The primary outcome was overall mental health conditions as assessed by the Chinese version of Depression Anxiety Stress Scales-21 (DASS-21) (29, 34, 35). DASS-21 is a 21-item self-report questionnaire assessing overall mental health conditions over the past week on a 4-point Likert scale. The possible

responses ranged from "0" (did not apply to me at all) to "3" (applied to me most of the time). The overall mental health condition score was the sum of the 21 items (range = 0–63). The raw score obtained was multiplied by 2 to compute the final score. The lower the score, the better the overall mental health conditions. DASS-21 has shown good internal consistency for the depression (Cronbach's alpha = 0.83), anxiety (Cronbach's alpha = 0.80), and stress (Cronbach's alpha = 0.82) subscales (35).

The secondary outcomes included depressive symptoms, anxiety symptoms, stress levels, insomnia severity, functional disability, HRQOL, HPBs, and intervention acceptability. The Chinese version of the Insomnia Severity Index (ISI) (36) was employed to measure perceived insomnia severity and the associated impairment on a 5-point Likert scale, ranging from "0" (no problem) to "4" (very severe problem). The total score (range = 0–28) was calculated by summing up the 7-item scores. The higher the sum, the higher the perceived severity of insomnia symptoms. The Chinese version of ISI has demonstrated satisfactory psychometric properties (Cronbach's alpha = 0.83) (37).

Functional disability was measured by the Chinese version of the Sheehan Disability Scale (SDS) on an 11-point Likert scale (38). SDS is a 3-item scale that assesses functional impairment in three domains: work or school, social life, and family life (38). The sum of the 3-item scores represents a single-dimensional measure of global functional impairment that ranges from 0 (unimpaired) to 30 (highly impaired). The Chinese version of the SDS has demonstrated good psychometric properties (Cronbach's alpha = 0.89) (39).

HRQOL was measured by the Hong Kong version of the Short Form (Six-Dimension) Health Survey (SF-6D) (40). SF-6D is a preference-based single index measure of health in six dimensions, encompassing physical functioning, role limitation, social functioning, bodily pain, mental health, and vitality. The total score was calculated using a scoring algorithm based on the Hong Kong population norms, with a range of 0.315 (the worst HRQOL) to 1 (full health) (41). The Hong Kong version of SF-6D has demonstrated adequate psychometric properties (Cronbach's alpha = 0.71) (40).

HPBs were assessed using the Chinese version of the Health-Promoting Lifestyle Profile (HPLP-II) (42). HPLP-II is a 52-item scale designed to evaluate overall health-promoting lifestyle and six specific domains of HPBs, including spiritual growth, interpersonal relations, nutrition, physical activity, health responsibility, and stress management, on a 4-point Likert scale ranging from 1 (never) to 4 (routinely). The sum of the scores on the 52 items yields the overall health-promoting lifestyle score (range = 52–208), whereas the specific domain scores were computed by adding the scores of respective items (range = 8–32 or 9–36). The higher the score, the more the HPBs. The Chinese version of HPLP-II has demonstrated very good psychometric properties in an adult Chinese Hong Kong population (Cronbach's alpha = 0.95) (21).

The Chinese version of the Credibility-Expectancy Questionnaire (CEQ) was adopted to evaluate intervention acceptability (43). CEQ is a 6-item scale, in which the mean of the first three items yielded a rating of intervention credibility, whereas the mean of the remaining three items was for intervention expectancy. The higher the scores, the higher the intervention credibility and success expectancy. The Chinese version of the CEQ has demonstrated adequate psychometric properties in an adult Chinese Hong Kong population (Cronbach's alpha = 0.74–0.80) (21).

Statistical analysis

Sample size estimation was conducted using G*Power 3 (44). Based on a 5% α error probability and 80% power in a two-tailed test and accounting for an anticipated study attrition rate of 20% (14, 16), an estimated total sample size of 96 (i.e., 48 in each group) was considered necessary to detect a between-group difference of 0.66 in depression and anxiety symptoms as measured by DASS-21 (18, 21).

The R version 4.1.2 (45) was used to conduct statistical analyses. Statistical significance was determined using two-tailed tests with a value of p of less than 0.05. Cohen's d was used as the effect size measure, with magnitudes of 0.2 considered as a small effect, 0.5 as a medium effect, and 0.8 as a large effect (46). Between-group differences of baseline characteristics were assessed using independent-samples t-test or chi-square test of independence. The efficacy of Lifestyle Hub on various outcome measures (except intervention acceptability) from baseline (Week 0) to immediate post-intervention (Week 9) was evaluated using a linear mixed-effects model (LMM) based on the intention-to-treat principle. The LMM employs maximum likelihood estimation and assumes data is missing at random (47, 48). The durability of Lifestyle Hub from immediate post-intervention (Week 9) to 1-month follow-up assessments (Week 13) as well as intervention acceptability in the LH were assessed using paired-samples t-tests. Study attrition was defined as the number of dropouts throughout the entire study, which comprised dropouts during the intervention, at immediate post-intervention (Week 9), and at 1-month follow-up (Week 13) assessments. The between-group difference in study attrition was estimated using the chi-square test of independence. Intervention usage was defined as the amount of time participants spent on the eight 60-min weekly sessions. Specifically, participants were considered to have completed a session if a minimum of 60 min were spent. In addition, submodule completion was reported in mean and cumulative percentages.

Results

Participant characteristics

In sum, 546 prospective participants completed the online screening for eligibility, of which 348 were excluded due to a variety of reasons (Figure 1). The 198 eligible individuals were invited to complete the baseline assessment. Among them, 106 individuals completed the baseline assessment and were randomly assigned to either the LH intervention group ($n = 53$) or the WL control group ($n = 53$). The mean age of the participants was 35.7 years ($SD = 12.0$), and the majority of participants were female (77.4%). The participants, in general, had a normal level of DASS-21 measured depressive (mean = 7.2; $SD = 6.4$) and anxiety (mean = 6.6; $SD = 5.6$) symptoms as well as a moderate level of stress (mean = 11.8; $SD = 6.7$) at baseline. There was no significant difference between the LH and the WL groups in any baseline characteristics ($ps > 0.05$; Table 2).

Intervention dropout

The study attrition rates (i.e., the number of dropouts throughout the entire study period) of the LH and WL groups were 20.8%

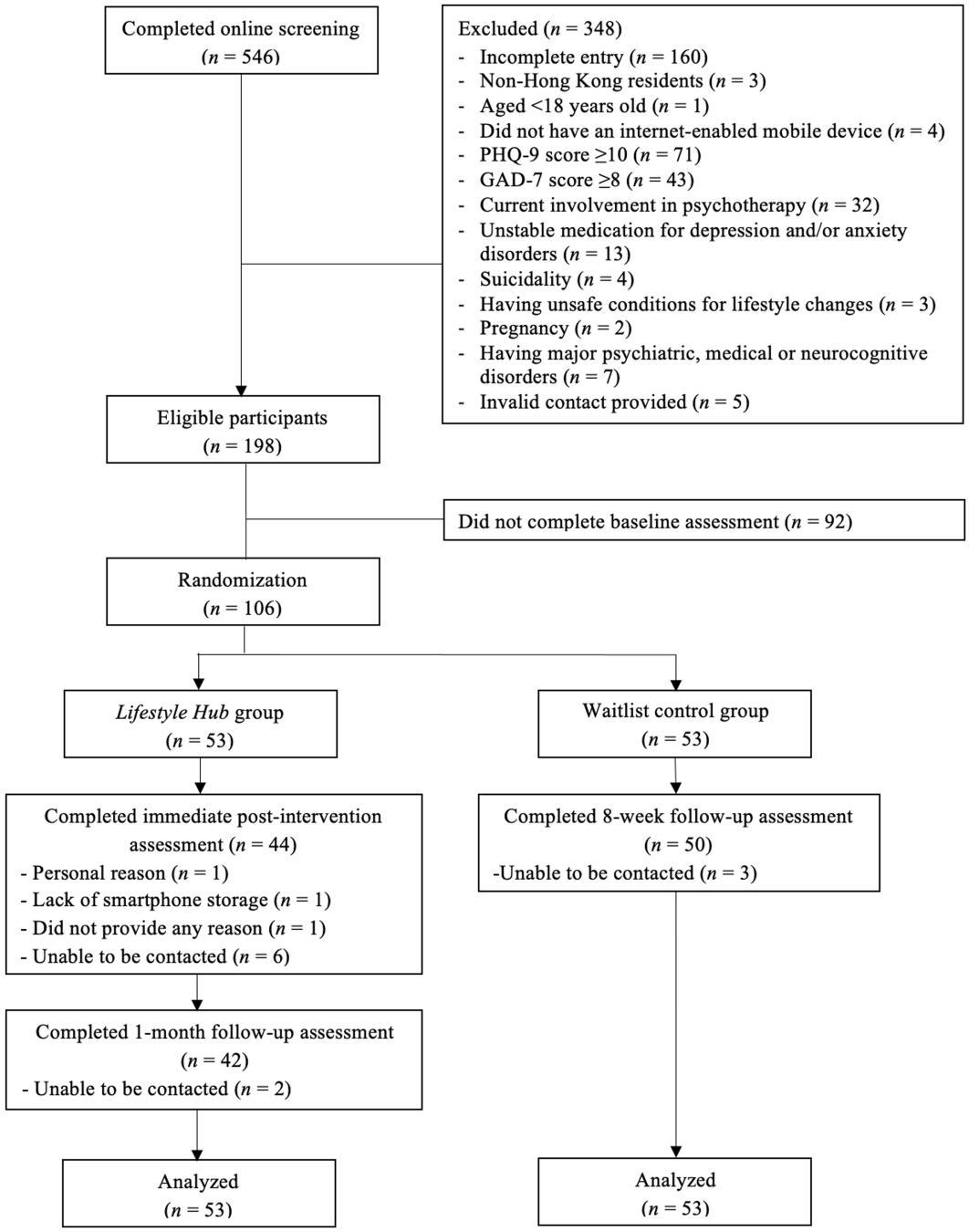

FIGURE 1
CONSORT flow diagram.

($n = 11$) and 5.7% ($n = 3$), respectively. The chi-square test of independence suggested there were statistically significant differences in study attrition between the two groups ($\chi^2 = 4.03$, $p < 0.05$). Specifically, 3 LH participants withdrew during the eight-week intervention period. The reasons for withdrawal included personal reasons ($n = 1$) and lack of smartphone storage ($n = 1$), while the remaining participant did not provide any reason. At the immediate post-intervention and 1-month follow-up, an additional 8 LH participants withdrew from this study because they were uncontactable. For the WL group, 3 participants could not be reached at immediate post-intervention.

Intervention usage

At Week 9, the 44 LH participants who completed the immediate post-intervention assessment had a mean Lifestyle Hub utilization of 11 days ($SD = 8.2$) and a mean submodule completion rate of 57.8% (i.e., 26 out of 45 submodules, $SD = 15.5$). Furthermore, the submodule completion was measured cumulatively. Specifically, 4 participants (9.1%) had completed all submodules, 25 participants (56.8%) completed at least 70% of submodules, 28 participants (63.6%) completed at least 50% of submodules, and 35 participants (79.5%) completed at least 30% of submodules.

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TABLE 2 Baseline characteristics.

Variable	LH (n = 53)	WL (n = 53)	Total (n = 106)	p-value
Age, years	34.36 (12.20)	37.02 (11.72)	35.69 (11.98)	0.26
Female, *n* (%)	41 (77.36)	41 (77.36)	82 (77.36)	1
Level of education *n*, (%)				0.62
Primary or below	0 (0)	0 (0)	0 (0)	
Junior secondary	0 (0)	1 (1.89)	1 (0.94)	
Senior secondary	3 (5.66)	7 (13.21)	10 (9.43)	
Diploma/certificate	5 (9.43)	3 (5.66)	8 (7.55)	
Associate degree	3 (5.66)	4 (7.55)	7 (6.60)	
Bachelor's degree	23 (43.40)	22 (41.51)	45 (42.45)	
Master's degree or above	19 (35.85)	16 (30.19)	35 (33.02)	
Marital Status *n*, (%)				0.42
Single	38 (71.70)	33 (62.26)	71 (66.98)	
Married	12 (22.64)	18 (33.96)	30 (28.30)	
Divorced/widowed	3 (5.66)	2 (3.77)	5 (4.72)	
Number of children *n*, (%)				0.57
0	42 (79.25)	39 (73.58)	81 (76.42)	
1	6 (11.32)	7 (13.21)	13 (12.26)	
≥2	5 (9.43)	7 (13.21)	12 (11.32)	
Employment status *n*, (%)				0.23
Full-time	28 (52.83)	36 (67.92)	64 (60.38)	
Part-time	12 (22.64)	10 (18.87)	22 (20.75)	
Not applicable	13 (24.53)	7 (13.21)	20 (18.87)	
Monthly income *n*, (%)				0.05
≤HK$ 5,000	21 (39.62)	11 (20.75)	32 (30.19)	
HK$ 5,001 - 10,000	3 (5.66)	4 (7.55)	7 (6.60)	
HK$ 10,001 - 20,000	8 (15.09)	10 (18.87)	18 (16.98)	
HK$ 20,001 - 30,000	3 (5.66)	13 (24.53)	16 (15.09)	
HK$ 30,001 - 50,000	12 (22.64)	13 (24.53)	25 (23.58)	
HK$ 50,001 - 70,000	4 (7.55)	2 (3.77)	6 (5.66)	
HK$ 70,001 - 90,000	0 (0)	0 (0)	0 (0)	
> HK$ 90,000	2 (3.77)	0 (0)	2 (1.89)	
DASS-21				
Total	25.02 (15.78)	26.30 (15.81)	25.66 (15.73)	0.68
Anxiety	6.94 (6.12)	6.30 (5.10)	6.62 (5.62)	0.56
Depression	6.53 (6.23)	7.92 (6.53)	7.23 (6.38)	0.26
Stress	11.56 (6.96)	12.08 (6.50)	11.81 (6.71)	0.69
CEQ				
Credibility	5.73 (1.28)	5.82 (1.57)	5.78 (1.43)	0.74
Expectancy (%)	49.09 (16.88)	51.55 (19.23)	50.32 (18.04)	0.49
SDS	2.40 (3.24)	3.72 (4.83)	3.06 (4.14)	0.10
ISI	6.96 (4.13)	6.30 (4.68)	6.63 (4.41)	0.44
SF-6D	0.79 (0.11)	0.76 (0.13)	0.78 (0.12)	0.24
HPLP-II				
Total	67.49 (17.07)	66.06 (22.43)	66.77 (19.38)	0.72
Health Responsibility	8.32 (3.78)	8.06 (4.88)	8.19 (4.34)	0.76

(Continued)

TABLE 2 (Continued)

Variable	LH (n = 53)	WL (n = 53)	Total (n = 106)	p-value
Physical Activity	8.98 (4.02)	7.96 (4.84)	8.47 (4.45)	0.24
Nutrition	12.62 (3.65)	12.98 (4.37)	12.80 (4.01)	0.65
Spiritual Growth	13.58 (4.91)	13.13 (5.27)	13.36 (5.07)	0.65
Interpersonal Relations	13.79 (4.70)	13.43 (4.33)	13.61 (4.50)	0.68
Stress Management	10.19 (3.22)	10.49 (4.22)	10.34 (3.74)	0.68

Data were presented as mean (*SD*) unless otherwise specified. CEQ, Credibility-Expectancy Questionnaire; DASS-21, Depression Anxiety Stress Scales-21; HPLP-II, Health-Promoting Lifestyle Profile; ISI, Insomnia Severity Index; LH, Lifestyle medicine intervention group; SDS, Sheehan Disability Scale; SF-6D, Short Form (Six-Dimension) Health Survey; WL, Waitlist control group.

Between-group comparisons

The LMM analyses revealed that participants using the Lifestyle Hub had significant improvement in overall mental health conditions ($d = 0.52$, $p < 0.01$), depressive symptoms ($d = 0.56$, $p < 0.05$), anxiety symptoms ($d = 0.33$, $p < 0.01$), stress ($d = 0.44$, $p < 0.05$), insomnia severity ($d = 0.29$, $p < 0.01$), overall HPBs ($d = 0.31$, $p < 0.01$), dietary quality ($d = 0.13$, $p < 0.05$), and stress management ($d = 0.36$, $p < 0.001$) from baseline to immediate post-intervention relative to the WL control group. However, no significant between-group difference was observed in functional impairment, HRQOL, health responsibility, physical activity level, spiritual growth, and interpersonal relations ($ps > 0.05$; Table 3).

Within-group comparisons

The paired-samples t-tests showed that there were no significant differences in any outcomes from immediate post-intervention (Week 9) to 1-month follow-up (Week 13) in the LH group ($ps > 0.05$; Table 4).

Intervention acceptability

The paired-samples t-test revealed a significant within-group difference in intervention credibility [$t(43) = -3.12$, $p < 0.01$] from baseline to immediate post-intervention in the LH (Week 9). No significant difference in intervention expectancy was observed [$t(43) = -1.24$, $p = 0.22$; Table 3].

Discussion

This RCT examined the efficacy and acceptability of a smartphone-delivered multicomponent LM intervention, Lifestyle Hub, for improving mental health among a nonclinical population of Chinese adults. The results indicated that Lifestyle Hub had small to moderate effects ($d = 0.29$–0.56) in improving overall mental health conditions, depressive symptoms, anxiety symptoms, stress, and perceived insomnia severity relative to the WL control group at immediate post-intervention. In addition, the LH group had significant improvement in overall HPBs, dietary quality, and stress management compared with the WL control group at immediate post-intervention ($d = 0.13$–0.36). Contrary to our hypotheses, no significant between-group differences were observed in functional impairment, HRQOL, health responsibility, physical activity level, spiritual growth, and interpersonal relations. The intervention gains in the LH group were maintained at the 1-month follow-up. Overall, the LH participants indicated that Lifestyle Hub was an acceptable intervention for improving mental health, although a statistically significantly higher level of study attrition was observed in the LH group relative to the WL group.

The findings regarding the improvement in depressive symptoms ($d = 0.56$), anxiety symptoms ($d = 0.33$), and perceived insomnia severity ($d = 0.29$) at immediate post-intervention are in line with our previous RCT examining the efficacy of Lifestyle Hub in managing depressive symptoms among Chinese adults with at least moderate depressive symptomatology (21). Notably, these effect sizes are generally superior to previous meta-analyses examining the effects of multicomponent LM intervention on improving depressive symptoms ($d = 0.16$), anxiety symptoms ($d = 0.14$), and insomnia symptoms ($d = 0.32$) in diverse populations (14, 16, 17). Overall, our findings suggest that Lifestyle Hub can simultaneously improve CMD symptoms, stress, and perceived insomnia severity, even within a nonclinical sample where perhaps limited room for improvement is anticipated (14, 16, 17). This encouraging evidence provided preliminary support for the proposition that multicomponent LM interventions may serve as a transdiagnostic health management intervention for CMDs (17, 49, 50). However, more studies are needed to draw a definitive conclusion regarding the transdiagnosticity of the LM approach across these disorders (17).

Contrary to the hypothesis, Lifestyle Hub did not result in a significant improvement in health responsibility compared to the WL control group at immediate post-intervention. This finding is noteworthy, as our previous RCT found a moderate to large between-group improvement in health responsibility at immediate post-intervention ($d = 0.78$) (21). Previous studies suggested that concerns about health responsibility tend to emerge when individuals become ill (e.g., diagnosed with a health problem, experienced active symptoms, or received feedback from a health professional) or are able to acknowledge the potential link between their past behaviors and current health issues (51, 52). Therefore, a speculative reason for the contrasting results is that the nonclinical population in this RCT was less likely to connect their current lifestyle choices with their mental health conditions, resulting in a lower level of health responsibility compared to our previous RCT which targeted depressed individuals. Promoting health responsibility is important within the LM approach. A higher level of health responsibility could empower individuals to engage in more HPBs (53), thereby maximizing intervention outcomes and sustaining intervention gains in

TABLE 3 Effects of Lifestyle Hub at the immediate post-intervention assessment (Week 9) (based on the intention-to-treat principle).

Outcomes	Lifestyle Hub group			Waitlist control group			*p*-value	Between-group effect size
	Baseline *M (SD)*[a]	Post-intervention *M (SD)*[b]	Within-group effect size	Baseline *M (SD)*[a]	Post-intervention *M (SD)*[c]	Within-group effect size	Group x time effect	
DASS-21								
Total Score	25.02 (15.78)	19.59 (13.17)	0.41	26.30 (15.81)	28.12 (18.90)	0.06	<0.01**	0.52
Anxiety	6.94 (6.12)	5.23 (4.47)	0.32	6.30 (5.10)	6.96 (5.75)	0.08	<0.01**	0.33
Depression	6.53 (6.23)	4.82 (4.69)	0.32	7.92 (6.53)	8.64 (8.24)	0.05	<0.05*	0.56
Stress	11.56 (6.96)	9.55 (6.64)	0.37	12.08 (6.50)	12.52 (6.98)	0.04	<0.05*	0.44
CEQ								
Credibility	5.73 (1.28)	6.58 (1.34)	0.60	5.82 (1.57)	–	–	–	–
Expectancy (%)	49.09 (16.88)	54.63 (16.85)	0.22	51.55 (19.23)	–	–	–	–
SDS	2.40 (3.24)	2.77 (4.80)	0.18	3.72 (4.83)	4.62 (5.91)	0.15	0.73	0.34
ISI	6.96 (4.13)	6.16 (4.98)	0.11	6.30 (4.68)	7.68 (5.60)	0.28	<0.01**	0.29
SF-6D	0.79 (0.11)	0.82 (0.09)	0.21	0.76 (0.13)	0.76 (0.13)	0.01	0.22	0.49
HPLP-II								
Total	67.49 (17.07)	73.07 (16.36)	0.45	66.06 (22.43)	66.34 (25.69)	0.00	<0.01**	0.31
Health Responsibility	8.32 (3.78)	8.66 (3.65)	0.16	8.06 (4.88)	8.30 (5.39)	0.04	0.61	0.08
Physical Activity	8.98 (4.02)	9.91 (3.39)	0.37	7.96 (4.84)	7.94 (5.22)	0.00	0.06	0.44
Nutrition	12.62 (3.65)	13.98 (3.39)	0.48	12.98 (4.37)	13.42 (4.86)	0.07	<0.05*	0.13
Spiritual Growth	13.58 (4.91)	14.05 (4.32)	0.22	13.13 (5.27)	12.90 (5.82)	0.03	0.08	0.22
Interpersonal Relations	13.79 (4.70)	14.41 (4.26)	0.16	13.43 (4.33)	13.16 (4.72)	0.08	0.10	0.28
Stress Management	10.19 (3.22)	12.07 (3.53)	0.64	10.49 (4.22)	10.62 (4.42)	0.02	< 0.001***	0.36

DASS-21, Depression Anxiety Stress Scales-21; CEQ, Credibility-Expectancy Questionnaire; SDS, Sheehan Disability Scale; ISI, Insomnia Severity Index; SF-6D, Short Form (Six-Dimension) Health Survey; HPLP-II, Health-Promoting Lifestyle Profile. *$p < 0.05$; **$p < 0.01$, ***$p < 0.001$.

[a]$n = 53$.

[b]$n = 44$.

[c]$n = 50$.

the long run (15). To improve health responsibility among nonclinical populations, future smartphone-delivered multicomponent LM interventions could incorporate more comprehensive lifestyle psychoeducation regarding the relationship between lifestyle choices and the development of CMDs. Moreover, structured self-reflection questions could be utilized to raise their awareness and strengthen their motivation to engage in healthy lifestyles (54).

Furthermore, our results demonstrated nonsignificant group-by-time interaction in functional impairment, HRQOL, spiritual growth, and physical activity level between the LH and WL groups, while the previous RCT found significant improvements in these outcomes with small to large effect sizes ($d = 0.11–0.89$) (21). The observed discrepancies may be attributed to floor effects, given the current study had comparatively low scores in SDS and high scores in HRQOL, spiritual growth, and physical activity at baseline. In addition, these differences were perhaps due to the changing COVID-19 measures. The current study was conducted at the beginning of the second wave of the COVID-19 outbreak in Hong Kong, while our previous RCT (21) was conducted at the later stage of the same outbreak. The tightened social distancing measures, such as prohibited group gatherings and dine-in ban, and lockdown protocols implemented during the early stage of the outbreak might have had a more significant impact on individuals' daily functioning (e.g., work, school, social), activity level, and quality of life, given they had less time to process and adapt to the changes (55, 56). It is possible that a stronger result would have resulted in the absence of COVID-19 restrictions. Further studies are warranted to fully understand the efficacy of Lifestyle Hub for improving mental health in nonclinical populations.

In our study, the LH group demonstrated a significantly higher (20.8%) study attrition rate than the WL control group (5.7%). Despite a higher attrition rate relative to our previous RCT (21), the LH group in the current study reported a lower attrition rate than general smartphone-delivered interventions for improving mental health in nonclinical populations (i.e., 27%) (57). We were unable to determine specific reasons for study attrition in the LH group because most of the participants who dropped out were not contactable at post-intervention time points. The significant difference in study attrition between the LH and WL groups may be attributable to our study design. A previous meta-analysis suggested that participants in WL are more motivated to remain in the trial as compared to participants in the intervention group who already had access to all the intervention content (57). Another possibility may be related to the fact that Lifestyle Hub was a pure self-help intervention without any human encouragement or support provided to the participants (58).

TABLE 4 Effects of Lifestyle Hub at the 1-month follow-up assessment (Week 13).

	Post-intervention *M (SD)*[a]	Follow-up *M (SD)*[b]	Within-group effect size (*d*)	*p*-value
DASS-21				
Total Score	19.59 (13.17)	20.05 (15.40)	0.06	0.67
Anxiety	5.23 (4.47)	5.43 (5.00)	0.14	0.36
Depression	4.82 (4.69)	5.14 (5.66)	0.05	0.73
Stress	9.55 (6.64)	9.48 (6.52)	0.01	0.96
SDS	2.77 (4.80)	2.76 (4.37)	0.00	1
ISI	6.16 (4.98)	6.07 (4.40)	0.01	0.96
SF-6D	0.82 (0.09)	0.81 (0.13)	0.07	0.70
HPLP-II				
Total	73.07 (16.36)	74.02 (20.08)	0.06	0.58
Health Responsibility	8.66 (3.65)	9.81 (4.92)	0.25	0.06
Physical Activity	9.91 (3.39)	10.31 (3.29)	0.14	0.32
Nutrition	13.98 (3.39)	14.29 (3.95)	0.06	0.63
Spiritual Growth	14.05 (4.32)	13.76 (4.99)	0.01	0.96
Interpersonal Relations	14.41 (4.26)	14.24 (4.83)	0.05	0.64
Stress Management	12.07 (3.53)	11.62 (3.22)	0.12	0.27

DASS-21, Depression Anxiety Stress Scales-21; SDS, Sheehan Disability Scale; ISI, Insomnia Severity Index; SF-6D, Short Form (Six-Dimension) Health Survey; HPLP-II, Health-Promoting Lifestyle Profile.
[a]$n = 44$.
[b]$n = 42$.

While this RCT has contributed to the body of evidence supporting the efficacy of the LM approach in improving mental health in nonclinical populations, the results should be considered in light of the following potential limitations. Despite utilizing open recruitment strategies to enhance the generalizability of the sample, the included sample was predominantly female (77.4%) and those with higher educational attainment (75.5%). Moreover, the lack of blinding of participants might threaten the internal validity of the study findings. In addition, the potential improvements in outcomes may be masked by the floor effect, given a nonclinical sample was targeted in this RCT. Besides, the medium- and long-term effects of Lifestyle Hub are unclear, considering that the only follow-up assessment was conducted at 1-month post-intervention. Further investigation into the durability of the Lifestyle Hub is needed since the LM approach stresses long-term benefits (15).

This RCT represents a pioneer attempt to investigate the efficacy of a smartphone-delivered multicomponent LM intervention for improving mental health among a nonclinical population. Several research endeavors are important to be considered in future literature. First, future trials that include participants with a variety of diagnostic profiles (e.g., depression, anxiety, and /or insomnia) are warranted to establish the transdiagnostic potential of the LM approach. Additionally, it is crucial for upcoming causal research to understand the direct impacts of LM on CMDs and the underlying mechanisms of change. Concurrently, identifying the potential moderators and mediators as well as delineating the direct and indirect effects of LM on CMDs are also important (17). Second, therapy outcome studies that employ the dismantling design are needed to identify active intervention components that drive the observed clinical effects (59). Such investigation could lead to the optimization and inform the development of more streamlined and cost-effective intervention protocols. Third, future studies could enhance the depth of their findings by utilizing qualitative research methods (e.g., focus groups, interviews) to gain insight into the processes by which participants initiate and sustain lifestyle modifications. Also, qualitative investigations could be employed to elucidate specific intervention components and features that yield favorable experiences for participants as well as to evaluate intervention satisfaction. Fourth, future research might enroll participants with more severe depressive and anxiety symptomatology to provide more robust evidence for the clinical utility of smartphone-delivered lifestyle medicine interventions (14, 16, 17, 21). Lastly, while this RCT has provided support for greater dissemination and accessibility of smartphone-delivered lifestyle-based mental health care, it remains unclear how these interventions can be effectively integrated into the current mental health systems and delivered at the population level. As recommended by recent guidelines, a potential option may be incorporating lifestyle-based mental health care as the initial step within a stepped care model for CMDs (11, 22–24). Future clinical trials and cost-effectiveness analyses are warranted to investigate this possibility.

In summary, smartphone-delivered multicomponent LM intervention may serve as an efficacious, safe, and acceptable option for improving overall mental health conditions, insomnia severity, overall HPBs, dietary quality, and stress management in nonclinical adult populations. Future research is needed to investigate the long-term efficacy of Lifestyle Hub and how to maximize the benefits of smartphone-delivered LM interventions at the population level.

Data availability statement

The datasets presented in this article are not readily available because the data underlying this article will be shared on reasonable

request to the corresponding author. Requests to access the datasets should be directed to FY-YH, fionahoyy@cuhk.edu.hk.

Ethics statement

The studies involving humans were approved by Survey and Behavioral Research Ethics Committee, The Chinese University of Hong Kong. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

VWW and FY-YH designed the study protocol, developed the intervention, performed the data analysis, and contributed to the writing of the manuscript. JTT and N-KS assisted in developing the intervention and data collection and contributed to the writing of the manuscript. CN and JS verified the intervention content and contributed to the writing and reviewing of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

CN had served as a consultant for Lundbeck, Grunbiotics, Servier, Janssen-Cilag, Wyeth, and Eli Lilly, received research grant support from Wyeth and Lundbeck, and speaker honoraria from Servier, Lundbeck, Bristol-Myers Squibb, Organon, Eli Lilly, GlaxoSmithKline, Janssen-Cilag, Astra-Zenaca, Wyeth, and Pfizer, none related to this publication.

The remaining 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 association between Long-COVID symptomology, perceived symptom burden and mental health in COVID-19 patients in Shijiazhuang, China: a population-based health survey

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Background: Long-COVID (LC) refers to post-acute COVID-19 symptoms that can last for months or longer after the initial infection, affecting the physical health of infected patients. This study aims to investigate the association between the symptomology of LC and the mental health of patients in China. It also aims to examine the relationship between the perceived symptom burden and mental health of these patients.

Methods: A population-based stratified cluster sample was recruited, using a standard sampling procedure, from a prefecture-level city in Northern China. Participants included patients who had tested positive for COVID-19 after December 2022. LC symptomology was assessed using a LC symptoms checklist where the perceived symptom burden was measured by the included 5-point Likert scales. Mental health of patients was measured using the Depression, Anxiety, and Stress Scale (DASS), the original Connor-Davidson Resilience Scale (CD-RISC), and the Duke-UNC Functional Social Support Questionnaire (DUFSS). Data were analysed using multiple linear regression models.

Results: About 25% of respondents, experienced COVID symptoms lasting longer than two months that could only be explained by the infection. Post-exertional malaise (22.2%) and fatigue (21.2%) were the most common symptoms. After controlling for potential confounding variables, LC symptomology was significantly and positively associated with depression ($t=2.09$, $p=0.037$) and anxiety ($t=4.51$, $p<0.001$), but not stress. Perceived symptoms burden was also positively and significantly related to depression ($\beta=0.35$, $p<0.001$), anxiety ($\beta=0.54$, $p<0.001$), and stress ($\beta=0.35$, $p<0.001$), suggesting a dose-response relationship between perceived symptom burden and mental ill health.

Conclusion: This study highlights the importance of recognising the risk of LC, patients' perception of the symptom burden and its potential impact on mental health. Healthcare professionals should be aware of the complexity of psychological comorbidities among infected patients reporting prolonged symptoms, and be able to give advice regarding long-term management of the symptoms.

KEYWORDS

Long-COVID, depression, anxiety, stress, mental health, post-COVID conditions

Introduction

The COVID-19 pandemic has not only caused almost 800 million cases and 7 million deaths globally, but also the long-lasting and profound changes at the personal level, such as social interactions, lifestyles, and mental-wellbeing. It also affected the population at the social level including the global economy, healthcare system, and social inequalities (1, 2). In October 2021, the World Health Organization (WHO) defined Long-COVID (LC) as the condition typically occurs in individuals with a history of probable or confirmed SARS-CoV-2 infection, usually 3 months after onset, lasting for at least 2 months and cannot be explained by any alternative diagnosis (3). With global numbers of infections of COVID-19 exceeding 500 million, a conservative estimate of people being currently affected by LC worldwide could be more than 100 million (4). Typical acute COVID-19 cases are characterised by respiratory symptoms, fever, and neurological symptoms (5). The duration and severity of acute COVID-19 cases vary, with some patients being asymptomatic, while others require hospitalisation and mechanical ventilation. The average duration of a COVID-19 infection is typically shorter than 4 weeks (6). The new-onset conditions including cardiovascular, thrombotic/cerebrovascular disease, type 2 diabetes, myalgic encephalomyelitis/chronic fatigue syndrome (ME/CFS) and dysautonomia, especially postural orthostatic tachycardia syndrome (POTS), could last for a long time even years. These symptoms could be commonly called LC. It also have different labels, such as post-acute sequelae of COVID-19, post-acute COVID-19, or post-COVID-19 condition (7).

It has been widely reported that the risk of psychiatric symptoms was associated with COVID-19 infection. A recent meta-analysis revealed that up to one in four patients experienced neuropsychiatric symptoms spanning sleep disorders, fatigue, anxiety, and post-traumatic stress (PTSD) after the onset of COVID-19 with an approximate follow-up duration of 77 days (8). Studies have further explored potential correlations between the risk of LC and mental health problems. Specifically, LC was found to be associated with increased display of depression, anxiety, PTSD, and weakened life satisfaction (9), which might be partially attributed to the persistent physical symptoms of LC (10). In China, few studies have focused on evaluating the impact of LC on COVID survivors. Zhao et al.'s study (11) found that approximately 9.6% of hospitalised patients suffering from moderate impairment reported mainly mental health and cognitive symptoms 20 months after recovery. Several factors were reported to be predictive of long-term physical and cognitive symptoms, which included age, hospital stay, sex, and comorbidities. However, the sample was recruited in 2021 and was not based on a randomised sampling method. Another study conducted in China has found that having at least one LC symptom increased the risk of depression or anxiety by 3.44-fold (12). However, the study sample was limited to hospitalised patients recruited in 2020. Given the limitations of these studies, there is a need to further study the mental health effect of LC, particularly in patients who were infected in the later period of the pandemic using a random community-based sample.

The extent of suffering from chronic illness is not just determined by the severity of the illness itself, but rather moderated by external and subjective factors (13). As The Burden of Treatment Theory posits, management of chronic conditions involves routine work for patients to control their illness. As treatment burdens accumulate, some patients become overwhelmed leading to poorer outcomes, stress on caregivers, and increased healthcare costs (14). In addition, personality factors also play an important role when patients cope with the illness. According to Leventhal's self-regulatory model, patients' "illness representations" (beliefs about cause, timeline, consequences, etc.), reflecting their perceived burden, affect their self-management behaviors, psychological adjustment, and mental health (15). Therefore, the perceived burden of illness of patients

Abbreviations: CD-RISC, Connor-Davidson Resilience Scale; CFS, chronic fatigue syndrome; COVID-19, coronavirus disease 2019; DASS-21, 21-item Depression, Anxiety and Stress Scale; DUFSS, Duke-UNC Functional Social Support Questionnaire; ICU, Intensive Care Unit; I-CVI, item-level content validity index; IQR, Interquartile Range; LASSO, least absolute shrinkage and selection operator; LC, Long-COVID; OR, odds ratio; PEM, postexertional malaise; S-CVI/Ave, average scale-level content validity index.

suffering from Long-COVID, like any other chronic conditions, may also have a direct impact on their mental health.

In terms of the relationship between the perceived severity of LC symptoms and the mental health of patients, few studies have been conducted. In the study by Sivan and colleagues, it was found a positive correlation between the perceived severity of 12 types of LC symptoms and cognitive symptoms, PTSD, depression, and anxiety (16). However, in another study of patients with LC symptoms, the perceived severity of autonomic dysfunction and anxiety, as well as emotional well-being were not positively correlated (17).

Therefore, this study aims to describe the common symptoms related to LC and to quantify the prevalence of these symptoms among community-dwelling COVID patients. It also aims to examine the relationship between the LC symptomology and the mental health status of these patients, as well as the relationship between the perceived burden of the LC symptoms and the level of mental health problems. It is hypothesised that LC symptomatology is associated with the mental health of patients and that there is a positive dose-response relationship between the perceived burden of LC symptomatology and the severity of mental health problems.

Materials and methods

Settings and participants

This was a population-based cross-sectional health survey using a stratified cluster random sample recruited from Shijiazhuang, a prefecture-level city in Northern China. Since residents of the city were housed in compounds in China, two compounds from the list of compounds within each jurisdiction in the city were randomly selected in accordance with the population size of jurisdictions. In total, eight compounds were selected as the sample frame. Two buildings were then randomly selected from each compound for the recruitment of the sample. Additional buildings will be selected if the sample size does not reach the expected level. The researchers joined the WeChat group of the selected buildings to distribute the online questionnaire with the permission of the compound's management. The online survey was designed using the Tencent platform which could be easily distributed through social media platforms. For participants who were not familiar with mobile technologies, a printed questionnaire was delivered by post and collected through a neighbourhood collection point designated by the researchers.

The survey was conducted in May and June 2023, approximately 5 months after the peak of COVID-19 infection in December 2022. Only participants aged 25-54 years were included to reduce potential age-related biases (18, 19). Participants who were not diagnosed as positive (hospital or self-tested antigen) in China after December 2022 were excluded. Participant's participation in the survey implied their consent, which was stated in the promotional materials and on the survey's front page. The study was approved by the Macau University of Science and Technology Medical Ethics Committee (MUST-HSS-20230505001).

Sample size

Based on the literature, it was estimated that the prevalence of unresolved COVID-19-related symptoms at about 4 months among COVID-19 survivors was 45% (20). Using the prevalence-based calculation of the sample size with a precision of 5% and a confidence interval of 95% was estimated that a sample of at least 380 would be required to provide sufficient power for the study (21). Given an estimated 20% of invalidation rate, the final required sample size was estimated to be about 460.

Measures

Mental Health status was assessed using the Depression, Anxiety, and Stress Scale (DASS) (22). The DASS designed to assess the severity of symptoms related to depression, anxiety, and stress. Participants are asked to rate the extent to which they have experienced each symptom over the past week using a 4-point Likert scale ranging from 0 (Did not apply to me at all) to 3 (Applied to me very much or most of the time). The final scores will be for depression (7 items, range 0-21), anxiety (7 items, range 0-21) and stress (7 items, range 0-21).

The LC symptomology was assessed by the Long-COVID Symptoms Checklist of 15 questions on symptoms commonly identified with patients with LC symptoms. Patients were asked if the symptoms persisted for at least two months after diagnosis of COVID-19, or if they had developed any new symptoms that had been present for a minimum of two months following their initial diagnosis. In this study, LC symptomatology was defined as having at least one of the symptoms reported on the Symptom Checklist. The validity of the Long-COVID Symptoms Checklist was tested by 10 global experts from cardiology, respiratory medicine, intensive care, and internal medicine. The content validity of the scale was calculated using the item-level content validity index (I-CVI) and the average scale-level content validity index (S-CVI/Ave). An I-CVI $\geq$ 0.78 and an S-CVI/Ave $\geq$ 0.90 were considered acceptable (23). Additionally, to evaluate the internal consistency of the items measuring Long-COVID with respect to the underlying construct, Cronbach's α reliability coefficient was computed using SPSS software (SPSS 26.0: SPSS; Chicago, IL, USA). The I-CVI of each item of the Checklist ranged from 0.8 to 1.0, and the S-CVI/Ave was 0.87 with an I-CVI $\geq$ 0.78 and an S-CVI/Ave $\geq$ 0.90 considered acceptable (23). For internal consistency, Cronbach's alpha coefficient was calculated as 0.80 with a value exceeding 0·7 regarded as acceptable (24).

To assess the burden of LC symptoms, patients were asked to rate each symptom on the Long-COVID Symptom Checklist the degree to which it interfered with their daily activities (including work and household duties) on a 5-point Likert scale ranging from 0 (Not at all) to 4 (Very much). The total perceived burden was assessed using the total score summing the responses on each item.

Resilience was examined by using the shortened version of the Connor-Davidson Resilience Scale (CD-RISC2) (25). The scale is based on two items that they believed captured the essence of

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resilience conceptually from the 25-item the Connor-Davidson Resilience Scale. It uses 5-point Likert-type response scale, ranging from "not at all" (0 points) to "almost completely" (4 points) (26). Participants rated each item based on their experiences during the past month. Higher scores indicate higher levels of resilience.

Social Support was assessed using The Duke-UNC Functional Social Support Questionnaire (DUFSS), which is a multidimensional social support scale consisting of 8 items used to measure an individual's perceived social support (27). The DUFSS is a reliable and valid self-report tool that has been used in research with medical patients (28). Scores range from 8 to 40, with higher scores indicating greater perceived social support.

Other information collected included demographics, pre-COVID-19 health status, vaccination history, date of their first COVID-19 symptom onset, symptoms in the acute infection phase, hospitalisation during the acute symptomatic period, and how they confirmed their COVID-19 infection.

Statistical analysis

The statistical analyses were performed in STATA 15.1 (StataCorp LLC, TX, USA). Descriptive analyses were performed to examine the participants' demographic and health-related profiles, the prevalence of symptoms, and scores on psychological scales. Continuous variables are expressed as the mean (SD), while binary and categorical variables are presented as counts and percentages. Bivariate analyses were conducted between LC symptomology, demographic, health-related and other study variables, and the three mental health variables, namely depression, anxiety, and stress separately. For the selection of variables to be included in further multiple linear regression analyses, a criterion of $p<0.1$ was applied. For the association between LC symptomology and mental health, multiple linear regression analyses were employed since the raw scores of the DASS were used as the outcome measures. The possible moderating effect of resilience and social support between LC symptomology and poor mental health was checked by testing their corresponding interaction terms in the regression models. The analyses of the relationship between the perceived burden of LC and mental health were only conducted in the subgroup of patients with LC symptomology; namely, patients responded positively to the question "experienced lingering symptoms at least lasting for 2 months that cannot be explained except due to the infection.". A similar approach to the aforementioned analyses for the association between LC symptomology and mental health was adopted. A type I error rate of 5% was used for all 2-tailed hypotheses testing for independent variables and 1% for the interaction terms.

Results

In total, 781 patients tested positive with COVID-19 were recruited. Of these 482 respondents provided useful information

TABLE 1 Descriptive information on the demographics, premorbid health, vaccination, hospitalisation, resilience, social support, and mental health symptoms (N=482).

	Overall
N	482
Age	
25-34 years	130 (26.97)
35-44 years	153 (31.74)
45-54 years	199 (41.29)
Sex	
Male	195 (40.46)
Education	
Below bachelor's degree	179 (37.1)
Smoking Status	
Yes	69 (14.32)
Alcohol Drinking	
Yes	113 (23.44)
Comorbidity of Mental Disorders	
Yes	7 (1.45)
Number of Vaccination	
Less than 3	108 (22.41)
Vaccination Type	
Inactivated	322 (66.80)
Recombinant	147 (30.50)
Others	13 (2.70)
Symptoms in acute phase	
Exhaustion	
Yes	206 (42.74)
Headache	
Yes	202 (41.91)
Dyspnea	
Yes	60 (12.45)
Fever	
Yes	420 (87.14)
Coughing	
Yes	231 (47.93)
Ear, Nose and Throat	
Yes	121 (25.10)
Muscles and Joints Pain	
Yes	270 (56.02)
Hospitalised	

(Continued)

TABLE 1 Continued

	Overall
Yes	6 (1.24)
ICU	
Yes	3 (0.62)
Resilience (mean (SD))	4.90 (1.94)
SocialSupport (mean (SD))	27.37 (7.21)
Depression (mean (SD))	
None/mild/moderate	421 (87.34)
Serious/Extreme serious	61 (12.66) 15.90 (4.74)
Anxiety (mean (SD))	
None/mild/moderate	353 (73.24)
Serious/Extreme serious	129 (26.76) 12.17 (4.83)
Stress (mean (SD))	
None/mild/moderate	361 (74.90)
Serious/Extreme serious	121 (25.10) 17.22 (3.77)

for data analyses, after removing 299 questionnaires having inconsistent answers on geographical information or confirmation date of infection. A comparison between the respondents and non-respondents indicated no differences in demographic variables. Table 1 presents patients' demographics, basic health information, and scores on mental health measures. Of the total 482 respondents, there were 195 (40.5%) males, with 374 (77.6%) receiving three or more doses of vaccine, and the most commonly received vaccine was the domestically produced inactivated vaccine (66.8%), followed by the domestically produced recombinant protein vaccine (30.5%). The most prevalent symptom of acute-phase infection reported by participants was fever (87.1%), followed by muscle and joint pain (56.0%), cough (47.9%), fatigue (42.7%), headache (41.9%), ENT abnormalities (25.1%), and finally shortness of breath (12.4%). Seven (n=7, 1.5%) of the respondents reported pre-morbid mental health problems, and 6 (1.2%) were hospitalised during the acute phase of the infection, with half (50%) of these hospitalised patients receiving treatment in the ICU. In terms of the outcome measures of the study, namely the mental health status, 61 (12.7%) exhibited symptoms of severe to extremely severe depression symptoms (mean=15.9, s.d=4.7), 26.8% (n=129) anxiety (mean=12.2, s.d=4.8), and 25.1% (n=121) stress (mean=17.2, s.d=3.8).

The results of LC symptomology were summarised in Table 2. As shown, among all respondents, 25.5% had symptoms that persisted for more than two months and could not be explained by causes other than COVID-19 infection. In addition, the top five common symptoms were postexertional malaise (22.2%), fatigue (21.2%), brain fog (14.3%), sleep (11.6%), shortness of breath (11.4%), and palpitations (10.2%).

The unadjusted bivariate relationships between LC symptomology, other study variables, and depression, anxiety, and stress were summarised in Table 3. As shown, a few variables were related to the mental health variables. LC symptomology, resilience, social support, and premorbid mental health problems were significantly related to all three aspects of mental health of interest. In addition, education level was significantly associated with stress and marginally related to anxiety. All other variables were insignificantly related to the mental health variables with a p-value much greater than 0.1. Hence, they were not included in further analyses. The results obtained from the multiple linear regression analyses were presented in Table 4. After adjusting for other variables in the model, the LC symptomology was still positively and significantly associated with depression ($t=2.09$, $p=0.037$) and anxiety ($t=4.51$, $p<0.001$), but not stress. The regression coefficient of LC symptomology was 1.13 (s.e. = 0.54) for depression suggesting a difference in the depression score of more than 1 unit between patients with LC symptomology and those without. The regression coefficient of LC symptomology for anxiety was 2.35 (s.e. = 0.52) indicating a difference of more than 2.3 units in the anxiety score between groups. In terms of the interaction terms between LC symptomology and resilience, as well as social support, the results indicated that none were significant even at the 5% types I error rate.

For the relationships between the perceived burden of LC symptoms and mental health, the results were presented in Table 5. As shown, after adjusting for variables including premorbid mental health problem, education level, resilience, and social support, positive and significant associations were found between the perceived burden of LC and depression, anxiety, and stress. The regression coefficients of the perceived burden of LC for depression and stress were 0.38 (s.e. = 0.07) and 0.35 (s.e. = 0.08) respectively, indicating, on average, for each increase in 1 unit of perceived burden

TABLE 2 The frequency (%) of Long-COVID symptoms in the sample.

Long-COVID Symptoms	Frequency (%)
Dyspnea	55 (11.41)
Fatigue	102 (21.16)
Postexertional Malaise	107 (22.20)
Brain Frog	69 (14.32)
Sleep problems	56 (11.62)
Cough	43 (8.92)
Chest Pain	19 (3.94)
Sore Throat	23 (4.77)
Anosmia	46 (9.54)
Headache	16 (3.32)
Palpitations	49 (10.17)
Muscles and Joints Pain	40 (8.30)
Digestive Abnormalities	30 (6.22)
Hair Loss	44 (9.13)
Allergies	22 (4.56)
Risk of Long-Covid	123 (25.52)

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TABLE 3 Unadjusted association between Long-Covid Symptomology, demographics, premorbid health, vaccination, hospitalisation, resilience, social support, and mental health symptoms.

Variables	Depression	Anxiety	Stress
Age	$F_{(2, 479)}$ = 0.65, p=0.521	$F_{(2, 479)}$ = 0.02, p=0.984	$F_{(2, 479)}$ = 1.98, p=0.140
Sex	t_{480} = 1.44, p=0.152	t_{480} = 1.34, p=0.181	t_{480}= -0.12, p=0.907
Education level	t_{480}= -0.20, p=0.846	t_{480}= -1.90, p=0.059	***t_{480}= -2.12, p=0.035***
Premorbid mental health problem	t_{480}= ***-3.90, p<0.001***	t_{480}= ***-4.47, p<0.001***	***t_{480}= -2.04, p=0.042***
Smoking	t_{480} = 0.12, p=0.908	t_{480} = 0.54, p=0.590	t_{480} = 0.42, p=0.677
Drinking	t_{480} = 0.07, p=0.946	t_{480}= -0.57, p=0.569	t_{480}= -0.11, p=0.915
Number of vaccination	t_{480} = 1.419, p=0.234	t_{480}= -0.43, p=0.670	t_{480} = 0.01, p=0.996
Vaccine type	$F_{(2, 479)}$ = 1.91, p=0.150	$F_{(2, 479)}$ = 1.01, p=0.364	$F_{(2, 479)}$ = 1.41, p=0.244
Hospitalisation	t_{480}= -0.45, p=0.655	t_{480}= -0.42, p=0.672	t_{480} = 0.77, p=0.444
Resilience	***r= -0.32, p<0.001***	***r= -0.32, p<0.001***	***r= -0.27, p<0.001***
Social support	***r= -0.29, p<0.001***	***r= -0.26, p<0.001***	***r= -0.19, p<0.001***
Long-COVID Symptomology	t_{480}= ***-2.77, p<0.001***	t_{480}= ***-5.22, p<0.001***	t_{480}= ***-2.41, p=0.017***

The bold values indicated significance of p value (p<0.05).

measure there was a corresponding increase of 0.38 units in the depression and 0.35 in the stress scores. Among the three mental health variables, anxiety had the largest increase in the score with an increase of each unit of perceived burden of LC there was an increase of 0.54 units (s.e. = 0.07, t=8.24, p<0.001). These results suggested a positive dose-response relationship between the perceived burden of LC symptoms and mental health problems. As in the previous analyses, none of the interaction terms between perceived burden and resilience, as well as social support were significant.

Discussion

This study aimed to investigate the prevalence of common symptoms of LC, and the propensity of LC in a community sample of COVID-19 patients. It also aimed to examine the relationship between LC symptomology and the mental health status, as well as the relationship between the perceived symptom burden of LC and mental health problems. The results suggested that patients exhibited the overall LC symptomology was about 25% among patients who had tested positive for COVID-19 after December 2022. Postexertional malaise and fatigue were the most prevalent LC symptoms, accounting for 22.2% and 21.2% of all LC patients, followed by cognitive impairment including brain frog (14.3%), and sleep problems (11.6%). The results further suggest a positive and significant association between LC symptomatology and poor mental health, particularly depression and anxiety. In terms of the perceived burden of LC symptoms, it is related to the mental health of patients also demonstrating a positive dose-response relationship with depression, anxiety, and stress.

The results on symptomatology, in general, are consistent with those reported in the literature, though some minor discrepancies are found in other less commonly reported symptoms, such as headaches and muscle aches that have been ranked less prevalent in the current study (29, 30). Furthermore, some differences in the prevalence of symptoms have also been identified compared to previous studies on COVID-19 patients one-year post-infection in China (12, 31). In Zhang's study, the prevalence of muscle and joint pain was 11.8%, whereas in the current study, it was 8.3% (12). While the prevalence of brain fog and palpitations were 14.3% and 10.2% in this study, they are higher than that reported in the literature of 2.2% and 5.8% (31) This study also found that patients with LC symptomology scored significantly higher in depression and anxiety, but not stress. In terms of the propensity of these symptoms, these patients reported postexertional malaise, fatigue, brain fog, shortness of breath, and insomnia, as the most common symptoms, indicating that these symptoms had a greater impact on people's lives and work. In the present study, postexertional malaise (PEM), a distinguishing feature of chronic fatigue syndrome (CFS) (32), was most prevalent and reported to be the most burdensome among other symptoms identified as post-COVID-19 sequelae. There could be many explanations for this result. One possible

TABLE 4 Result of the adjusted association between the Long-COVID Symptomology and mental health (N=482).

Variables retained in the model	Depression				Anxiety				Stress			
	β	s.e.	t	p-value	β	s.e.	t	p-value	β	s.e.	t	p-value
Risk of Long-COVID	1.13	0.54	2.09	0.037	2.35	0.52	4.51	<0.001	0.87	0.56	1.55	0.122
Premorbid mental health problem	6.26	1.96	3.20	0.001	7.25	1.89	3.83	<0.001	2.70	2.05	1.23	0.188
Education level	–	–	–	–	1.28	0.47	2.70	0.007	1.46	0.51	2.85	0.005
Resilience	-0.62	0.14	-4.33	<0.001	-0.63	0.14	-4.60	<0.001	-0.63	0.15	-4.25	<0.001
Social support	-0.12	0.04	-3.12	0.001	-0.10	0.04	-2.70	0.007	-0.06	0.04	-1.69	0.092
Model statistics	$F_{(4, 477)}$ =21.06, p<0.001, R^2 = 15.0%				$F_{(5, 476)}$ =17.09, p<0.001, R^2 = 15.2%				$F_{(5, 476)}$ =10.62, p<0.001, R^2 = 10.0%			

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TABLE 5 Result of the association between the perceived symptom burden of Long-COVID and depression, anxiety, and stress (N=123).

Variables retained in the model	Depression				Anxiety				Stress			
	β	s.e.	t	p-value	β	s.e.	t	p-value	β	s.e.	t	p-value
Burden of Long-COVID	0.38	0.07	5.45	<0.001	0.54	0.07	8.24	<0.001	0.35	0.08	4.37	<0.001
Premorbid mental health problem	2.59	3.20	0.81	0.420	3.95	3.01	1.31	0.192	0.82	3.60	0.23	0.821
Education level	–	–	–	–	0.73	0.47	0.89	0.373	1.79	0.98	1.82	0.071
Resilience	-0.51	0.25	-2.03	0.045	-0.72	0.24	-3.03	0.003	-0.64	0.28	-2.24	0.027
Social support	-0.15	0.07	-2.21	0.029	-0.11	0.06	-1.73	0.085	-0.06	0.08	-0.75	0.454
Model statistics	$F_{(4, 118)}$ =13.55, p<0.001, R^2 = 31.5%				$F_{(5, 117)}$ =21.38, p<0.001, R^2 = 47.7%				$F_{(5, 117)}$ =7.46, p<0.001, R^2 = 24.2%			

reason may relate to the potential physiological responses for the infection in different body parts including the brain, such as neuroinflammation (33). This has highlighted how the chronic and debilitating fatigue associated with CFS can significantly impact patients' work productivity and quality of life, posing psychological distress (34). Moreover, symptoms related to CFS are relatively difficult to diagnose in hospitals to receive appropriate rehabilitation recommendations (35).

For the relationship of LC and mental health, the changes to routine happened due to pandemic, such as financial instability, social distance and mask wearing, have been challenging people's psychological needs that previously fulfilled for about 3 years (36–38). Moreover, as for patients developed LC symptoms, they might experience additional symptoms related to brain function leading to a worse mental health outcome compared to those who recovered well from COVID-19 infection (39). The perceived burden of LC symptoms further exhibits the impact of the disease on the mental health of patients. There could be many reasons attributing to the interplay between the actual severity of the physical illness, treatment demands and individuals' perceptions of their ability to adapt (40). According to the Burden of Treatment Theory (14), the perceived disease burden in LC patients may be aggregated by the difficulties of managing the symptoms. Overall, medical expenses on the treatment, which was estimated at $9,000 per person annually, could be a stress for many people (41). Moreover, the increased stringency of containment measures during the pandemic resulted in unemployment also exerted additional pressure on patients (42). As a result, patients who would like to retain their jobs are more likely to keep working and not take any medical leaves, thus becoming an additional layer of burden.

The findings highlight the need to provide mental health support for those severely affected by COVID-19 infection, particularly those who developed LC symptoms. In 2020, the National Health Commission of China issued "Rehabilitation Program for Discharged COVID-19 Patients" (43) recommending respiratory training, physical exercises, psychological support, and activities to regain daily living abilities to address residual respiratory, physical, and psychological dysfunctions like cough, fatigue, and anxiety that may persist post-hospitalisation. To date, the treatment strategies for LC in designated clinics or outpatient services mainly focused on symptom relief (44), with both Western and Chinese medicine focusing on physical rehabilitation (45, 46). In terms of mental health services in general, and particularly for patients with LC symptoms, it is a lacking area. China has very few numbers of mental health professionals relative to its large population (47). There is also a lack of mental health rehabilitation services, and the utilisation of telemedicine is also low mainly due to the limited access to facilities (47). With such limited resources, well-designed and validated preventive programs using a mHealth approach for early detection, intervention, treatment and management are urgently needed for the patient population with LC symptoms (48, 49).

Limitations

There are several limitations to our study that should be noted. First, our sample was limited to individuals who self-reported LC symptoms, which may not be representative of all patients with LC symptoms. Out of the total sample, only 7 patients reported pre-morbid mental problems, which could limit the generalisation of correlation found between pre-morbid mental problems and mental illness severity after COVID-19 infection. Second, due to the study design being a cross-sectional survey, it would be difficult to draw any conclusion on the causality of the results obtained. Longitudinal studies could undoubtedly provide more powerful data for interpreting causality. While many other countries have established app-based COVID-19 syndromic surveillance systems (50, 51), a similar tracking platform has not yet been deployed in China (52). In addition, our study was conducted in a single city in the northern part of China. This may not be representative of the whole country due to possible geographical differences across the land, thus making it difficult to generalise the findings. For better evidence of the effect of LC on the mental health of infected patients' studies of a stronger design, such as a cohort study, should be conducted. Furthermore, the study should also be expanded to a wider geographical region with more diverse populations.

However, despite these limitations, our study also has important contributions. To our knowledge, this is one of the first studies to investigate the impacts of perceived LC burden on mental health in China through a standardised assessment procedure. While larger and more rigorous studies are still needed, our findings provide valuable preliminary insights into how LC may be associated with increased mental illness severity.

Conclusion

The present study provides evidence that LC symptomology is associated with mental health problems of patients and that there is a dose-response relationship between the burden of LC symptoms and mental health problems. Long-term management and rehabilitation are essential in providing support to these patients. Continued investigation of how LC may influence mental well-being may also provide insights to guide targeted interventions and management strategies.

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 informed consent and study protocol was confirmed by the Macau University of Science and Technology Medical Ethics Committee (MUST-HSS-20230505001).

Author contributions

YL: Conceptualization, Formal analysis, Methodology, Visualization, Writing – original draft. LL: Formal analysis, Supervision, Writing – review & editing. YX: Conceptualization, Supervision, Writing – review & editing. ZQ: Investigation, Validation, Writing – original draft. YZ: Investigation, Validation, Writing – original draft.

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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 of social support on home isolation anxiety and depression among college students in the post-pandemic era: the mediating effect of perceived loss of control and the moderating role of family socioeconomic status

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Background: There is an escalating concern about the rising levels of anxiety and depression among college students, especially during the post-pandemic era. A thorough examination of the various dimensions of social support and their impact on these negative emotions in college students is imperative.

Aim: This study aimed to determine if a perceived loss of control mediates the relationship between social support and levels of anxiety and depression among college students during the post-pandemic era. Additionally, it examined whether family socioeconomic status moderates this mediated relationship.

Methods: We administered an online cross-sectional survey in China, securing responses from 502 participants. The sample comprised home-isolated college students impacted by COVID-19. Established scales were employed to assess social support, anxiety, depression, perceived loss of control, and family socioeconomic status. Analytical techniques included descriptive statistics, correlation analysis, and a bootstrap method to investigate mediating and moderating effects.

Results: Social support was found to negatively affect anxiety and depression in college students, with perceived loss of control partially mediating this relationship. In addition, family socio-economic status was shown to moderate this moderating process. Furthermore, family socioeconomic status influenced this mediation, with higher socioeconomic families exhibiting a stronger moderating effect on perceived loss of control across different dimensions of social support.

Conclusion: This study may help to develop strategies to mitigate the impact of anxiety and depression in the lives and studies of university students during unexpected public health crises, and to promote better mental health among college students.

KEYWORDS

social support, post-pandemic era, college students, depression and anxiety, perceived loss of control, family socioeconomic status

1 Introduction

From the onset of the swift proliferation of the COVID-19 virus, it has aroused a broad spectrum of global attentiveness. Following suit, individuals have embarked upon a phase of production and living termed the "Post-Pandemic Era," whose profound ramifications reverberate globally (1–4). The Post-Pandemic Era does not signify a complete eradication or total recuperation from the pandemic; rather, it denotes a period wherein the pandemic may still manifest in cyclical and scalable outbreaks, enduring over an extended duration, and perpetually impacting various domains (5–7). In March 2022, influenced by the Omicron variant of COVID-19, numerous regions in China witnessed a dramatic escalation in infection numbers (8, 9). In response to the outbreak, several local governments intensified their efforts in implementing "collective isolation" and "home isolation" measures (10, 11). Especially, the "citywide static management" measures adopted by Shanghai have elicited widespread public concern and attention (12). Although such measures exhibit significant efficacy in curtailing the dissemination of the virus (13, 14), the accompanying requisition for a vast populace to adhere to home isolation, the strain on medical resources, the scarcity of daily necessities, and the precipitous ascent in prices, have all contributed to the escalating anxiety amongst the citizenry (15–17). Some studies posit that the inadequacy of medical resources and the rapid augmentation of infection numbers are the principal catalysts inciting adverse repercussions on public mental health (18). Yet, there are perspectives that highlight the prolongation of home isolation and the frequent use of social media as pivotal factors also leading to the intensification of negative sentiments (19–21).

It is noteworthy that in the Post-Pandemic Era, compared to the resilience and positive outlook displayed during the initial phase of the pandemic, the populace tends to exhibit a more psychologically fragile demeanor during periods of home isolation (22, 23). The isolation policies and scarcity of resources are perceived as primary catalysts triggering and exacerbating psychological issues (24). Post-traumatic stress disorders are commonly manifested in individuals after encountering exceptional threats or calamities (25, 26). Anxiety and depression constitute two significant facets of this manifestation, often coexisting within the same individual either concurrently or at different junctures (27–29). Some studies assert that they are distinctly different, independent entities (30, 31). However, other studies have discerned that they represent overlapping syndromes, manifesting at different points on a phenomenological or temporal continuum, sharing common characteristics with essentially analogous clinical presentations (32–35). Psychological experts have discovered that post public health crisis, the comorbidity rate of anxiety and depression escalates to 60–70% (36). A substantial portion of COVID-19 patients exhibit symptoms indicative of a mixed anxiety-depression condition (37). Research indicates that during the spread of the pandemic in the first half of 2022 in China, the rapid proliferation and persistence of the COVID-19 virus posed a series of psychological challenges to the public, particularly in the comorbid manifestation of anxiety and depression. The clinical features generally encompass pessimism, sorrow, fear, concern, along with a loss of interest and vitality (38).

These emotions not only impact individuals' psychological well-being, but may also jeopardize physical health through interference with immune and endocrine functions (39–42). College students, representing a vulnerable faction amidst this pandemic, have manifested as a high-risk populace for anxiety and depression (43). The outbreak's emergence chanced upon the season of Chinese students returning to academia, where the abrupt instigation of isolation policies left numerous students marooned within their homes, hotels, or proximate to their institutions, in anticipation of quarantine cessation (44, 45). The pandemic's instability within the Post-Pandemic Era further incites emotional fluctuations among university students (46, 47). Moreover, the decline in psychological well-being levies a hefty toll on society, families, and individuals (48, 49). Therefore, devising effective psychological intervention measures to address the mental challenges brought forth by home isolation during this era is of paramount importance. These initiatives aim to confront the academic and life adversities encountered by students both online and offline during home isolation, bolstering their psychological resilience, aiding them in overcoming the impacts of anxiety and depression, and rekindling their zeal and motivation towards academia and life.

Social support embodies the composite resources an individual garners within a social milieu, unveiling the intimate interaction between the individual and society (50, 51). Such support not only facilitates the redistribution of resources but also furnishes material and psychological sustenance for individuals amidst adversities, aiding in the mitigation of negative emotional onslaughts (52, 53). Studies delineate that amidst the Epidemic prevention and control, social support can significantly diminish residents' anxiety (54). Elevated social support signifies heightened societal concern towards individual health, thereby attenuating negative emotional experiences (55). Further discoveries elucidate that the linkage between social support and psychological well-being is modulated by cognitive and expressive modalities, where proactively leveraging social support assists individuals in adopting more apt emotional regulation strategies. Compared to those with lower perceived social support, individuals with higher perceived support witnessed a 63% reduction in depression risk (56). This support predominantly emanates from family, friends, and other supportive connections, yet extant research chiefly centers on the psychological health impacts of family and friends on individuals in the post-pandemic epoch (57–59). Some studies suggest that the role of social groups and communities in alleviating the effects on individuals during pandemics remains contentious (60–62). Research regarding the assistance of communities and other similar entities is still notably lacking. Amid the advent of public health emergencies, other social supports can furnish individuals with critical resources like medical aid and materials, or facilitate resource interchange, factors that are quintessential for individuals' productivity and livelihood during home isolation. Therefore, during the post-pandemic phase, a better comprehension of perceived social support across different ecological dimensions for individuals undergoing home isolation is of pivotal importance. In the post-pandemic epoch, China has instituted a networked management strategy rooted in community engagement, wherein streets and communal spheres have become the bedrock of residents' daily endeavors (63). Amid abrupt epidemic onslaughts, students find themselves compelled into a state of dispersed isolation, rendering the community grid-based governance a pivotal adjunct of support during such junctures. Therefore, drawing from the aforementioned studies, we postulate that during the span of home isolation, the perceived social support among Chinese university students exhibits a negative correlation with their anxiety and depressive symptomatology.

When individuals harbor the conviction that they possess the capability to steer the outcomes of events, envisaging effective methodologies and indeed possessing such methodologies, they experience a sense of control (64). Conversely, sentiments such as hopelessness, helplessness, and diminished self-efficacy manifest a perceived loss of control, serving as potent conduits to depression (65, 66). Certain inquiries posit that unpredictable adversities could engender a perceived loss of control in individuals, subsequently precipitating a decline in the perceived meaningfulness of existence (67). Extant research delineates that perceived loss of control mediates the nexus between uncontrollable stressors and substance abuse (68). A prolonged engagement with a perceived loss of control could propel individuals into a chasm of hopelessness, ensnaring them in a tempest of negative emotions, and rendering them incapable of envisioning plans for their future existence (69, 70). Though some studies suggest that social support may ameliorate the anxiety, depression, and insomnia experienced by university students during the pandemic by bolstering individual self-control capacities (56, 71), unforeseen instances of home isolation, shortages in essential commodities and medical resources, coupled with a downturn in familial economic conditions, may plunge individuals into a profound sense of perceived loss of control (72, 73). Research has unveiled that amidst the COVID-19 era, university students are grappling with a salient psychological quandary of losing normalcy, with loss of control and avoidance emerging as primary determinants impacting mental well-being (74). Among them, medical students during the COVID-19 tenure, encounter difficulties in attaining relaxation and a sense of control, necessitating psychological interventions to ameliorate their mental tribulations (75). Further studies have discerned that those students with pre-existing health conditions may confront a dearth of medical resources during isolation, rendering their survival milieu increasingly stringent, which in turn may precipitate a further decline in their sense of control, potentially exacerbating their health statuses (76–78). Based on the aforementioned perspectives, we posit the first hypothesis in this study.

> *H1*: Social support can reduce anxiety and depression among college students in long-term home isolation.

Moreover, social support can empower individuals to enhance their sense of control over external circumstances, leveraging the aid of others to alleviate their own perceived loss of control. Therefore, we propose a second hypothesis.

> *H2*: Social support alleviates college students' anxiety and depression by reducing their perceived loss of control.

Family socioeconomic status (SES) comprehensively reflects the status of a family's core members in terms of economic resources, social hierarchy, and societal prestige (79). This status is not only a reflection of social stratification but also plays a crucial role throughout an individual's life, profoundly impacting their growth and development (80, 81). Social support theory suggests that the impact of social support on individual psychological health can lead to different outcomes in specific contexts (82). The accessibility of social support is not entirely influenced by the social environment. Some studies have highlighted that individual differences play a role in the extent of social support received, which can have varying effects in different situations (83). For instance, within the same context of social support, groups with a lower socioeconomic status have been observed to have higher incidences of certain diseases and disabilities compared to those with higher socioeconomic statuses (84).

Theoretical research on family socioeconomic status demonstrates a significant correlation between varying social statuses and psychological health issues (85). Of particular concern is the intimate link between low socioeconomic status and psychological health problems, notably marked by an increased risk of loss of psychological control (86). Studies indicate that in families with lower socioeconomic status, the probability of developing psychological disorders such as anxiety and depression is substantially heightened (87, 88); on the other hand, a higher socioeconomic status might play a role in alleviating or ameliorating these issues of mental health issues (89).

Research during periods of family isolation indicates uneven distribution of resources across communities, leading to heightened tension and anxiety among residents. For instance, upscale neighborhoods in city centers may have access to special supply menus, a privilege not extended to other regular communities (90). For college students, despite their independence, they still rely on their families' financial support (91). The economic condition of the family often determines the quantity and quality of social resources accessible to these students. Especially in the post-pandemic era of family isolation, family socioeconomic status emerges as a key influencing factor (92). Students from economically disadvantaged backgrounds might feel more isolated due to a lack of social resources, exacerbating feelings of anxiety and depression (93, 94). This highlights the importance of social resources during crises and the impact of family background on mental health. Based on these observations, we propose the following hypotheses.

> *H3*: Family socioeconomic status plays a moderating role in the effect of social support on college students' perceived loss of control, i.e., higher family socioeconomic status moderates college students' perceived loss of control more.

> *H4*: Family socioeconomic status plays a moderating role in the effect of social support on college students' anxiety and depression, i.e., higher family socioeconomic status has a greater moderating role in the effect of social support on college students' anxiety and depression.

The research hypothesis model diagram is shown in Figure 1.

2 Methods

2.1 Process and participants of the survey

2.1.1 Design and procedure

This study employed a cross-sectional design, utilizing the online survey platform "Wenjuanxing",[1] to analyze the current status and relationships among the variables. Our survey targets were university

1 http://www.sojump.com

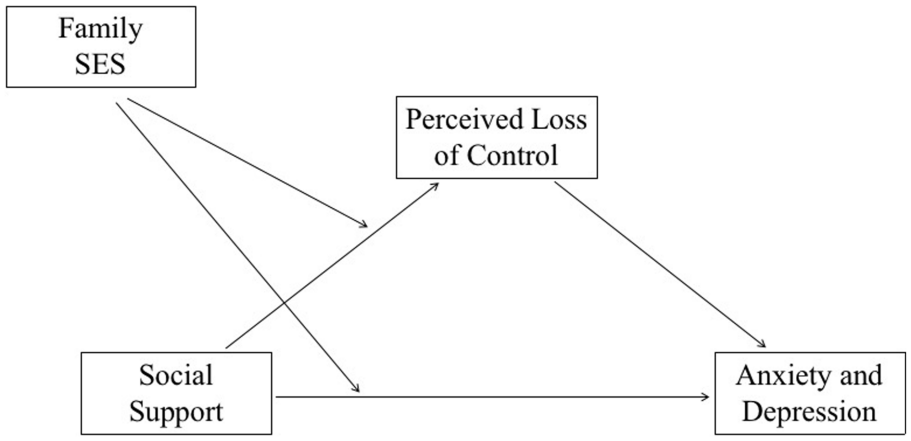

FIGURE 1
Research hypothesis model diagram.

students aged 18 and above residing in China. Inclusion criteria encompassed university students aged 18 and above, residing in China in areas under residential isolation due to the impact of COVID-19, and expressing willingness to participate in the online survey. Additionally, exclusion criteria were stipulated. The data collection spanned from April 1 to May 1, 2022, coinciding with the outbreak of the COVID-19 Omicron variant in China. During this period, the Chinese government implemented residential isolation measures in multiple areas to safeguard public health. Before participating in the survey, we provided the respondents with an informed consent form, requesting them to fill it out. Ultimately, we successfully collected 502 valid questionnaires. The survey tools included four scales, and we also collected basic demographic information from the participants.

2.1.2 Sample characteristics

Of the 502 respondents included in this study, 259 were male and 243 were female. The age range was 18–32 for 470 (94%), and 32 (6%) were over 32 years old. Of these, 205 were undergraduate students (including high school and middle school), 135 were master's students, and 62 were doctoral students. The isolation showed that isolation with family was 252, isolation with friends (including classmates, roommates, etc.) was 173, and isolation alone was 77. Isolation with family (50%) was the highest and isolation alone (15%) was the lowest.

2.2 Measurement

Dambi's revised Perceived Social Support Scale (PSSS) was used (95), which has a total of 12 entries and is scored on a 5-point Likert scale (1 = completely disagree, to 5 = completely agree). The dimensions are categorized into three dimensions: family support, friend support, and other support. The scale is a cumulative score, with higher scores indicating a higher level of social support for the subjects. Taking into account the specific characteristics of university students in home isolation during the epidemic, we added, for example, "The neighborhood committee/street/school gave me enough support during the isolation period" as a question item for other support. In this study, the Cronbach's α coefficient was 0.956.

The perceived loss of control was measured using a scale developed by Wen (96), the Chinese version of which has been shown to be reliable (97). The scale consists of 17 items, such as "I feel powerless to do anything." A 5-point Likert scale was used (1 = not at all to 5 = fully), and the Cronbach's coefficient in this study was 0.968.

Anxiety and depression were measured using a scale developed by Augustine (DASS-21) (98) with 14 items such as "I find it difficult to calm down." A 5-point Likert scale was used (1 = not at all to 5 = fully). The total scale score was the sum of the scores for each question. The higher the score, the more intense the subject's anxiety. In this study, the Cronbach's α coefficient was 0.970.

Family socioeconomic status (SES) was measured using a scale developed by Ren Chunrong (99), the Chinese version of which has been shown to be reliable (100). The scale includes parents' occupation, income, and education level, of which the income subscale is divided into 5 levels, with the higher the level, the higher the score (1 being the lowest and 5 being the highest); parents' education level is divided into 5 categories, with the value of 1–5 points assigned sequentially; and occupation is divided into 5 levels, with the value of 1–5 points assigned sequentially. In the comprehensive method, the factor analysis method is used to calculate the socioeconomic status index of the individual's family, and the formula is as follows:

$$FamilySES = \frac{\beta_1 \times Z_{education\ level} + \beta_2 \times Z_{occupation} + \beta_3 \times Z_{family\ income}}{First\ eigenvalue}$$

First, the scores of the three variables representing education level, occupation, and family income were converted into standard scores and subjected to principal component analysis to derive the value of the characteristic root of the first factor. Second, the component matrix was used to derive the coefficient of the educational level of the primary caregiver β_1, the coefficient of the occupation of the primary caregiver β_2, and the coefficient of the family income β_3, on the basis of which the data were entered into the formula for the overall calculation of the scores as the socioeconomic status of the university students' families, and the higher the score, the higher the

socioeconomic status of the family. In this study, Cronbach's α coefficient is 0.915.

The validity of the questionnaire used in this study was verified using KMO and Bartlett's test, the coefficient result of the KMO test was 0.977 and the Chi-square value of Bartlett's test was 21087.018 (Sig. = 0.000 < 0.01).

Table 1 presents the details of factor extraction and the information content of the extracted factors. As can be discerned from the table, the factor analysis extracted four factors, all with eigenvalues >1. After rotation, the variance explained by these four factors are 23.287, 20.018, 17.738, and 7.705%, respectively. The cumulative variance explained post-rotation is 68.749%.

This study employed the Varimax rotation method to rotate the data, determining the relationship between the factors and the research items. Table 2 showcases the information extraction for each factor related to the research items and the corresponding relationships between them. As can be observed from the table, the communalities for all research items exceed 0.4, indicating a robust association between the research items and the factors, suggesting that the factors effectively extract information. While ensuring that the factors capture a majority of the information from the research items, the emphasis of subsequent analyses lies in discerning the specific relationships between the factors and the research items (a factor loading with an absolute value >0.4 signifies a correspondence between the item and the factor).

2.3 Data analysis

In order to test the hypotheses of the proposed model, we performed statistical analysis using SPSS 26.0 and PROCESS software, structured as follows. Demographic descriptive analysis was performed on the sample of subjects. The correlations with the scales and data were first analyzed using Cronbach's coefficient for the reliability test and Harman but for the causal play for the common method bias analysis, and then constructing the correlation of the variables to analyze the correlation and the degree of correlation between the variables. The mediation analysis and moderated effects were conducted in conjunction with Hayes (101) PROCESS model4 and model8. A moderated mediation effect can be considered to be present if the bootstrap confidence interval does not include zero.

3 Results

Data variables for four variables, anxiety and depressed, social support, perceived loss of control, and family socioeconomic status, were tested for normality. The absolute values of kurtosis were all less than 3, and the current data distribution flat state approximates normal distribution. The skewness is all around 0, and the current data distribution is shifted to approximate a normal distribution. Correlation analysis of the four variables showed that social support was negatively correlated with anxiety and depression ($r = -0.488$, $p < 0.01$), and negatively correlated with perceived loss of control ($r = -0.345$, $p < 0.01$). Perceived loss of control was positively correlated with anxiety and depressed ($r = 0.499$, $p < 0.01$). As shown in the Table 3.

The mediation effect analysis was performed using the bootstrap method in the Process macro program, combined with the stepwise test using model4, and the regression analysis showed that social support had a significant negative effect on the perceived loss of control ($\beta = -0.37$, $t = -8.223$, $p = 0.000 < 0.01$). The perceived loss of control ($\beta = 0.404$, $t = 9.591$, $p = 0.000 < 0.01$) and social support ($\beta = -0.412$, $t = -9.130$, $p = 0.000 < 0.01$) significantly influenced anxiety and depression ($R^2 = 0.349$, $F = 133.8347$, $p < 0.01$). These results suggest that social support negatively affects anxiety and depressive mood and that this relationship is mediated by a sense of loss of control (see Table 4). In addition, mediated effects with moderation were analyzed using Model8 through the bootstrap method in the Process macro program (see Figure 2). Social support ($\beta = -0.448$, $t = -9.576$, $p = 0.000 < 0.05$) and family socioeconomic status ($\beta = -0.177$, $t = -4.159$, p = $0.000 < 0.05$). Social support*family socioeconomic status (interaction term) on the perceived loss of control ($\beta = -0.29$, $t = -7.435$, $p = 0.000 < 0.05$), so social support, family socioeconomic status, and the interaction term have a significant negative effect on the sense of loss of control. Social support ($\beta = -0.381$, $t = -7.677$, $p = 0.000 < 0.05$). Family socioeconomic status ($\beta = -0.187$, $t = -4.422$, $p = 0.000 < 0.05$). Social support * family socioeconomic status (interaction term) ($\beta = -0.043$, $t = -1.059$, $p = 0.290 > 0.05$). Perceived loss of control ($\beta = 0.374$, $t = 8.554$, $p = 0.000 < 0.05$). This shows that social support, family socioeconomic status, has a significant negative effect on anxiety and depression and perceived loss of control has a significant positive effect on anxiety and depression. While the interaction term social support*family socioeconomic status (interaction term) has no effect on anxiety and depression (see Table 4).

TABLE 1 Variance explained.

Factor ID	Eigenvalue			Variance explained before rotation			Variance explained after rotation		
	Total	Variance explained (%)	Cumulative (%)	Total	Variance explained (%)	Cumulative (%)	Total	Variance explained (%)	Cumulative (%)
1	19.464	39.721	39.721	19.464	39.721	39.721	11.411	23.287	23.287
2	6.628	13.527	53.249	6.628	13.527	53.249	9.809	20.018	43.305
3	4.477	9.137	62.386	4.477	9.137	62.386	8.692	17.738	61.044
4	3.118	6.364	68.749	3.118	6.364	68.749	3.776	7.705	68.749

Extraction method: principal component analysis.

TABLE 2 Rotated factor loadings.

Item code	Factor loading coefficient				Communality
	Factor 1	Factor 2	Factor 3	Factor 4	
Anxiety and depression (AAD)1	0.126	**0.820**	−0.168	−0.098	0.725
AAD2	0.237	**0.751**	−0.189	−0.144	0.676
AAD3	0.242	**0.776**	−0.208	−0.119	0.719
AAD4	0.240	**0.786**	−0.196	−0.080	0.720
AAD5	0.212	**0.807**	−0.217	−0.101	0.753
AAD6	0.224	**0.790**	−0.178	−0.126	0.722
AAD7	0.209	**0.782**	−0.181	−0.060	0.692
AAD8	0.234	**0.793**	−0.195	−0.078	0.728
AAD9	0.235	**0.809**	−0.180	−0.064	0.746
AAD10	0.259	**0.784**	−0.208	−0.051	0.728
AAD11	0.264	**0.767**	−0.204	−0.112	0.713
AAD12	0.203	**0.778**	−0.236	−0.063	0.706
AAD13	0.188	**0.796**	−0.220	−0.110	0.730
AAD14	0.222	**0.779**	−0.224	−0.099	0.716
Perceived social support (PSS)1	−0.108	−0.184	**0.791**	0.130	0.687
PSS2	−0.095	−0.199	**0.787**	0.066	0.671
PSS3	−0.136	−0.180	**0.779**	0.049	0.660
PSS4	−0.144	−0.187	**0.788**	0.061	0.681
PSS5	−0.160	−0.176	**0.747**	0.076	0.621
PSS6	−0.114	−0.169	**0.761**	0.049	0.623
PSS7	−0.126	−0.175	**0.782**	0.094	0.668
PSS8	−0.128	−0.128	**0.766**	0.090	0.628
PSS9	−0.121	−0.155	**0.789**	0.123	0.676
PSS10	−0.078	−0.221	**0.769**	0.085	0.654
PSS11	−0.104	−0.181	**0.770**	0.034	0.638
PSS12	−0.174	−0.194	**0.769**	0.059	0.663
PSS13	−0.165	−0.231	**0.757**	0.121	0.668
Perceived loss of control (PLOC)1	**0.795**	0.204	−0.108	−0.021	0.686
PLOC2	**0.789**	0.160	−0.132	−0.038	0.667
PLOC3	**0.807**	0.167	−0.157	−0.062	0.707
PLOC4	**0.780**	0.233	−0.134	−0.030	0.681
PLOC5	**0.783**	0.172	−0.136	−0.068	0.666
PLOC6	**0.770**	0.196	−0.181	0.024	0.664
PLOC7	**0.786**	0.200	−0.106	−0.033	0.670
PLOC8	**0.778**	0.192	−0.113	−0.122	0.670
PLOC9	**0.761**	0.156	−0.087	−0.049	0.614
PLOC10	**0.781**	0.164	−0.138	−0.025	0.656
PLOC11	**0.788**	0.169	−0.065	−0.049	0.657
PLOC12	**0.795**	0.208	−0.106	−0.036	0.688
PLOC13	**0.808**	0.161	−0.101	−0.035	0.691
PLOC14	**0.790**	0.168	−0.117	−0.008	0.665

(Continued)

TABLE 2 (Continued)

Item code	Factor loading coefficient				Communality
	Factor 1	Factor 2	Factor 3	Factor 4	
PLOC15	**0.770**	0.210	−0.094	−0.028	0.647
PLOC16	**0.788**	0.175	−0.134	−0.060	0.673
PLOC17	**0.772**	0.167	−0.100	−0.028	0.635
Family SES1	−0.048	−0.172	0.135	**0.849**	0.771
Family SES2	−0.074	−0.089	0.140	**0.824**	0.713
Family SES3	−0.048	−0.165	0.107	**0.861**	0.782
Family SES4	−0.078	−0.173	0.144	**0.832**	0.749
Family SES5	−0.061	−0.138	0.160	**0.821**	0.722

Extraction method: principal component analysis. Rotation method: Kaiser normalization with maximum variance. Numbers in the highlighted in bold indicate factor loadings with an absolute value >0.4.

TABLE 3 Correlation analysis of the four variables.

	Mean	Standard deviation	Anxiety and depression	Social support	Perceived loss of control	Family SES
Anxiety and depression	2.380	0.995	1			
Social support	3.915	0.854	−0.488**	1		
			0.000			
Perceived loss of control	2.299	0.916	0.499**	−0.345**	1	
			0.000	0.000		
Family SES	4.049	0.944	−0.322**	0.297**	−0.177**	1
			0.000	0.000	0.000	

**Significant correlation at 0.01 level (two-tailed).

TABLE 4 Summary of regression models.

Variables	Perceived loss of control				Anxiety and depression			
	β	t	LLCI	ULCI	β	t	LLCI	ULCI
Constant	2.369	63.071	2.295	2.442	1.537	13.992	1.321	1.753
Social support	−0.448	−9.576	−0.540	−0.356	−0.381	−7.677	−0.479	−0.284
Family SES	−0.177	−4.159	−0.260	−0.093	−0.187	−4.422	−0.270	−0.104
Social support*Family SES (interaction term)	−0.290	−7.435	−0.367	−0.213	−0.043	−1.059	−0.121	0.036
Perceived loss of control					0.374	8.554	0.288	0.460
R^2	0.213				0.374			
F	44.8107**				74.2595**			

*$p < 0.05$, **$p < 0.01$.

When analyzing the moderating effect of family socioeconomic status, moderation was found to be significant at (M − 1SD), M, and (M + 1SD), with effect values of −0.341, −0.381, and −0.422, respectively, with 95% CIs of [−0.439, −0.244], [−0.479, −0.284] and [−0.565, −0.278] (see Table 5). Thus, the mediating effect of family socioeconomic status on the effect of social support on the perceived loss of control was significant and varied across the different dimensions, suggesting that the mediation was moderated. A simple slope analysis (see Figure 3) showed that perceived loss of control was significantly reduced as the level of social support increased, and that the higher the family socioeconomic status, the greater the degree of moderation of perceived loss of control. This finding suggests that family socioeconomic status significantly enhances the mediating effect of social support on anxiety and depression.

Because the different dimensions of social support differed in terms of family socioeconomic status, to further explore the role of the

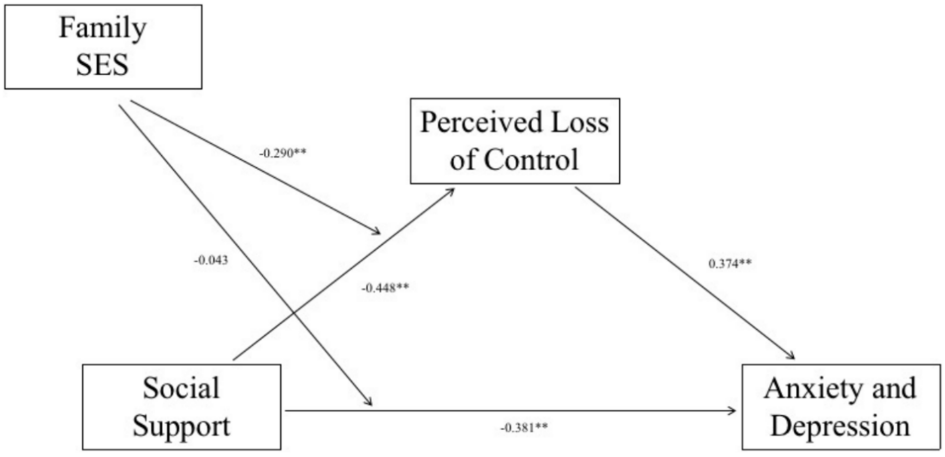

FIGURE 2
Test results of the mediator model with moderation. **$p < 0.01$.

TABLE 5 Results of the conditional indirect effect.

Level of moderating variable	Effect	*s.e.*	*t*	*p*	LLCI	ULCI
Low level (M − 1SD)	−0.341	0.050	−6.892	0.000	−0.439	−0.244
Mean value	−0.381	0.050	−7.677	0.000	−0.479	−0.284
High level (M + 1SD)	−0.422	0.073	−5.762	0.000	−0.565	−0.278

dimensions in social support, the mediating effect of perceived loss of control with moderation between the dimensions of social support and anxiety and depressive mood was analyzed using model8 in the Process macro program.

As illustrated in Tables 6–8, family support ($\beta = -0.384$, $t = -8.496$, $p = 0.000 < 0.05$), friend support ($\beta = -0.396$, $t = -8.911$, $p = 0.000 < 0.05$), other support ($\beta = -0.423$, $t = -9.346$, $p = 0.000 < 0.05$), family support*family socioeconomic status (interaction term) ($\beta = -0.252$, $t = -6.482$, $p = 0.000 < 0.05$), friend support*family socioeconomic status (interaction term) ($\beta = -0.264$, $t = -6.908$, $p = 0.000 < 0.05$), and other support*family socioeconomic status (interaction term) ($\beta = -0.274$, $t = -7.288$, $p = 0.000 < 0.05$) all had a significant negative effect on perceived loss of control, but no effect on either anxiety or depression.

As can be seen in Tables 9–11, under family, friends, and other support, both families with lower family socioeconomic status (M-1SD) and families with higher family socioeconomic status (M + 1SD) had significant negative effects on perceived loss of control. And under different dimensions of social support, family support in higher family socioeconomic status ($\beta = -0.338$, $t = -4.933$, $p < 0.05$) had an effect value of −0.338, with a 95% CI not containing 0. Friend support ($\beta = -0.349$, $t = -5.054$, $p < 0.05$) had an effect value of −0.349, with a 95% CI not including 0. Other support ($\beta = -0.408$, $t = -5.835$, $p < 0.05$) had an effect value of −0.408, with a 95% CI not including 0. All these findings indicate a stronger mitigating effect on college students' perceived loss of control during home isolation.

4 Discussion

Empirical studies suggest that, influenced by a family's socioeconomic status, the enhancement of various social support ecosystems (including family, friends, and other forms of support) more markedly reduces the perceived loss of control among families with a higher socioeconomic status compared to those with a lower one. This underscores the pivotal moderating role that family socioeconomic status plays in the relationship between social support and perceived loss of control. Compared to other studies that have found the impact of support from family and friends on an individual's emotions during pandemics, the assistance, particularly from the community, streets, and neighborhoods, plays an indispensable role in alleviating the perceived loss of control among quarantined college students.

Furthermore, in the post-pandemic era, social support has exerted a protective buffering effect on college students' emotions, primarily mediated by the perceived loss of control. Family socioeconomic status further modulates this mediating effect. The interaction between social support and anxiety and depression (with perceived loss of control as the mediator) indicates that social support can significantly alleviate both anxiety and depression, thereby confirming *Hypothesis 1*. Through its influence on perceived loss of control, social support indirectly mitigates anxiety and depression, validating *Hypothesis 2*. As the degree of social support increases, the perceived loss of control among college students noticeably diminishes, leading to a reduction in anxiety and depression. The effect of social support on the perceived loss of control depends on family socioeconomic status. The mediating role of perceived loss of control in the relationship between social support and anxiety and depression becomes more pronounced across different socioeconomic backgrounds, further endorsing *Hypothesis 3*.

Research indicates that while college students indeed experience anxiety and depression during periods of isolation from their families, these negative emotions are influenced by factors such as social support, a perceived loss of control, and family socioeconomic status. Social support is a multifaceted system, encompassing both emotional and material backing from family and friends, as well as information

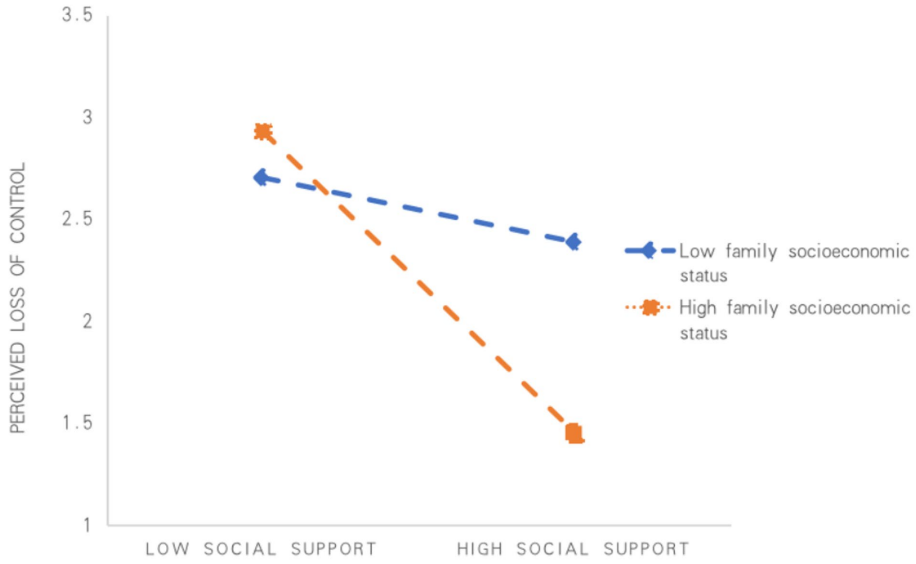

FIGURE 3
Mediating moderating effect between social support and anxiety and depression.

TABLE 6 Summary of regression models for dimensions of family support.

Variable	Perceived loss of control				Anxiety and depression			
	β	*t*		*β*	*t*		*β*	*t*
Constant	2.358	61.742	2.283	2.433	1.471	13.606	1.259	1.683
Family support	−0.384	−8.469	−0.473	−0.295	−0.333	−7.143	−0.425	−0.242
Family socioeconomic status	−0.173	−4.037	−0.258	−0.089	−0.181	−4.310	−0.263	−0.098
Family support*Family SES (interaction term)	−0.252	−6.482	−0.328	−0.176	−0.005	−0.114	−0.081	0.072
Perceived loss of control					0.399	9.252	0.314	0.484
R^2	0.181				0.367			
F	36.6858**				72.0518**			

*$p < 0.05$, **$p < 0.01$.

TABLE 7 Summary of regression models for dimensions of friend support.

Variable	Perceived loss of control				Anxiety and depression			
	β	t		β	t		β	t
Constant	2.362	62.382	2.287	2.436	1.493	13.557	1.276	1.709
Friend support	−0.396	−8.911	−0.484	−0.309	−0.315	−6.711	−0.407	−0.223
Family SES	−0.182	−4.254	−0.267	−0.098	−0.200	−4.679	−0.284	−0.116
Friend support*Family SES (interaction term)	−0.264	−6.908	−0.339	−0.189	−0.036	−0.919	−0.113	0.041
Perceived loss of control					0.393	8.949	0.307	0.479
R^2	0.196				0.356			
F	40.3588**				68.6067**			

*$p < 0.05$, **$p < 0.01$.

TABLE 8 Summary of regression models for dimensions of other support.

Variable	Perceived loss of control				Anxiety and depression			
	β	*t*		*β*	*t*		*β*	*t*
Constant	2.367	62.796	2.293	2.441	1.533	14.035	1.319	1.748
Other support	−0.423	−9.346	−0.512	−0.334	−0.370	−7.761	−0.463	−0.276
Family SES	−0.178	−4.168	−0.262	−0.094	−0.187	−4.429	−0.269	−0.104
Other support*Family SES (interaction term)	−0.274	−7.288	−0.348	−0.200	−0.041	−1.072	−0.117	0.034
Perceived loss of control					0.376	8.639	0.290	0.461
R^2	0.206				0.376			
F	43.0307**				74.7078**			

*$p < 0.05$, **$p < 0.01$.

TABLE 9 Results of conditional indirect effects on dimensions of family support.

Level of moderating variables	Effect	*s.e.*	*t*	*p*	LLCI	ULCI
Low level (M − 1SD)	−0.329	0.049	−6.757	0.000	−0.425	−0.233
Mean value	−0.333	0.047	−7.143	0.000	−0.425	−0.242
High level (M + 1SD)	−0.338	0.068	−4.933	0.000	−0.472	−0.203

TABLE 10 Results of conditional indirect effects on dimensions of friend support.

Level of moderating variables	Effect	*s.e.*	*t*	*p*	LLCI	ULCI
Low level (M − 1SD)	−0.281	0.049	−5.760	0.000	−0.377	−0.185
Mean value	−0.315	0.047	−6.711	0.000	−0.407	−0.223
High level (M + 1SD)	−0.349	0.069	−5.054	0.000	−0.484	−0.213

TABLE 11 Results of conditional indirect effects on dimensions of other support.

Level of moderating variables	Effect	*s.e.*	*t*	*p*	LLCI	ULCI
Low level (M − 1SD)	−0.331	0.048	−6.955	0.000	−0.424	−0.237
Mean value	−0.370	0.048	−7.761	0.000	−0.463	−0.276
High level (M + 1SD)	−0.408	0.070	−5.835	0.000	−0.546	−0.271

and tangible assistance from the broader community (102–104). In environments of seclusion, care from relatives, material aid from communities, and information exchanges among peers all contribute to cultivating a sense of belonging and compassion in college students, alleviating their feelings of anxiety and depression (105). Notably, support from friends holds particular significance. This is likely because the Chinese government's home isolation policy coincided with the academic term, amplifying the importance of this support due to the unique situation of college students.

In the post-pandemic period, especially during home quarantine, community support acts as the foundation for all supportive mechanisms, especially within the framework of the home isolation policy (106). Local communities and neighborhoods proactively care for each resident's welfare, distribute essential items, and provide indispensable social backing (107, 108). Alongside tangible support, there is a heightened focus on mental well-being. Studies have shown that reducing the perceived loss of control in college students can significantly lessen their anxiety and depression, subsequently influencing their outlook on future academic and personal pursuits. When individuals feel they are losing control in their personal and professional lives, it can lead to a pessimistic view of the future, potentially triggering panic. Such feelings can have lasting effects on their daily routines and long-term goals.

The relationship between social support and feelings of anxiety and depression is largely influenced by family socioeconomic status and the sense of losing control. Specifically, as family socioeconomic status rises, social support becomes more effective in alleviating negative emotions by suppressing the perceived loss of control. Family socioeconomic status not only reflects an individual's perceived resources and societal standing but also profoundly impacts a college student's quality of life, emotional perception, and coping mechanisms. Generally, individuals from higher socioeconomic backgrounds may exhibit stronger logical reasoning and decision-making capabilities (109, 110). Conversely, compared to students from affluent families, those from families with lower educational and income levels might face restrictions in accessing materials and resources (111, 112), potentially heightening their risk of anxiety and depression during pandemics.

Students from higher socioeconomic backgrounds display distinct advantages in information access, emotional regulation, and resource acquisition, which in turn reduces anxiety and depression during home isolation. In contrast, students from lower socioeconomic standings exhibit elevated levels of anxiety and depression, with concerns about their academic and personal futures possibly exacerbating these feelings. Given their typically limited family

reserves and the pandemic's impact on their education, these students might grapple with escalating anxiety and depression as isolation persists. Hence, prioritizing their mental well-being is essential. We advocate for educational institutions and community organizations to provide enhanced psychological support to these students, guiding them to view the pandemic from a balanced perspective and alleviate their distress.

In this study, we explored the impact of social support on the emotions of college students, particularly during home isolation in the post-pandemic era. Research indicates that support from friends, encompassing emotional comfort, encouragement, and practical information exchange, positively influenced college students. Furthermore, the wider community, serving as an extended social entity, made significant contributions by providing housing and medical assistance. This external support alleviated the students' perceived loss of control, an emotion that intensifies during isolation and major pandemics. From a psychological perspective, a perceived loss of control is inherently linked to anxiety and depression. When individuals feel they lack control over their lives and futures, it gives rise to feelings of anxiety, concern, and even panic. However, such emotions tend to diminish with external support and understanding. Hence, our research emphasizes the profound role of multifaceted social support in alleviating anxiety and depression among college students. This insight offers a novel perspective, highlighting the potential of bolstering social support to enhance individual mental health within specific socio-cultural contexts. Such understanding not only furnishes actionable insights for mental health professionals but also guides policymakers in formulating effective support mechanisms during public health crises.

4.1 Main contributions

This study elucidates several novel theoretical viewpoints. Firstly, it was discovered that college students' perceived loss of control serves as a partial mediator between social support and feelings of anxiety and depression. Additionally, family socioeconomic status moderates this mediating effect, highlighting the intricate dynamic relationship between social support and emotional distress in college students. Secondly, through an analysis of family socioeconomic status, the study offers fresh insights into research related to college students' anxiety and depression in the post-pandemic era. Lastly, this investigation deepens our understanding of the potential mechanisms influencing negative emotions, offering suggestions for more targeted intervention measures.

4.2 Practical implications

This article, based on empirical research, proposes the following recommendations to enhance social support and alleviate the emotional distress of college students isolated at home during the pandemic:

Disseminate accurate pandemic information: College students' anxiety and perceived loss of control largely stem from their limited understanding of the pandemic and concerns about the future. Providing them with accurate information promptly can foster a positive mindset, thereby reducing psychological stress.

Address specific psychological needs: During home isolation, some students may experience anxiety due to academic challenges, health concerns, or job-seeking pressures. Communities and educational institutions must recognize and cater to these students' needs, offering targeted psychological support and resource sharing.

Enhance the provision of online resources: Educational institutions should amplify the dissemination of online academic and employment-related resources. This can assist students in better planning for their future, consequently reducing feelings of anxiety and depression.

Adopt a holistic intervention strategy: Our research emphasizes the pivotal role of support from family, friends, and other social networks in mitigating college students' perceived loss of control and associated negative emotions. Notably, assistance from communities and neighborhoods during the post-pandemic period plays an indispensable role in regulating students' emotions. Moreover, a family's socioeconomic status significantly moderates the students' perceived loss of control. We advocate for an integrated intervention approach that consolidates various resources to bolster the mental health of college students during the pandemic.

By implementing these strategies, we can not only alleviate the negative emotions of college students during the pandemic but also foster a more conducive environment for their holistic development.

4.3 Limitations

During home isolation, college students face confinement, significantly limiting their interactions with the external environment and impeding their ability to access information promptly. Concurrently, concerns about potential infections and dwindling resources intensify negative emotions. Undeniably, this scenario heightens psychological stress among college students, potentially triggering a range of mental health issues. This study empirically examined the interplay between social support, perceived loss of control, family socioeconomic status, and the resultant feelings of anxiety and depression, aiming to identify strategies to alleviate psychological stress during isolation. However, this research primarily centers on a specific group of college students, excluding a broader population and lacking cross-regional comparisons or evaluations under varying pandemic intensities. Subsequent studies might delve deeper into these aspects, exploring other determinants and mechanisms influencing negative emotions during pandemics, beyond the impacts of perceived loss of control and family socioeconomic status. These considerations pave the way for future explorations. Lastly, while this study amassed extensive cross-sectional data, in discussing potential risks in the post-pandemic era, it provides only correlational rather than causal evidence. Hence, this study cannot fully elucidate the psychological shifts among college students. Future research might employ longitudinal studies to probe into mental health issues in the post-pandemic age.

5 Conclusion

This study indicates that during the post-pandemic period, there is a negative correlation between social support and anxiety and depression among college students in home isolation. In this

relationship, the perceived loss of control acts as a partial moderating factor, while family socioeconomic status is believed to influence this moderating effect. Notably, among college students with higher family socioeconomic status, the modulating effect of social support on anxiety and depression (with perceived loss of control as a mediator) is more pronounced, and the support from community neighborhoods and the like played a significant role during this pandemic. These findings offer a deeper understanding of the role of social support in alleviating negative emotions such as anxiety and depression in the post-pandemic era. They provide a foundation for formulating more effective intervention strategies during crises, thereby mitigating negative emotions and promoting mental well-being.

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

The studies involving humans were approved by the Institutional Review Board of Shanghai Jiao Tong University. The studies were conducted in accordance with the local legislation and institutional requirements. The 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

HS: Writing – original draft.

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Conflict of interest

The author declares 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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Exposure to urban green spaces and mental health during the COVID-19 pandemic: evidence from two low and lower-middle-income countries

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Introduction: The COVID-19 pandemic has had a significant impact on mental health globally, with limited access to mental health care affecting low- and middle-income countries (LMICs) the most. In response, alternative strategies to support mental health have been necessary, with access to green spaces being a potential solution. While studies have highlighted the role of green spaces in promoting mental health during pandemic lockdowns, few studies have focused on the role of green spaces in mental health recovery after lockdowns. This study investigated changes in green space access and associations with mental health recovery in Bangladesh and Egypt across the pandemic.

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Methods: An online survey was conducted between January and April 2021 after the first lockdown was lifted in Bangladesh (n = 556) and Egypt (n = 660). We evaluated indoor and outdoor greenery, including the number of household plants, window views, and duration of outdoor visits. The quantity of greenness was estimated using the normalized difference vegetation index (NDVI). This index was estimated using satellite images with a resolution of 10x10m during the survey period (January-April 2021) with Sentinel-2 satellite in the Google Earth Engine platform. We calculated averages within 250m, 300m, 500m and 1000m buffers of the survey check-in locations using ArcGIS 10.3. Multiple linear regression models were used to evaluate relationships between changes in natural exposure and changes in mental health.

Results: The results showed that mental health improved in both countries after the lockdown period. People in both countries increased their time spent outdoors in green spaces after the lockdown period, and these increases in time outdoors were associated with improved mental health. Unexpectedly, changes in the number of indoor plants after the lockdown period were associated with contrasting mental health outcomes; more plants translated to increased anxiety and decreased depression. Refocusing lives after the pandemic on areas other than maintaining indoor plants may assist with worrying and feeling panicked. Still, indoor plants may assist with depressive symptoms for people remaining isolated.

Conclusion: These findings have important implications for policymakers and urban planners in LMICs, highlighting the need to increase access to natural environments in urban areas to improve mental health and well-being in public health emergencies.

KEYWORDS

green space exposure, NDVI, mental health, LMIC, COVID-19

1 Introduction

The COVID-19 pandemic originated in Wuhan, China, in December 2019 and rapidly became a global crisis. On March 11, 2020, the World Health Organization declared it a pandemic due to its rapid transmission (1). By March 15, 2023, it had infected over 681 million people and resulted in 6.8 million deaths worldwide (2). To contain the viral spread, governments implemented various measures such as lockdowns, curfews, quarantines, and other non-pharmaceutical interventions (3). The Bangladesh government imposed a complete lockdown on March 26, 2020 and continued till May 31, 2020 (4), followed by zonal lockdowns from June 20, 2020 to July 9, 2020 (5). Similarly, Egypt implemented a nationwide lockdown from March 25 to June 27, 2020 (6). With no vaccine and limited understanding of the virus, these forms of social distancing were considered the most effective method of prevention and regulation during some periods of the pandemic (3, 7). However, such restrictions had profound consequences, affecting daily life, economies, and health, leaving many uncertain about the pandemic's duration and the prospect of gaining control over it (8).

Correspondingly, the pandemic had substantial negative impacts on mental health worldwide, with numerous studies highlighting the harmful effects of social isolation and lockdowns on mental health (9–14). The pandemic led to increased symptoms of depression, anxiety, post-traumatic stress disorder (PTSD), distress, and insomnia (15). One review concluded that over 95% of people reported PTSD symptoms, 72% reported distress, 45% reported anxiety symptoms, and 34% reported insomnia during the pandemic (16). Such impacts were particularly acute in low- and middle-income countries (LMICs) due to their limited access to mental health care (17). A meta-analysis of 40 developing countries reported that distress (29%) and depression (27%) were the most prevalent mental health symptoms during COVID-19 (18).

Research on exposure to green spaces and benefits to mental health has gained attention from researchers and healthcare professionals in recent years. *The stress reduction theory* suggests that green spaces can induce a sense of emotional well-being and a calming effect on individuals (19). Thus, exposure to green spaces can promote relaxation and stress reduction. Further, *attention restoration* could be another established theory that suggests attention restoration in green space is associated with improved psychological well-being, including reduced symptoms of depression and anxiety (19). Earlier studies have shown that exposure to green spaces can have positive impacts on mental health, reducing symptoms of anxiety and depression, as well as promoting overall well-being (20–22). Green spaces have also played an essential role in alleviating the negative mental health burden during the COVID-19 lockdown (23, 24). A study in Spain reported individuals turned to green spaces as a source of comfort, both directly and indirectly, to alleviate the negative effects of the pandemic (25). A study in Bulgaria showed that visible access

to the greenery around the home and neighborhood was associated with decreased symptoms of depression and anxiety during the pandemic (26). Window views of greenery have been found to provide micro-restorative episodes that aid in healing, psychological regeneration, and rehabilitation from traumatic events (27), including during lockdowns (26). A study from Italy reported greener views and access to private green spaces were associated with better mental health outcomes (28).

While the mental health benefits of urban green spaces are well understood in high-income countries (HICs) (29–31), the evidence does not represent the diversity of urban living conditions in rapidly urbanizing LMICs. The existing evidence largely excludes the types of urban environments where most of the world's population lives (32). Consequently, researchers and policymakers should avoid assuming that findings from HICs can be automatically applied to LMICs, given the diverse urban conditions and environmental and cultural differences between these countries (33). Informal settlements and slums often characterize cities in LMICs, and people living in these areas may not have the same level of access to green space as those in more affluent areas (32). This lack of access to green space in low-income cities may have different impacts on mental health than in HIC cities, where the availability and quality of green space may differ. To date, few studies have focused on the association between green space exposure and mental health in LMICs (34). A spatial epidemiological study conducted in Bangladesh (a tropical climate) found a negative correlation between vegetation and psychological well-being (35). A study in India (a sub-tropical climate) found a positive association between lack of park access and depression (36).

Furthermore, a study in Egypt (a hot and dry climate) focused on the impact of the green space on people's happiness (37). This existing literature shows contrasting findings before the pandemic and does not inform the role of green spaces in mental health during the pandemic. We know only one study that answers this literature gap: spending time in a home garden was associated with less anxiety and stress during the COVID-19 lockdown in India (38).

Further limiting our understanding of green space exposure and mental health during the pandemic is the limited research comparing associations during and after lockdowns. The importance of green spaces during lockdowns has been widely recognized (26–28). The green space's role in mental health recovery after lockdowns may be equally important. As the world continues to navigate through the pandemic's aftermath, policymakers and mental health professionals must focus on developing effective interventions and policies to support mental health recovery. The focus of the current study is to examine exposure to green spaces and mental health recovery following lockdowns in two LMICs. The two countries represent radically different climates, with Bangladesh being tropical and Egypt being deserts (39). This distinction allows for exploring how access to nature and its impact on mental health may differ in different climate zones, which is essential in developing targeted interventions for LMICs. Our primary research question (RQ) included: How were changes in nature access associated with recovery from poor mental health after lockdowns? By emphasizing the recovery phase of the pandemic, we sought to complement existing research, which primarily focused on the immediate effects of the pandemic (23, 40).

2 Materials and methods

2.1 Study design

A retrospective study design was adopted to conduct the study. Online surveys were administered between January and April 2021, when lockdowns were lifted and people were getting used to the 'new normal' of the pandemic in Bangladesh and Egypt. The survey used a free version of an online survey platform, KoBoToolbox,[1] allowing the survey to be distributed and completed without face-to-face interaction. The target population was the general people aged 18 and above. We used a snowball sampling approach and distributed the invitations through email and various social media platforms (e.g., Facebook, WhatsApp, LinkedIn). Participants were informed about the study and allowed to withdraw at any time. A total of 1,216 respondents (556 from Bangladesh and 660 from Egypt) were included in the analysis.

The survey consisted of six sections. These included socio-demographic information, potential risk factors, potential mediators, perceived exposure to indoor and outdoor nature, and self-reported mental health. Respondents were asked to provide data for two time points: the period of lockdown during the pandemic and the post-lockdown period (the current time of the survey administration). The survey also collected the geolocation of the participants, which was used to calculate objective greenness levels at both periods. The survey form was written in English and translated into local languages. The research was approved by the ethics committee of the Institute of Disaster Management, Khulna University of Engineering and Technology, Khulna, Bangladesh and the Psychology Department, Faculty of Arts, Menoufia University, Egypt.

2.2 Nature exposure measures

2.2.1 Perceptions

We adopted two measures for perceived indoor nature exposure: the number of household plants and window views (41). The first was measured by asking, "How many indoor plants are in this home?" Respondents answered it numerically (i.e., 0, 1, or 2 plants). The second was measured by asking about the visibility of 13 built or natural spaces/elements through any of the windows of their residence. Respondents scored these as present or absent, providing binary measures for each type. The spaces/elements included industrial building(s), courtyard/housing block patio, urban area (houses and streets), road, park(s), river(s), lake(s), agricultural area(s), countryside, woodland(s)/forest, hill(s)/mountain(s), and little access to outdoor visual elements because of neighbor's walls or no window views. Responses were categorized as natural (park, river, lake, agriculture, countryside, woodland/forest, hill/mountain), built (industrial buildings, houses and street, road, neighbors wall), or mixed (at least one item in the natural category and at least one in the built category). Respondents indicated their perceived indoor nature exposure during the lockdown and at the current time.

1 https://www.kobotoolbox.org/

We measured perceived outdoor nature exposure with two items: spaces accessed outdoors and hours spent outdoors. Spaces accessed outdoors were asked first and included responses for during the lockdown ("Which outdoor spaces did you have physical access to during the COVID-19 lockdown?") and current time ("Which outdoor green spaces have you visited in the last four weeks?"). Time spent outdoors was also asked for these two-time points and was measured by asking, 'How many hours did you spend each day at the places you visited, on average?' If participants spent time at two or more outdoor spaces, they were requested to provide the total average number of hours per day for all those spaces. Duration was scored on a 4-point scale: <1 h, 1–2 h, 3–5 h, and > 5 h, following a previous study (42). Because of slight differences in how the survey was administered between countries, we could not use the data from the spaces accessed outdoors in analyses. Our perceived outdoor nature exposure was limited to total time outdoors during the lockdown and current time.

2.2.2 Objective greenness

To measure the quantity of greenness, we initially considered three metrics: the normalized difference vegetation index (NDVI), enhanced vegetation index (EVI), and soil-adjusted vegetation index (SAVI). NDVI is a remote sensing index used to estimate vegetation cover and productivity. It is based on the difference in reflectance between the near-infrared (NIR) and red (RED) bands of electromagnetic radiation. The result of the NDVI calculation ranges from −1 to 1, with higher values indicating more excellent vegetation cover and productivity (43). EVI is similar to NDVI but was designed to reduce the influences of atmospheric and soil noise on the vegetation signal. We considered EVI since it can be an appropriate measure in regions with high atmospheric aerosol content, such as deserts, which may influence NDVI. SAVI corrects for the influence of soil brightness on the vegetation signal and is also particularly useful in regions with high soil brightness, such as deserts and semi-arid regions (44). These indices were estimated using satellite images with a resolution of 10 × 10m during the survey period (January–April 2021) with Sentinel-2 satellite in the Google Earth Engine platform. We calculated averages within 250 m, 300 m, 500 m and 1,000 m buffers of the survey check-in locations using ArcGIS 10.3 (Esri, Redlands, CA, United States). NDVI and EVI values were highly correlated, $r = 0.68$ to 1.0 (Supplementary Figure S1), and there were no changes between the lockdown and the current time in SAVI. For these reasons, NDVI was chosen for analysis. NDVI values across buffer sizes were also highly correlated $r = 0.88$ to 0.96 (Supplementary Figure S1), and 500 m was selected to correspond to the previous nature and health research (45).

2.3 Mental health measures

Several scales are generally accepted to measure mental health, including the 7-item Generalized Anxiety Disorder (GAD-7) scale, 9-item Patient Health Questionnaire (PHQ-9), and 4-item Patient Health Questionnaire (PHQ-4) to evaluate mental health (46–48). To keep the questionnaire brief, we used the 2-item Patient Health Questionnaire (PHQ-2) and 2-item General Anxiety Disorder (GAD-2) to measure depression and anxiety disorder, respectively. GAD-2 evaluated the frequency of participants feeling nervous, anxious, or on edge and unable to stop or control worrying over the last two weeks in lockdown and the current period (49). PHQ-2 rated the frequency of feeling down, depressed, or hopeless and having little interest or pleasure in doing things over the past two weeks for the same period (50). The response options were on 4-point Likert scales: 0 (not at all), 1 (several days), 2 (more than half of the day), and 3 (almost every day). The total score ranges from 0 to 6, with a cut-off value of ≥3 indicating a higher risk of anxiety and depression.

2.4 Covariates

We assessed socio-demographic variables, potential risk factors, and household characteristics that might affect mental health outcomes. Based on previous research (51, 52), we asked about gender, age, marital status, and family income in local currency (BDT and Egyptian pound) converted to USD (0–100, 101–200, 201–400, and > 400 USD). We also evaluated past COVID-19 diagnoses of respondents and their family members, providing four options: tested positive at least once, tested negative and never tested further positive, never tested, or at least one of the family members tested positive for COVID-19. We asked whether respondents had a chronic physical illness since these can influence mental health (53) and green space use (54). Two potential risk factors were also measured, including habit of smoking and body mass index (BMI). Smoking can have negative impacts on mental health (27), and BMI can influence quality of life (55).

2.5 Analysis

In this study, both the exposure and outcome variables were assessed at two-time points, allowing us to capture changes and developments over time in response to the intervention or exposure. In contrast, covariates, including socio-demographic and health-related variables, were collected at a single point in time. This design was chosen to examine how changes in exposure levels corresponded to changes in the outcome variables and whether socio-demographic characteristics influenced these changes. We compared the lockdown and current time values for all variables. These were tested with chi-square values of independence for count variables and paired sample *t*-tests for continuous variables. Next, we compared change scores for all variables between the countries using chi-squared tests and independent sample *t*-tests. Change scores were calculated as the current time value minus the lockdown period value.

Multiple linear regression models were used to assess associations between changes in mental health and changes in natural exposure. Separate models were run for anxiety and depression in each country. Bangladesh models included socio-demographic variables, potential risk factors, household characteristics, COVID-19 diagnosis, changes in the number of indoor plants, changes in window views of nature, changes in time spent outdoors, and greenness (NDVI-500). Models showed no evidence of multicollinearity, as demonstrated by variance inflation factor (VIF) values ≤2.5 and pairwise correlation values ≤0.7 (Supplementary Table S2). Normality tests on outcome variables were performed using Skewness and Kurtosis with a critical value of 3.0 and a visual inspection of histograms (Supplementary Table S3). The outcome values of depression and anxiety were distributed normally. All analyses were conducted with SPSS v21 (IBM, Armonk, New York) with an alpha set for significance at $p < 0.05$.

3 Results

3.1 Descriptive statistics

The characteristics of respondents are provided in Table 1. Most were female, aged >25 years, single, lived in an urban area, and reported a monthly family income between 201 and 400 USD. Most also reported they never tested for COVID-19 and did not have a long-standing illness or habit of smoking. Egypt respondents were more likely to be female, over 25, single, urban residents, and earning monthly incomes of 201–400 USD. The proportion of respondents who had never been tested for COVID-19 was higher in Bangladesh than in Egypt. In comparison, the proportion of respondents without a long-term illness or habit of smoking was higher in Egypt than in Bangladesh.

3.2 Changes in mental health and nature exposure

Anxiety and depression levels decreased in Bangladesh and Egypt from the lockdown to the current time (Figure 1, Supplementary Table S1). Bangladesh witnessed more substantial decreases in depression than Egypt. No between-country differences were seen for decreases in anxiety.

Nature access changed from the lockdown to the current time with varying patterns. In both countries, hours spent outdoors increased while indoor plants decreased. Window views of nature increased in Bangladesh but decreased in Egypt. Greenness also increased in Bangladesh but decreased in Egypt.

TABLE 1 Descriptive statistics of respondents in Bangladesh and Egypt ($N = 1,216$).

	Total	Bangladesh ($N = 556$)		Egypt ($N = 660$)		Country differences
	N (%) or Mean(SD)	N	%	N	%	p
	1,216 (100)	556	100	660	100	
Gender						0.000
Male	472 (38.8)	280	50.4	192	29.1	
Female	744 (61.2)	276	49.6	468	70.9	
Age						0.000
≤25	257(21.1)	252	45.3	5	0.8	
>25	959(78.7)	304	54.7	655	99.2	
Marital status						0.000
Single	1,108 (91.1)	451	81.1	657	99.5	
Married	108 (8.9)	105	18.9	3	0.5	
Current place of residence						0.000
Urban	1,026 (84.4)	434	78.1	592	89.7	
Rural	190 (15.6)	122	21.9	68	10.3	
Monthly family income (USD)						0.000
0–100	167 (13.7)	142	25.5	25	3.8	
101–200	189 (15.5)	118	21.2	71	10.8	
201–400	732 (60.2)	168	30.2	564	85.5	
>400	128 (10.5)	128	23	0	0	
COVID-19 diagnosis						0.004
Tested positive at least once	62 (5.1)	23	4.1	39	5.9	
Never tested positive	137 (11.3)	68	12.2	69	10.5	
Never tested	323 (75.9)	437	78.6	486	73.6	
At least one family member has tested positive	94 (7.7)	28	5	66	10	
Presence of long-standing illness						0.030
Yes	88 (7.2)	50	9	38	5.8	
No	1,128 (92.8)	506	91	622	94.2	
Habit of smoking						0.000
Yes	97 (8)	82	14.7	15	2.3	
No	1,119 (92)	474	85.3	645	97.7	
BMI	23.66 (4.1)	23.53	4.14	23.77	4.07	0.307

Comparisons between countries calculated with independent sample t-tests or chi-squared tests depending on measure (count vs. continuous).

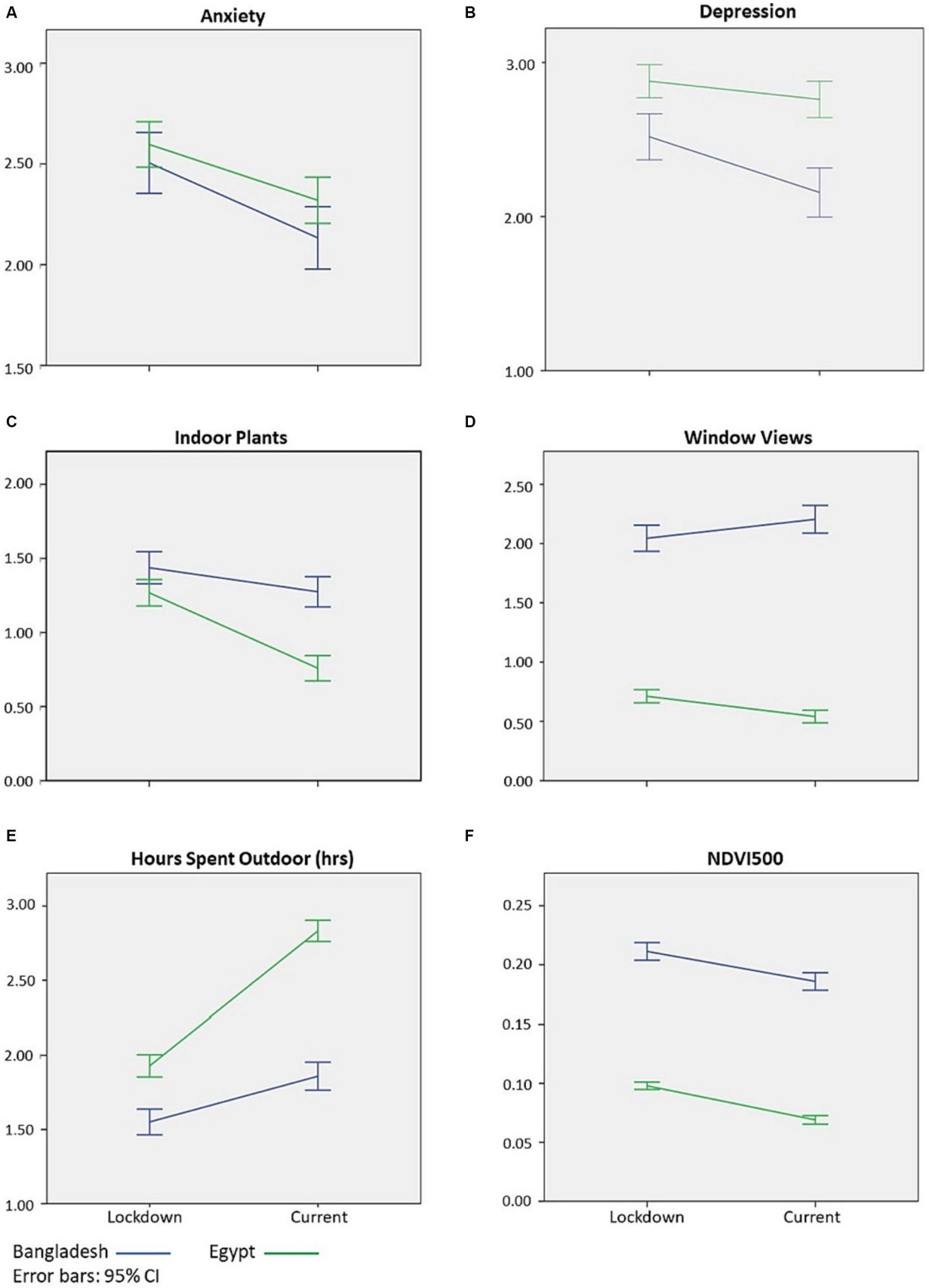

FIGURE 1
Changes in mental health **(A,B)**, perceived nature exposure **(C–E)**, and greenness **(F)** from the COVID-19 lockdown period to the current time in Bangladesh and Egypt (*N* = 1,216). CI, confidence intervals; NDVI500, normalized difference vegetation index within a 500 m buffer of survey respondent, hrs = hours.

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TABLE 2 Associations between changes in anxiety and nature exposure from the COVID-19 lockdown to the current time in Bangladesh and Egypt ($N = 1,216$).

	Bangladesh ($N = 556$)					Egypt ($N = 660$)				
	B	Std. B	95% CI		*p*	*B*	Std. B	95% CI		*p*
Gender	0.344	0.095	0.03	0.658	0.032	0.025	0.009	−0.195	0.246	0.822
Age	−0.251	−0.069	−0.562	0.06	0.114	0.022	0.001	−1.343	1.388	0.974
Marital status	−0.342	−0.074	−0.732	0.048	0.085	−0.618	−0.032	−2.419	1.182	0.5
Current place of residence (urban)	0.055	0.013	−0.305	0.416	0.764	0.021	0.005	−0.31	0.352	0.899
Monthly family income	−0.221	−0.135	−0.36	−0.082	0.002	−0.072	−0.026	−0.284	0.14	0.507
COVID-19 diagnosis	−0.135	−0.042	−0.399	0.128	0.313	−0.004	−0.002	−0.16	0.152	0.955
Presence of long-standing illness	−0.47	−0.075	−0.987	0.047	0.075	0.398	0.071	−0.075	0.871	0.099
Habit of smoking	0.506	0.099	0.058	0.953	0.027	0.631	0.072	−0.075	1.338	0.08
BMI	0.024	0.056	−0.012	0.061	0.19	0.022	0.068	−0.003	0.046	0.078
Nature exposure										
Δ indoor plants	0.094	0.052	−0.06	0.247	0.232	0.169	0.16	0.088	0.25	0.000
Δ Window views of nature	−0.023	−0.014	−0.157	0.112	0.742	0.072	0.043	−0.056	0.2	0.269
Δ Time spent outdoors	−0.264	−0.156	−0.403	−0.124	0.000	−0.04	−0.037	−0.122	0.042	0.34
Δ $NDVI_{500}$	1.135	0.031	−1.872	4.142	0.459	−1.277	−0.014	−8.271	5.717	0.72
R^2/Adjusted R^2	0.086/0.064					0.046/0.027				

Δ = value at the current time minus value in the lockdown period.

TABLE 3 Associations between changes in depression and nature exposure from the COVID-19 lockdown to the current time in Bangladesh and Egypt ($N = 1,216$).

	Bangladesh ($N = 556$)					Egypt ($N = 660$)				
	B	Std. B	95% CI		*p*	*B*	Std. B	95% CI		*p*
Gender	0.308	0.083	−0.018	0.633	0.064	0.1	0.031	−0.153	0.352	0.438
Age	−0.285	−0.077	−0.607	0.038	0.084	−0.384	−0.023	−1.945	1.176	0.629
Marital status	−0.203	−0.043	−0.607	0.202	0.326	−0.281	−0.013	−2.34	1.778	0.789
Current place of residence (urban)	0.028	0.006	−0.345	0.402	0.882	0.056	0.011	−0.323	0.434	0.772
Monthly family income	−0.146	−0.087	−0.29	−0.002	0.047	−0.035	−0.011	−0.278	0.207	0.776
COVID-19 diagnosis	−0.045	−0.014	−0.318	0.228	0.747	−0.059	−0.026	−0.237	0.12	0.519
Presence of long-standing illness	0.029	0.004	−0.507	0.565	0.916	0.15	0.024	−0.391	0.692	0.586
Habit of smoking	0.809	0.155	0.345	1.273	0.001	0.474	0.048	−0.334	1.283	0.25
BMI	0.022	0.05	−0.015	0.06	0.242	0.014	0.038	−0.014	0.042	0.336
Nature exposure										
Δ indoor plants	0.094	0.051	−0.065	0.253	0.246	−0.119	−0.099	−0.211	−0.026	0.012
Δ Window views of nature	−0.037	−0.023	−0.177	0.102	0.598	−0.138	−0.073	−0.285	0.008	0.063
Δ Time spent outdoors	−0.256	−0.147	−0.4	−0.111	0.001	0.012	0.01	−0.082	0.106	0.801
Δ $NDVI_{500}$	−0.658	−0.017	−3.776	2.459	0.679	−1.223	−0.012	−9.22	6.774	0.764
R^2/Adjusted R^2	0.066/0.044					0.025/0.005				

Δ = value at the current time minus value in the lockdown period.

3.3 Associations between changes in mental health and natural exposure

Changes in natural exposure partially corresponded with changes in mental health (Table 2, 3). In Bangladesh, increased outdoor time was associated with decreased anxiety and depression. In Egypt, a increase in the number of indoor plants was associated with increased anxiety but decreased depression. No other changes in natural exposure predicted changes in mental health. Overall, models of nature exposure, socio-demographic variables, potential risk factors,

household characteristics, and COVID-19 diagnosis poorly explained changes in anxiety and depression. Variance explained ranged from 3% for depression to 5% for anxiety in Egypt models. The variance explained was greater in Bangladesh models, ranging from 7% for depression to 9% for anxiety.

4 Discussion

4.1 Summary of main findings

The COVID-19 pandemic had a significant impact on people's mental health. In LMICs, where access to mental health care is often limited, it is essential to identify alternative strategies to support mental health during these challenging times (17). One such strategy is access to nature, which has numerous mental health benefits (56, 57). However, the extent to which people in LMICs had access to nature and how such exposure influenced mental health recovery across the pandemic remains unclear.

This study investigated changes in nature exposure and associations with changes in mental health in two LMICs. Results showed that mental health improved in Egypt and Bangladesh after lockdowns. In addition, residents of both countries increased their time spent outdoors after lockdowns, and these changes were associated with reductions in anxiety and depression in Bangladesh. Changes in nature exposure were not associated with mental health recovery in Egypt, except that increase in the number of indoor plants were unexpectedly associated with increased anxiety but decreased depression. The study's focus on mental health recovery aligns with the current global situation of most countries transitioning out of response to recovery. Therefore, the current study's findings provide insights into how nature exposure might continue to support recovery from poor mental health during the pandemic in LMICs.

The observed decreases in anxiety and depression after lockdowns have been documented in other contexts. For instance, an Italian study showed relief from psychological distress and symptoms after the pandemic (58). The relaxation of lockdown measures may have reduced social isolation, increased social support, and more significant opportunities for engagement in recreational activities (59). Additionally, reducing COVID-19 cases and deaths may have reduced anxiety about the virus and its impact on health (60). While there is a lack of previous studies comparing green space use or access and associations with mental health in LMICs, findings from cross-country studies shed light on the observed differences between Egypt and Bangladesh. Ribeiro et al. (61) examined the relationship between nature exposure and mental health outcomes during the pandemic in Spain and Portugal. They are engaging with natural environments, whether in public or private green spaces, during lockdown periods positively reduced stress and improved mental well-being. Research before the pandemic identified differences between LMICs concerning perceived safety, preferred amenities, and the impact of climate on green space use (62). Considering this body of evidence, it is reasonable to attribute the differences in mental health recovery between Egypt and Bangladesh to various factors, such as variations in the study samples, severity of lockdown measures, cultural approaches to coping mechanisms, and mental health services.

We found that residents in both countries increased their time outdoors after lockdowns, likely due to lockdowns restricting people's outdoor access. These changes may have led to a greater appreciation of the benefits of spending time in nature and motivated spending time outdoors (63). Similar findings have been seen in Scotland, where 80% of adults visited nature outdoors at least once a week after lockdowns, whereas 71% visited nature outdoors during the initial lockdown period (64). A study in Norway reported that there was a shift from residential and commercial zones toward city green spaces, including forests and protected areas after the lockdown was lifted, indicating a growing interest in nature access among the public during the post-lockdown time (65).

We also found that residents decreased the number of indoor plants after lockdowns, possibly due to shifts in focus from indoor to outdoor spaces. As lockdowns lifted, people may have experienced a greater appreciation for spending time outdoors in natural environments. The restricted mobility and confinement indoors during the lockdown period could have intensified people's longing for open spaces and green surroundings. This newfound or reinvigorated appreciation for outdoor spaces might have led individuals to prioritize spending time outside rather than investing effort in maintaining indoor plants (66), which may have led to a decrease in their interest in keeping and maintaining indoor plants.

Increased time outdoors after lockdowns being associated with reduced anxiety and depression in Bangladesh aligns with earlier research. Spending time in green space can lead to numerous mental health benefits for mental health, including reduced symptoms of anxiety and depression before the pandemic (56, 57) and during it (38, 67). For instance, Beyer et al. (68) reported that time spent outdoors was negatively associated with depression (68), and Lesser and Nienhuis (69) found that inactive adults who spent more time outdoors during the pandemic experienced greater well-being (69). A study in Austria during the pandemic reported that spending time outdoors was associated with better mental health (70). Collectively, these findings can be explained by the biophilia hypothesis, which posits that humans have an innate connection to nature and that exposure to natural environments can positively impact mental health (71, 72). During lockdowns, people were restricted from going outdoors and connecting with nature. As restrictions lifted, people could spend more time outside and engage in outdoor activities (65). This increased exposure to nature may have contributed to the decrease in anxiety and depression.

Unexpectedly, our study found that increases in indoor plants were associated with increased anxiety and decreased depression in Egypt. Previous research suggests indoor plants positively affect mental health and well-being (28, 73). Residents who spent more time outdoors, engaging in recreational activities, and less time indoors after lockdowns may have felt less worried or panicked (66). In contrast, residents with more indoor plants could have continued indoor pursuits without these specific benefits derived from being outdoors but still felt less depressed while being isolated.

4.2 Study limitations

Several limitations to this study should be considered when interpreting the results. First, we used a retrospective study design with a single time point but repeated measures. Retrospective self-reported information on nature exposure and mental health during lockdowns may have been inaccurate. Participants may have underreported access and symptoms due to social desirability bias or other factors. This dataset also precluded us from establishing causal relationships between the variables. Second, we did not measure other potential factors that may have influenced the relationships between nature exposure and mental health. These factors include, but are not limited to, nature connection, types of recreational activities, quality of indoor living spaces, the

therapeutic aspects of plant care, and the psychological impacts of isolation. Future studies should consider these elements for a more comprehensive understanding of the multifaceted relationship between nature exposure and mental well-being. Third, we did not explore the mechanisms underlying the relationships between nature access and mental health. Future research could examine the biological, psychological, and social pathways through which natural exposure may influence mental health recovery.

5 Conclusion

Residents in two LMICs increased their time outdoors in nature and saw improvements in their mental health after COVID-19 lockdowns. Increases in time outdoors were associated with mental health recovery in one country (Bangladesh). Decreases in the number of indoor plants were associated with contrasting mental health outcomes in the other country (Egypt). Access to outdoor nature exposure, but not necessarily having indoor plants and green window views, may assist with mental health recovery following public health crises. These findings can inform mental health interventions, especially in LMICs and during times of crisis like the COVID-19 pandemic. Encouraging individuals to spend more time outdoors in natural settings could be an effective and accessible strategy for promoting mental well-being. Further, this study underscores the need for further research into the relationship between nature exposure and mental health in LMICs, as well as the importance of incorporating these findings into educational programs for healthcare professionals, urban planners, and the general public.

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 humans were approved by ethics committee of the Institute of Disaster Management, Khulna University of Engineering and Technology, Khulna, Bangladesh and Psychology Department, Faculty of Arts, Menoufia University, Egypt. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

MP: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. MoB: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. HÍ: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. MaB: Conceptualization, Formal analysis, Investigation, Writing – review & editing. ASD: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. MHa: Formal analysis, Methodology, Writing – review & editing. MHe: Formal analysis, Methodology, Writing – review & editing. SA: Formal analysis, Investigation, Methodology, Writing – review & editing. AMD: Formal analysis, Investigation, Methodology, Writing – review & editing. FS: Formal analysis, Investigation, Methodology, Writing – review & editing. MAl: Formal analysis, Methodology, Writing – review & editing. SB: Formal analysis, Funding acquisition, Investigation, Methodology, Writing – review & editing. MK: Formal analysis, Funding acquisition, Investigation, Writing – review & editing. MHo: Data curation, Formal analysis, Investigation, Writing – review & editing. MAz: Formal analysis, Methodology, Writing – review & editing. MR: Data curation, Investigation, Methodology, Writing – review & editing. SS: Formal analysis, Methodology, Writing – review & editing. RS: Formal analysis, Methodology, Writing – review & editing. JM-I: Investigation, Methodology, Writing – review & editing. DB-A: Investigation, Methodology, Writing – review & editing. AR-M: Formal analysis, Investigation, Methodology, Writing – review & editing.

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Conflict of interest

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Supplementary material

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Post-COVID-19 cognitive symptoms in patients assisted by a teleassistance service: a retrospective cohort study

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Introduction: Four years after the onset of the COVID-19 pandemic, the frequency of long-term post-COVID-19 cognitive symptoms is a matter of concern given the impact it may have on the work and quality of life of affected people.

Objective: To evaluate the incidence of post-acute COVID-19 cognitive symptoms, as well as the associated risk factors.

Methods: Retrospective cohort, including outpatients with laboratory-confirmed COVID-19 and who were assisted by a public telehealth service provided by the Telehealth Network of Minas Gerais (TNMG), during the acute phase of the disease, between December/2020 and March/2022. Data were collected through a structured questionnaire, applied via phone calls, regarding the persistence of COVID-19 symptoms after 12 weeks of the disease. Cognitive symptoms were defined as any of the following: memory loss, problems concentrating, word finding difficulties, and difficulty thinking clearly.

Results: From 630 patients who responded to the questionnaire, 23.7% presented cognitive symptoms at 12 weeks after infection. These patients had a higher median age (33 [IQR 25–46] vs. 30 [IQR 24–42] years-old, $p = 0.042$) with a higher prevalence in the female sex (80.5% vs. 62.2%, $p < 0.001$) when compared to those who did not present cognitive symptoms, as well as a lower prevalence of smoking (8.7% vs. 16.2%, $p = 0.024$). Furthermore, patients with persistent cognitive symptoms were more likely to have been infected during the second wave of COVID-19 rather than the third (31.0% vs. 21.3%, $p = 0.014$). Patients who needed to seek in-person care during the acute phase of the disease were more likely to report post-acute cognitive symptoms (21.5% vs. 9.3%, $p < 0,001$). In multivariate logistic regression analysis, cognitive symptoms were associated with female sex (OR 2.24, CI 95% 1.41–3.57), fatigue (OR 2.33, CI 95% 1.19–4.56), depression (OR 5.37, CI 95% 2.19–13.15) and the need for seek in-person care during acute COVID-19 (OR 2.23, CI 95% 1.30–3.81).

Conclusion: In this retrospective cohort of patients with mostly mild COVID-19, cognitive symptoms were present in 23.7% of patients with COVID-19 at 12 weeks after infection. Female sex, fatigue, depression and the need to seek in-person care during acute COVID-19 were the risk factors independently associated with this condition.

KEYWORDS

post-acute COVID-19 syndrome, mental fatigue, cognitive dysfunction, memory disorders, risk factors

Introduction

With the emergence of the coronavirus disease 2019 (COVID-19), the world has been forced to face a health crisis that has lasted for over 4 years. Although current case numbers have drastically reduced, COVID-19 is still a global health issue, with a high social burden, especially in developing countries (1). In this context, the COVID-19 pandemic represented a great stimulus for the development of telehealth services worldwide, as the pandemic necessitated innovative solutions to provide quality health care while preserving protective social distancing measures – in place at the time – for the safety and of both health care providers and the general population.

Currently, increasing attention is directed towards the burden associated with symptoms that persist beyond the acute phase of the infection (2). According to the National Institute for Health and Care Excellence (NICE), post-COVID-19 syndrome refers to signs and symptoms that develop during or after an infection consistent with COVID-19, continue for at least 12 weeks and are not explained by an alternative diagnosis (3). Post-COVID-19 syndrome may occur regardless of acute COVID-19 severity, although those who present severe COVID-19 or have several comorbidities are more prone to develop the syndrome (1, 4).

The symptoms of post-COVID-19 syndrome are heterogeneous, and may include, but are not limited to, fatigue, difficulty breathing, "brain fog," insomnia, joint pain, and cardiac issues (5). "Brain fog" is an umbrella term for the presence of cognitive symptoms, including mental fatigue, impaired concentration and memory that may impact daily activities. Fatigue and cognitive impairment, including "brain fog," are among the most common and debilitating long-term effects of COVID-19 (6). An Israeli cohort examined the long-term clinical outcomes in over 1.9 million people with mild COVID-19, and observed that unvaccinated SARS-CoV-2 infected patients had a higher risk for concentration and memory impairment hazard ratio 1.85, 95% confidence interval [CI] 1.58 to 2.17 – between 1 and 6 months after acute infection; and hazard ratio 12.8, 95% confidence interval 9.6 to 16.1 – 6 months to a year after COVID-19 diagnosis, when compared to uninfected people (7). Other neurological and neuropsychiatric symptoms such as anxiety and depression are also common components of the post-COVID-19 syndrome (8).

The increase in the incidence of cognitive symptoms is a matter of concern given the impact they may have on the work and quality of life of the affected patients. However, little is known about its determinants, especially in patients who have had mild cases of SARS-CoV-2 infection (9). Therefore, this study aimed to evaluate the incidence of cognitive symptoms in post-COVID syndrome, as well as the associated risk factors, in COVID-19 outpatients assisted by a Brazilian public telehealth service. The study is innovative for including patients attended via a telehealth service during acute COVID-19.

Methods

Study design and eligibility

This is a retrospective cohort, which included staff and students from a public university, the *Universidade Federal de Minas Gerais* (UFMG), located in Belo Horizonte, the capital of Minas Gerais state, in Southeast Brazil. The cohort consisted of a convenience sample of consecutive individuals who had laboratory-confirmed COVID-19 (by real-time reverse transcription-polymerase chain reaction assay [RT-PCR] or antigen testing), between December 01, 2020 and March 31, 2022. All patients had been followed during the acute phase of the disease by TeleCOVID-MG, a public telehealth service provided by the Telehealth Network of Minas Gerais (TNMG) (10). The study period comprehended patients who had acute COVID-19 during the second or third pandemic waves in Brazil. According to previous evidence, the second wave lasted from August 11, 2020, to December 25, 2021, with delta and gamma variants as dominant; and the third wave lasted from December 26, 2021, to May 5, 2022, marked predominantly by the omicron variant.

TeleCOVID-MG

TeleCOVID-MG was a public structured multilevel teleconsultation and telemonitoring program, developed by the TNMG, to assist patients with respiratory tract symptoms during the COVID-19 pandemic. This service was maintained in operation between May 2020 and March 2023. The TNMG represents a partnership between seven public Brazilian Universities, with a coordinating hub at the Telehealth Center at the University Hospital/UFMG (10). It is one of the largest telehealth services in Brazil and Latin America. TeleCOVID-MG was first implemented in two Brazilian medium-sized cities and then, in December 2020, it was expanded to assist students, faculty, and technical-administrative staff from UFMG, as well as healthcare professionals from UFMG's University Hospital. *Universidade Federal de Minas Gerais* is a public federal university with more than 40,000 students (undergraduate and postgraduate), and the staff has more than 10,000 people, including professors and administrative staff.

For the UFMG students and staff, access to the TeleCOVID-MG service was done through an online symptom auto-verification application developed by the pandemic committee of the university. Upon identification of any flu-like symptoms, patients were referred to a chatbot, a computer program that collected name, Brazilian identification number, telephone number, warning signs or any comorbidities which increased the risk of worse outcomes (11). In cases of suspicion of flu-like syndrome and according to the severity of the symptoms, the patient was assisted by a nurse or a physician through a phone call teleconsultation. At the end of the teleconsultation, the patient was advised to keep domiciliary isolation or to seek an onsite evaluation at the primary care center or at the emergency department, in case of warning signs such as fever for more than 3 days, signs of hemodynamic instability, decompensation of the underlying disease or any other critical clinical condition identified by the health professional. In addition, patients received a request for an RT-PCR laboratory test to identify SARS-CoV-2, which could be performed at the university itself or at the reference laboratory of the patient's preference. Positive antigen tests performed in duly accredited services were also accepted as laboratory confirmation for COVID-19 (12).

Data collection

For the present study, data was collected through two main steps. In the first step, we obtained information on the COVID-19 acute phase, while in the second we assessed post-acute COVID-19 symptoms. Data regarding the acute phase of COVID-19 was obtained from the TeleCOVID-MG database including: age, sex, COVID-19 acute symptoms, the date on which the laboratory exam was performed, comorbidities, and if the patient was vaccinated for COVID-19 before the laboratory confirmation. With regards to the post-acute disease stage, data was collected at least 6 months after the diagnostic laboratory test, through the application of a structured questionnaire, developed exclusively for this study. The questionnaire was based on clinical protocols for the management of post-COVID syndrome, by the Brazilian Ministry of Health and the health department of Belo Horizonte (13, 14), as well as on previously validated tools, including Generalized Anxiety Disorder–7 (GAD-7) (15), Posttraumatic Stress Disorder Checklist for DSM-5 (PCL-5) (16), Patient Health Questionnaire-9 (PHQ-9) (17), Chalder's Fatigue Scale (18, 19), New York Health Association's functional scale (20), and Charlson's comorbidity index (21).

The questionnaire was developed using *Google Forms*® and was composed of 82 questions, divided into twelve sections: researcher identification, demographic characteristics, respiratory manifestations, neuromusculoskeletal disorders, physical fatigue, mental fatigue, neuro-cognitive manifestations, other manifestations, comorbidities, life habits (smoking and physical activity), work impact and post-COVID-19 functioning (Supplementary file 1). The questionnaire investigated symptoms at different time points after the COVID-19 acute phase (up to 1 month, up to 3 months, up to 6 months, more than 6 months). For the present analysis, the occurrence of cognitive symptoms for at least 12 weeks was evaluated.

The constructs used to assess cognitive functions, namely memory problems, concentration problems, difficulties for thinking clearly and word finding difficulties, were obtained from the Chalder Fatigue Scale (18, 19). This is a previously validated instrument widely applied to measure physical and mental fatigue in patients with chronic fatigue syndrome (18, 19). Emerging literature has linked post-COVID cognitive symptoms to myalgic encephalomyelitis/chronic fatigue syndrome (ME/CFS) in which the Chalder Fatigue Scale is frequently used (22). The question "Did you have difficulties in thinking clearly?" was adapted from the Chalder Fatigue Scale's question: "Do you think as clearly as usual?." Similarly, the question "Did you have word finding difficulties?" was adapted from the Chalder Fatigue Scale: "Do you find it more difficult to find the correct word?." The question "Did you present memory loss?" was adapted from "Is your memory as good as usual?" and "Did you present alterations in concentration?" from "Do you have difficulty concentrating?" [(18), Supplementary file 1].

In the present study, the presence of cognitive symptoms in post-COVID-19 syndrome was considered if the patient had a positive response to at least one of the four questions related to the occurrence of memory problems, concentration problems, difficulties for thinking clearly and word finding difficulties. Other cognitive studies on post COVID have used a similar approach (23–25).

Regarding the presence of cognitive symptoms, patients were divided into two groups: those who presented at least one of the four cognitive symptoms (memory problems, concentration problems, word finding difficulties and difficulty in thinking clearly) and those who had no cognitive symptoms lasting at least 12 weeks from the onset of COVID-19 symptoms.

To evaluate neuropsychiatric manifestations, questions based on previously validated instruments (GAD-7 for anxiety, PCL-5 for post-traumatic disorder and PHQ-9 for depression) were included in the questionnaire (15–17).The PHQ-2, which is an abbreviated form of the PHQ-9, was used as a criterion for the occurrence of depression. In other words, the positive answer to the two PHQ-2 questions defined the occurrence of depression in the present study (questions 49 and 54 of Supplementary file 1).

Patients who practiced physical activities regularly in accordance with World Health Organization recommendations (at least 150 min of physical exercise at moderate intensity or 75 at vigorous intensity, weekly) were considered non-sedentary (26).

In order to assess the possible impact caused by the post-COVID-19 syndrome, patients were asked about eventual loss of ability to carry out their daily tasks, the need to leave work longer than the expected period of isolation (for the acute phase of COVID-19), as well as the need for any restrictions after returning to work, such as reducing the workload or adapting the activity carried out. Finally, survey participants rated themselves on a post-COVID functional status scale (13, 27).

The questionnaire was applied through phone calls by a team of eight trained researchers who were supervised by a senior researcher. A data collection protocol (Supplementary file 2) was created in order to standardize the collection and all team members were previously trained on the study protocol.

The questionnaire was applied from December 2021 to November 2022. Each participant received a single phone call at least 6 months after laboratory confirmation of COVID-19. The protocol for patient inclusion in the study involved four contact attempts, including two phone calls, one in the morning and one in the afternoon, and two standardized text messages through an app (*Whatsapp*®). This message consisted of a short text presenting the project, and the individual was

inquired about the best time for the telephone call. If the participant initially did not understand any question, as per the study protocol the researcher should explain the question, according to the collection manual. As the questionnaires were filled out, the senior researcher audited the responses. Periodic audits were performed weekly, in order to increase quality data and to reduce biases. Incorrect data were reported to applicators and corrected. Whenever necessary, researchers underwent refresher training before applying new questionnaires.

During the study period, 11,585 patients were treated by TeleCOVID-MG. Of these, 1,575 had a positive laboratory test (RT-PCR or antigen test) for SARS-CoV-2. All patients with positive tests in this period would be able to participate in the research through the application of the questionnaire on post-COVID symptoms. However, in 888 cases contact was unsuccessful, of these 873 patients did not answer calls, and 15 phone numbers were wrong. Among 687 patients who answered the call, 13 refused to participate in the study, and 44 were excluded by missing data in all questions concerning cognitive symptoms. In the end, a total of 630 participants were included in this study (Figure 1).

Statistical analysis

Descriptive analysis of the variables regarding the presence or absence of cognitive symptoms, patient characteristics and impact on daily activities was performed. Participants were categorized into three age groups: 17–40, 41–60, and >60 years (7). The wave the patient was infected was defined based on the date of the laboratory examination. Exams taken between November 8, 2020 and December 25, 2021 corresponded to the second wave; while the tests carried out between December 26, 2021 and March 31, 2022 referred to the third wave of COVID-19 in Brazil (28).

For the purpose of the current analysis, the number of comorbidities was defined according to a modified Charlson comorbidity index including: chronic cardiac disease, chronic respiratory disease (excluding asthma), chronic renal disease, liver disease, dementia, chronic neurological conditions, connective tissue disease, diabetes mellitus, HIV and malignancy (21). Obesity was not included in the original modified Charlson comorbidity index, but we opted to include it due to its probable association with adverse outcomes in patients with COVID-19.

The statistical method to analyze the association between patient characteristics and the occurrence of cognitive symptoms (each symptom separately and also at least one of the four symptoms) was based on Bursac et al.'s proposal (29). The authors suggest starting the selection of variables through an univate analysis with a cutoff *p*-value of 0.25, but we opted to be more strict and 0.20 as the cutoff point.

The selected characteristics (possible predictors of cognitive symptoms) were then included in multivariate logistic regression models. Variables that were considered possible consequences of

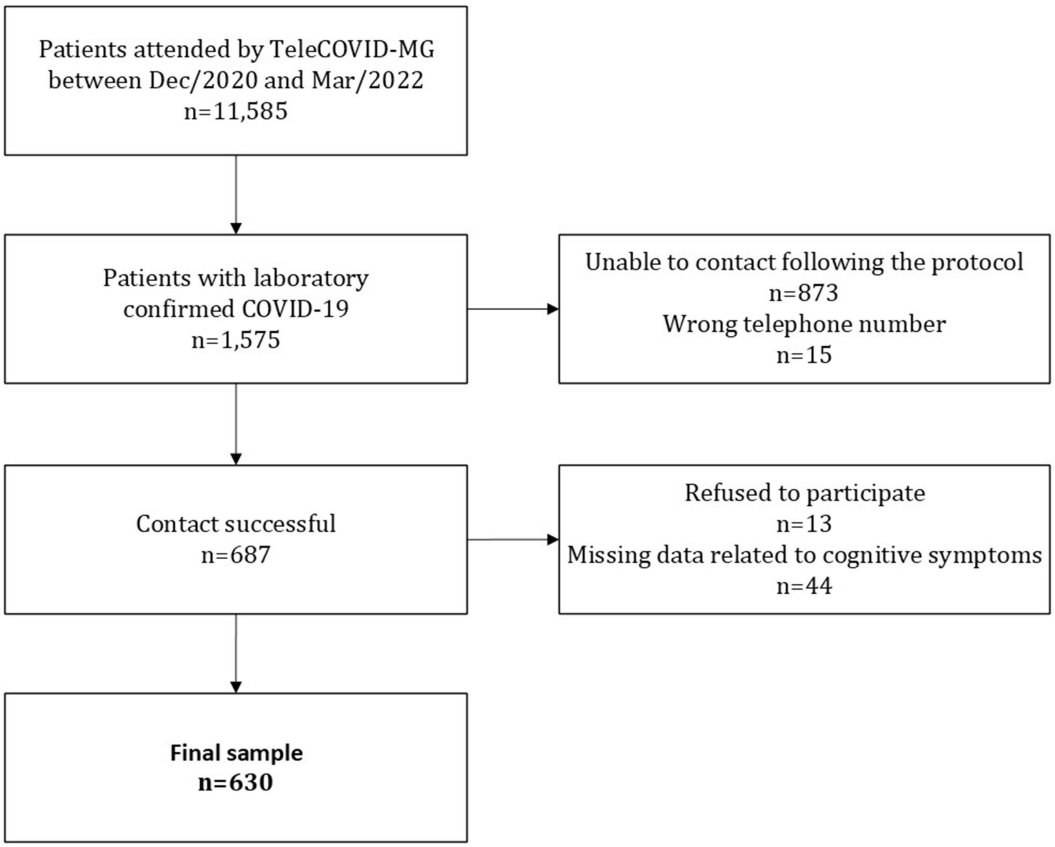

FIGURE 1
Flowchart of patients included in the study.

cognitive symptoms or other post-COVID-19 manifestations (such as loss of ability to perform daily tasks, absence from work longer than the usual period of isolation, restrictions on return to work and functional status post-COVID) were not tested in the multivariate models (Supplementary Table S1). A backward stepwise method was used to define significant characteristics, considering a cutoff point of 5%. The impact of significant characteristics was estimated using odds ratios (OR) and 95% confidence intervals. Deviance, Pearson, Hosmer-Lemeshow indicated well-adjusted final models.

As the presence of depression is linked to cognitive impairments, and a higher frequency of cognitive symptoms not always confirmed by the objective assessment (30), a subanalysis was conducted, excluding patients with depression.

Ethics statement

This study was approved by the Brazilian National Commission for Research Ethics (*Comissão Nacional de Ética em Pesquisa* on number CAAE 30350820.5.1001.0008), and it was conducted in accordance with the Declaration of Helsinki. All patients gave informed consent to participate in the study.

Results

Study population

Of the 630 post-COVID-19 patients included in the study, 149 (23.7%) reported cognitive symptoms at least 12 weeks after COVID-19 infection. The main characteristics of the study's population stratified by the presence of cognitive symptoms are presented in Table 1 and Supplementary Table S2.

The median age and proportion of women were higher in the group of patients with cognitive symptoms when compared to those without cognitive symptoms (33 [interquartile range (IQR) 25–46] vs. 30 [IQR 24–42] years-old, $p = 0.042$; 80.5% vs. 62.2%, $p < 0.001$). With regards to race, education, being a healthcare worker or intern, vaccination status, pregnancy, and physical activity, there were no statistically significant differences between groups. As for the presence of comorbidities, the vast majority of the sample (85.7%) did not present any comorbidity, and, among those who reported at least one comorbidity, there was no difference between groups. Patients with cognitive symptoms had a higher frequency of symptoms related to depression (11.4% vs. 1.7, $p < 0.001$), lower frequency of smoking (8.7% vs. 16.0%, $p = 0.026$), higher frequency of infection during the second wave (32.2 vs. 22.2%, $p = 0.014$) and sought in-person care more frequently (21.5% vs. 9.1%, $p < 0.001$), when compared to those without cognitive symptoms. When assessing patients per COVID-19 wave (Supplementary Table S3), there was a higher frequency of cognitive symptoms in the second wave.

Patients with cognitive symptoms reported a higher frequency of starting treatment for psychiatric diseases (21.5% vs. 10.4%, $p < 0.001$), greater loss of ability to perform day-to-day tasks (16.8% vs. 1.2%, $p < 0.001$), needed to be absent from work activities for a longer period (7.4% vs. 1.7%, $p < 0.001$) and reported having more limitations than patients without cognitive symptoms (44.3% vs. 9.6% to no impairment, 20.1% vs. 1.7% to mild impairment, $p < 0.001$).

Predictive factors for cognitive symptoms

The most prevalent cognitive symptoms in the sample studied were memory loss (17.5%), followed by word finding difficulties (16.2%), concentration problems (15.9%), and difficulty in thinking clearly (9.5%), as shown in Table 2. Among affected patients ($n = 149$), 23.5% had all four symptoms, 24.8% had three symptoms, 29.5% had two symptoms, and 22.1% had only one symptom.

In the multivariate analysis, a statistically significant association was observed between the occurrence of cognitive symptoms in post-COVID-19 syndrome and depression (OR 5.37 [95% IC 2.19–13.15]), as well as the presence of fatigue (OR 2.33 [95% CI 1.19–4.56]), female sex (OR 2.24 [95% CI 1.41–3.57]) and the need to seek in-person care in the acute phase of COVID-19 infection (OR 2.23 [95% CI 1.30–3.81]) (Table 3). In regards to each symptom, the same factors were associated (depression, fatigue, sex and need to seek in-person care), except for "thinking clearly," which showed no significant association with the need to seek in-person care, but had a significant association with COVID-19 acute infection during the second wave (OR 1.92 [95% CI 1.08–3.41]).

In the subanalysis excluding patients with depressive symptoms ($n = 25$), results were similar to the previous model (Supplementary Table S4).

Discussion

The present study found that cognitive symptoms are a prominent feature of post-COVID-19 syndrome, with a prevalence of 23.7%. Female sex OR 2.27 (95% CI [1.41–3.57]), fatigue OR 2.33 (95% CI [1.19–4.56]), depression OR 5.37 (95% CI [2.19–13.15]) and the need to seek in-person care in the acute phase of COVID-19 infection OR 2.23 (IC 95% [1.30–3.81]) were associated with cognitive symptoms. To the best of our knowledge, this is the first study in Latin America to address post-COVID-19 cognitive symptoms.

From the total sample, 12.1% required to seek in-person care and only 0.5% required hospitalization, which confirms that overall this is a cohort of mild cases of COVID-19. Even though the cases were mostly mild and patients were young, post-COVID-19 cognitive symptoms were reported by almost a quarter of them. This number corroborates previous studies in which cognitive symptoms, especially memory impairment, were highly prevalent among patients who had COVID-19 (6, 8, 31, 32). A recent systematic review, including data from 10,530 patients (59% women, average age 52 years, 51% who were hospitalized and 3% were admitted to an intensive care unit), has shown that cognitive symptoms were present in roughly one-third of patients at 12 or more weeks after the onset of COVID-19: brain fog (32, 10–54%), memory issues (28, 22–35%), attention disorder (22, 7–36%) (8). Interestingly, the prevalence of cognitive symptoms did not change significantly between mid-term (3 to 6 months) and long-term follow-up (6 or more months post-infection, lower than 5% change).

Women were 2.24 (95% CI 1.41–3.57) times more likely to have at least one of the four cognitive symptoms than men, with greater chances of having concentration problems (OR 2.66 [95% CI 1.48–4.78]), memory loss (2.09 [95% CI 1.24–3.54]), and word finding difficulties (2.24 [95% CI 1.29–3.87]). These findings are in line with two large cohorts in Iran and Norway, which also observed female sex

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TABLE 1 Baseline characteristics of the study cohort at 12 weeks after acute COVID-19 onset.

Characteristics	Total sample (n = 630)		Cognitive symptoms (n = 149)		No cognitive symptoms (n = 481)		p-value
Age (years)	31	(24–43)	33	(25–46)	30	(24-42)	**0.042**
Women	419	(66.5)	120	(80.5)	299	(62.2)	**<0.001**
Pregnancy	6	(1.4)	2	(1.7)	4	(1.3)	0.798
Healthcare Professional	127	(20.2)	37	(24.8)	90	(18.7)	0.202
Vaccination status							0.518
Two vaccine doses	416	(66.0)	102	(68.5)	314	(65.3)	
Partially vaccinated	121	(19.2)	25	(16.8)	96	(20.0)	
Unvaccinated	57	(9.0)	16	(10.7)	41	(8.5)	
Missing data	36	(5.7)	NA		NA		
COVID-19 wave							**0.014**
Second wave	155	(24.6)	48	(32.2)	107	(22.2)	
Third wave	474	(75.2)	101	(67.8)	373	(77.5)	
Other	1	(0.2)	0		1	(0.2)	
Modified Charlson Index							0.491
0 comorbidity	540	(85.7)	130	(87.2)	410	(85.2)	
1 comorbidity	85	(13.5)	17	(11.4)	68	(14.1)	
2 comorbidities	5	(0.8)	2	(1.3)	3	(0.6)	
Depression	25	(4.0)	17	(11.4)	8	(1.7)	**<0.001**
Fatigue	524	(83.2)	138	(92.6)	386	(80.2)	**<0.001**
Smoking	90	(14.3)	13	(8.7)	77	(16.0)	**0.026**
Sedentary lifestyle	266	(42.2)	72	(48.3)	194	(40.3)	0.084
Needed to seek in-person care	76	(12.1)	32	(21.5)	44	(9.1)	**<0.001**
Hospital admission	3	(0.5)	2	(1.3)	1	(0.2)	**1.000**
Started treatment for psychiatric diseases	82	(13.0)	32	(21.5)	50	(10.4)	**<0.001**
Loss of ability to carry out daily tasks	31	(4.9)	25	(16.8)	6	(1.2)	**<0.001**
Time away from work longer than the usual period of isolation	19	(3.0)	11	(7.4)	8	(1.7)	**<0.001**
Restrictions on returning to work	8	(1.3)	6	(4.0)	2	(0.4)	**<0.001**
Post-COVID functional status[a]							**<0.001**
No impairment	479	(76.0)	53	(35.6)	426	(88.6)	
Very mild impairment	112	(17.8)	66	(44.3)	46	(9.6)	
Mild impairment	38	(6.0)	30	(20.1)	8	(1.7)	
Moderate impairment	1	(0.2)	0		1	(0.2)	

Numbers: N (%) or median (IQR); IQR: interquartile range; NA: not applicable.
[a]No patients had severe impairment.

TABLE 2 Incidence of cognitive symptoms in the study population.

Symptom	Total sample (n = 630)
Memory loss	110 (17.5)
Word finding difficulties	102 (16.2)
Concentration problems	100 (15.9)
Difficulty thinking clearly	60 (9.5)
At least one of the four	149 (23.7)

Numbers: *N* (%).

as a risk factor for post-COVID brain fog (OR 1.4 [95% CI 1.06–1.90] and RR 2.0 [95% IC 1.3–3.2], respectively) (33, 34), and a recent Polish study with 303 outpatients, 47% of them healthcare professionals, and a median age similar to the present study. In this Polish study, 12 weeks after acute COVID-19, women reported problems with writing, reading, counting (17.0 vs. 5.1%) and communication of thoughts in a way that others can understand (34.3 vs. 20.7%) more often than men (35).

Patients who experienced fatigue were 2.33 (95% CI 1.19–4.56) times more likely to have cognitive symptoms than those who did not

TABLE 3 Predictors of cognitive symptoms according to the multivariate analysis ($n = 630$).

Variable	At least one cognitive symptom	Concentration	Memory	Word finding difficulties	Think clearly
Depression	5.37 (2.19–13.15)	6.72 (2.81–16.09)	3.76 (1.60–8.87)	2.81 (1.18–6.70)	4.31 (1.75–10.63)
Fatigue	2.33 (1.19–4.56)	3.23 (1.26–8.31)	3.87 (1.52–9.89)	2.35 (1.04–5.31)	3.93 (1.20–12.88)
Women	2.24 (1.41–3.57)	2.66 (1.48–4.78)	2.09 (1.24–3.54)	2.24 (1.29–3.87)	NA
Needed to seek in-person care	2.23 (1.30–3.81)	1.87 (1.02–3.43)	2.39 (1.36–4.20)	2.82 (1.61–4.95)	NA
COVID wave (second)	NA	NA	NA	NA	1.89 (1.07–3.34)

Numbers are presented as odds ratio (95% confidence interval); $p < 0.05$. NA: not applicable; $p > 0.20$ in the univariate analysis (Table 1).

experience it, with 3.23 (95% CI [1.26–8.31]) greater chance of having concentration problems; 3.87 (95% CI 1.52–9.89) greater chance of reporting memory problems, 2.35 (95% CI 1.04–5.31) greater chance of reporting word finding difficulties and 3.40 (95% CI 1.03–11.25) greater chance of having difficulty thinking clearly. A systematic review and meta-analysis that included almost 50,000 patients from various countries and settings, with different levels of severity, observed that approximately one-third of subjects experienced persistent post-COVID-19 fatigue and more than one-fifth of subjects exhibited cognitive impairment 12 or more weeks after confirming the diagnosis of acute COVID-19 (8).

Regarding the severity of disease, patients who needed to seek in-person care were 2.23 (95% CI 1.30–3.81) times more likely to have cognitive symptoms than those who did not, with 2.87 (CI 95% 1.02–4.43) greater chance of having concentration problems; 2.39 (CI 95% 1.36–4.20) greater chance of reporting memory problems and 2.82 (95% CI 1.61–4.95) greater chance of reporting word finding difficulties. This result agrees with the trend that the more severe the acute infection, the greater the chance of developing cognitive symptoms as a feature of the post-COVID-19 syndrome (36). In an ongoing cohort study that followed more than 70,000 adult participants during the COVID-19 pandemic, there was a higher prevalence of cognitive symptoms among individuals with moderate/severe COVID-19 when compared to mild cases (RR 1.9 [95% CI 1.3–2.9]) (34). In addition, a recent North American study of 89 patients hospitalized during acute SARS-CoV-2 infection with 6 months of follow-up found that having developed pneumonia after COVID-19 is a risk factor for cognitive symptoms (OR 1.69 [95% CI 1.16–2.46]) (37).

As for medical comorbidities, the presence of one or more of them did not influence the occurrence of persistent cognitive symptoms. This could be due to the nature of the sample, which consisted of patients with mild COVID-19. A systematic review and meta-analysis including 677,045 COVID-19 survivors demonstrated that underlying comorbidities may be a predisposing factor for the development of long-term COVID-19 symptoms (38). However, studies specifically assessing comorbidities as a risk factor for post-COVID-19 cognitive symptoms are needed.

Although the pathophysiology underlying post-COVID-19 cognitive symptoms is not understood, there are interesting. In the acute phase of the disease, the SARS-CoV-2 virus can penetrate the blood–brain barrier directly through the olfactory nerve, and viral proliferation can benefit from areas of cerebral hypoxia, increasing the central nervous system (CNS) viral load over time and affecting mitochondrial function. As brain tissues have high metabolic demand, this can lead to cognitive impairment (39). Another theory suggests that the impairment is not caused by a direct viral aggression to the CNS but by an overreaction of the immune system's response to the infection (40). It is also possible that those symptoms are the consequence of acute phase damage since the severity of acute disease is associated with cognitive symptoms (32). Finally, it is important to highlight that the inflammation and oxidative stress due to the SARS-CoV-2 infection may lead to neuropathological processes, such as cortical and hippocampal atrophy and small vessel disease, which could contribute to post-COVID-19 cognitive dysfunction symptoms (6). It should be noted that while symptoms related to concentration, language and memory have relatively well-defined neuroanatomical correlates, "thinking clearly" cannot be easily mapped into some brain neural circuitry or structure (41).

Cognitive subdomains such as memory and concentration are significantly impaired during and between episodes in individuals with depression (42). Multiple interacting neurobiological mechanisms (e.g., neuroinflammation and endothelial dysfunction) are implicated as subservient to cognitive deficits in depressive episodes (42, 43). In the current study, patients who experienced depression were 5.37 (95% CI [2.19–13.15]) times more likely to have cognitive symptoms than those who did not experience it, with 6.72 (95% CI [2.81–16.09]) greater chance of having concentration problems; 3.76 (95% CI [1.60–8.87]) greater chance of reporting memory problems, 2.81 (95% CI [1.18–6.70]) greater chance of reporting word finding difficulties, and 4.12 (95% CI [1.66–10.22]) greater chance of having difficulty thinking clearly. These results agree with a large longitudinal analysis of 1,733 consecutive patients with laboratory-confirmed COVID-19, in which 23% of patients reported concomitant symptoms of anxiety/depression 6 months after acute SARS-CoV-2 infection (44).

A systematic review that analyzed eight studies found considerable rates of depressive symptoms and clinically significant depression in post-COVID-19 syndrome. The frequency of depressive symptoms more than 12 weeks after a SARS-CoV-2 infection ranged between 11 and 28%. Two separate studies investigated the association between depression and neurocognitive functioning in post-COVID-19 syndrome and found that patients with depression tended to perform worse on neurocognitive tests compared to those without depression. Baseline markers of systemic inflammation and its change over time have been shown to predict depressive symptoms at three months of post-discharge follow-up. However, it remains to be seen whether the high frequency of depression among individuals with post-COVID-19 syndrome is a long-term consequence of the viral infection or a result of social, economic, and spatial factors (45). In the subanalysis excluding patients with depressive symptoms, we have obtained very similar results to the analysis using the full sample size. In other words, despite the overlap, post-COVID cognitive symptoms are not always linked to depression.

No association was found between the occurrence of persistent cognitive symptoms and the patient's vaccination status, although the impact of vaccination on post-COVID-19 syndrome differs across studies. An exploratory, observational single-center cohort study of patients hospitalized for COVID-19 demonstrated that vaccinated patients have a lower risk of developing impaired concentration (OR 0.49 [95% CI 0.24–0.98]) (37). Similarly, other studies also evidenced that vaccination reduces the risk of post-COVID outcomes (46) as reported in a meta-analysis, in which people who received two doses of vaccine were significantly less likely to develop this condition than unvaccinated people (47). With the widespread dissemination of COVID-19 vaccination, however, the evolving landscape necessitates further in-depth study. As vaccination reduces COVID-19 severity (48), there might be a positive impact in reducing persistent cognitive symptoms.

When evaluating cognitive symptoms, it is also important to understand their impact on patients' daily activities, more specifically in their professional lives, but evidence of this impact is still scarce. In the present study, patients with cognitive symptoms reported a higher frequency of time away from work longer than the usual period of isolation, fourteen, ten or seven days since the onset of symptoms, depending on the protocol used and the moment of the pandemic (7.0 vs. 1.7%), and restrictions on returning to work (4.0 vs. 1.4%, $p < 0.001$ for both). A previous study focused on evaluating the quality of life at work in 300 patients before COVID-19 up to over 12 weeks post-acute infection. Only 44.67% of patients presented a normal quality of life at work after 12 weeks of COVID-19 diagnosis, and the authors observed that memory and focus impairment after 12 weeks of COVID-19 diagnosis was a predictor of poor quality of life at work (49).

The main limitation of this study is its reliance on the report of cognitive symptoms and the lack of formal neuropsychological assessment. Self-report measures can be influenced by different factors, including mood status. For instance, depression is associated with cognitive complaints not necessarily confirmed by objective assessment (50). Nevertheless, we have confirmed a high frequency, even in patients without depressive symptoms. Other validated self-report measures of cognition could have been also used, for example, the Subjective Cognitive Decline Questionnaire (SCD-Q) (54). However, we opted for not including it to avoid the research questionnaire being extremely long, which could compromise data quality and response rate (51). The "temporal report" and recall biases may also be seen as potential limitations of the study. Additionally, other authors have already highlighted differences in the definitions of cognitive dysfunction, "brain fog," memory issues and attention disorder (8). Conversely, the homogeneity of the studied population constitutes a strength of this study.

Future studies must map specific cognitive deficits (e.g., attention, memory, executive function) using quantitative neuropsychological tests. Additionally, future studies are needed to better understand the underlying mechanisms of post-COVID cognitive symptoms, so effective therapeutic approaches can be developed in order to improve quality of life and to mitigate disease burden.

Conclusion

In this retrospective cohort of patients with mostly mild COVID-19, we have demonstrated that cognitive symptoms were common components of post-COVID-19 syndrome, present in 23.7% of patients at 12 weeks after acute COVID-19. Female sex, fatigue, depression and the need to seek in-person care during acute COVID-19 were independently associated with a higher risk for this condition.

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

This study was approved by the Brazilian National Commission for Research Ethics (Comissão Nacional de Ética em Pesquisa on number CAAE 30350820.5.1001.0008), and it was conducted in accordance with the Declaration of Helsinki. All patients gave informed consent to participate in the study.

Author contributions

LB: Writing – original draft, Writing – review & editing, Conceptualization, Data curation, Project administration. TC: Writing – original draft, Writing – review & editing, Data curation. BF: Writing – original draft, Data curation, Writing – review & editing. TP: Writing – original draft, Writing – review & editing, Data curation. DP: Writing – original draft, Writing – review & editing, Data curation. TF: Writing – original draft, Writing – review & editing, Data curation. LK: Writing – original draft, Writing – review & editing, Data curation. CO: Writing – original draft, Writing – review & editing, Conceptualization. AT: Writing – original draft, Writing – review & editing, Conceptualization. MM: Writing – original draft, Writing – review & editing, Conceptualization, Data curation, Project administration.

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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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Glossary

CI	Confidence Interval
CNS	Central Nervous System
COVID-19	Coronavirus Disease 2019
GAD-7	Generalized Anxiety Disorder–7
HIV	Human Immunodeficiency Virus
IQR	Interquartile Range
ME/CFS	Myalgic Encephalomyelitis/Chronic Fatigue Syndrome
NICE	National Institute for Health and Care Excellence
OR	Odds Ratio
PCL-5	Posttraumatic Stress Disorder Checklist for DSM-5
PHQ-2	Patient Health Questionnaire-2
PHQ-9	Patient Health Questionnaire-9
RT-PCR	Reverse Transcription-Polymerase Chain Reaction
SARS-CoV-2	Severe Acute Respiratory Syndrome Coronavirus 2
SCD-Q	Subjective Cognitive Decline Questionnaire
TNMG	Telehealth Network of Minas Gerais
UFMG	Universidade Federal de Minas Gerais

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Musculoskeletal disorders and quality of life for Chilean teachers during the COVID-19 pandemic at the academic year-end

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Introduction: Schoolteachers have reported multiple demands contributing to poor perceptions regarding their quality of life and high rates of musculoskeletal disorders. However, there are few studies about the association between musculoskeletal disorders and quality of life from the end of the academic period during the COVID-19 pandemic.

Objective: Evaluate musculoskeletal disorders rates and their association with quality of life perceptions among teachers from the last academic period during the COVID-19 pandemic.

Participants and methods: A total sample of 161 Chilean schoolteachers was included in a cross-sectional study musculoskeletal disorders prevalence was evaluated using the Standardized Nordic Questionnaire, and quality of life was evaluated through the Short-Form 12 Health Survey Instrument. A logistic regression was applied to evaluate the association between musculoskeletal disorders and quality of life perceptions adjusted by gender, age, and contract type.

Results: 98% of teachers have suffered from some type of musculoskeletal disorders during the last 12 months, and 64% have had six or more painful regions. Women showed a higher musculoskeletal disorders rate than men. The group of teachers with the most musculoskeletal disorders (≥p50) saw significantly greater risk of low scores on the physical (OR: 2.16; $p < 0.05$) and mental components (OR: 4.86; $p < 0.01$) of quality of life, regardless of gender, age, and contract type.

Conclusion: High musculoskeletal disorders rates suggest that preventive and informative actions must be taken regarding these disorders in order to protect teachers' mental and physical health, considering the effects of the school year and the COVID-19 health crisis.

KEYWORDS

quality of life, mental health, physical health, school teachers, musculoskeletal disorders, academic period

1 Introduction

The arrival of the COVID-19 pandemic in early 2020 led to quarantines and lockdowns for billions of people worldwide (1, 2). Confinement due to COVID-19 generated structural changes for the daily activities of most people (3, 4). In this sense, one job measure adapted worldwide to avoid spreading the SARS-CoV-2 virus was changing from in-person work to remote working in a wide range of job areas (5). The occupational format of remote working combined with COVID-19 confinement has been described as one of the main causes in the rise of occupational stress among working populations in general (6), with reports associating this phenomenon with the presence of musculoskeletal pain and deteriorating quality of life (QoL) with a subsequent impact on public health (7).

Teachers saw their work format severely impacted during the pandemic due to school closures, particularly due to increased work demand, less time for planning in-person tasks and transforming them into online formats, and precarious organizational factors in work (8, 9). In this context, reports during the COVID-19 health crisis indicated that schoolteachers saw significant QoL decreases compared to before the pandemic, due to longer work hours and deteriorated work-family balance (8, 10). Remote working among teachers was also reported as a factor associated with increased burnout, stress, and high emotional demands (11, 12) together with reports of significant mental health deteriorations like higher levels of distress, worsened lifestyle quality, and increased emotional exhaustion (13–15). In this regard, pre-pandemic reports indicated high rates of musculoskeletal disorders (MSD) among schoolteachers linked with significant QoL particularly their mental QoL (16–18). The evaluation of MSDs in Chilean teachers is of great importance due to the high prevalence of these disorders and their association with a low perception of quality of life (QoL). Reports before the pandemic by COVID-19 indicated that 91% had experienced some MSD in the last 12 months, and 28.86% had had pain in 6 or more body regions. Conversely, teachers without MSDs reported higher QoL scores than those with MSDs. In addition, those teachers with the highest prevalence of MSD (≥p75) showed a significantly increased risk of having low scores on the physical (OR: 2.82) and mental (OR: 2.65) components of the QoL (16). This report suggests that preventive and informative actions regarding MSDs should be taken to protect the mental and physical health of teachers, considering the multiple risk factors to which they are exposed due to their working conditions in Chile and worldwide. Therefore, although there is a substantial body of literature on the impaired mental health of teachers (8–15), the evaluation of MSDs in teachers needs to be assessed due to their high prevalence and association with QoL (16, 17).

In this sense, due to remote working among teachers during the pandemic, there have been reports of high exposure to job stress and heavy psychosocial demands, which in turn have led to more sedentary behavior and deficient ergonomic practices, as long workdays in front of screens have led to developing various MSD (19–22). However, both at the global level and in Chile, there are no reports about the rates of MSD associated with teachers' QoL in the context of the pandemic and especially during the end of the academic calendar, when teachers report greater time and effort spent on fulfilling the timeframes stipulated by their employers, thereby generating stress increases by up to 20% compared with the first months of the school year (23, 24). In addition, a UNESCO-conducted survey revealed that in Chile, about one-third of teachers work at two or three different schools daily, and nearly 20% have additional employment outside of teaching. These educators often perform extra work-related tasks at home or after hours (25). This perceived workload is highlighted in various studies as a potential health risk factor for Chilean teachers (8, 10, 16, 17, 26). In this regard, there is a research gap on the simultaneous impact of two critical periods that affect teachers' QoL and MSD, such as the COVID-19 pandemic and the end of the academic year-end. The following research problem focuses on understanding how the COVID-19 pandemic has affected the prevalence of MSD and QoL among Chilean teachers at the end of the last academic year. The pandemic has significantly altered teaching practices, possibly increasing stress and changing teachers' working conditions, which could influence the prevalence of MSD and their perception of QoL. However, the objective of the present study is to evaluate the prevalence of MSD and the QoL among Chilean school teachers at the end of the last academic school year during the COVID-19 pandemic. Therefore, we hypothesize that if we consider the new working conditions during the end of the school year, coupled with the pandemic context, and taking into account the particularly uncertain health, social, and political context of Chile (23–26), teachers will exhibit high prevalences of MSD and a deteriorated QoL, mainly in its mental component.

2 Materials and methods

2.1 Participants

166 teachers responded to the survey, of which six were excluded due to unsatisfactory responses to different instruments (exclusion criterion), leaving a total of 161 participants for analyses. Of these 161 teachers, 79.5% were female. The mean age was 40.2 years (SD ± 11.2 years) (for women 39.7 years and for men 42.5 years). Regarding marital status, 50.3% were married or lived in a steady relationship, 41% were single, and 8.7% were divorced. 62.1% had an indefinite-term contract. Concerning school types, 35.5% of the teachers belonged to public schools, 51.4% to subsidized private schools, and 13.1% to unsubsidized private schools. Finally, 58.4% of the teachers reported having children (see Table 1).

2.2 Procedures

A cross-sectional study was done between the months of November and December 2021, the final month of academic activities among schoolteachers in Chile (27). Snowball sampling was used for data gathering (28) with teachers contacted via social media (Facebook and Instagram) due to the impossibility of physical contact arising from the pandemic. The main criterion for the inclusion of teachers is that they are teaching. Each professor went through the instruments online using the SurveyMonkey platform (SurveyMonkey, San Mateo, CA) with detailed instructions, research objectives, and the researchers' contacts in case of any doubts. Before taking the surveys, the participants read and signed informed online consent on the same platform, detailing that their participation was totally anonymous, voluntary, and with a confidentiality commitment from the

TABLE 1 Sociodemographic characteristics, prevalence of musculoskeletal disorders and quality of life according to gender and age.

Variables	Total sample	Gender			Age		
		male (n = 29)	female (n = 132)	p	≤44 (n = 109)	≥45 (n = 52)	p
Age[a]	40.236 ± 11.215	42.46 ± 12.23	39.65 ± 10.94	0.162[b]	33.550 ± 5.568	54.25 ± 5.762	<0.001
Marital status							
Single	66 (40.99)	14 (48.28)	52 (39.39)	0.569[c]	56 (51.38)	10 (19.23)	<0.001[c]
Married/Partnered	81 (50.31)	12 (41.38)	69 (52.27)		52 (47.71)	29 (55.77)	
DWW[e]	14 (8.70)	3 (10.34)	11 (8.33)		1 (0.92)	13 (25.00)	
Type of contrat							
Fixed-term	61 (37.89)	9 (31.03)	52 (39.39)	0.401[d]	49 (44.95)	12 (23.08)	<0.05[d]
Indefinite-term	100 (62.11)	20 (68.97)	80 (60.61)		60 (55.05)	40 (76.92)	
Type of school							
Public (state)	66 (40.99)	11 (37.93)	43 (32.58)	0.835[c]	37 (33.94)	17 (32.69)	0.959[c]
Private (subsidized)	87 (54.04)	15 (51.72)	72 (54.55)		59 (54.13)	28 (53.85)	
Particular (non-subsidized)	20 (12.42)	3 (10.34)	17 (12.88)		13 (11.93)	7 (13.46)	
Number of child							
Without	67 (41.61)	14 (48.28)	53 (40.15)	0.422	60 (55.05)	7 (13.46)	<0.001
With	94 (58.39)	15 (51.72)	79 (59.85)		49 (44.95)	45 (86.54)	
MSD							
<p50	58 (36.02)	14 (48.28)	44 (33.33)	0.129[d]	42 (38.53)	16 (30.77)	0.337[d]
≥p50	103 (63.98)	15 (51.72)	88 (66.67)		67 (61.47)	36 (69.23)	
PCS	45.68 ± 8.13	47.68 ± 7.72	45.24 ± 8.18	0.140[b]	45.76 ± 7.78	45.51 ± 1.23	0.964[b]
<T-Score	54 (33.54)	13 (44.38)	41 (31.06)	0.115[d]	32 (29.36)	22 (42.31)	0.104[d]
≥T-Score	107 (66.46)	16 (55.17)	91 (68.94)		77 (70.64)	30 (57.69)	
MCS	33.25 ± 10.84	36.47 ± 14.13	32.54 ± 9.90	0.191[b]	31.85 ± 1.02	36.18 ± 1.48	0.008[b]
<T-Score	16 (9.94)	7 (24.14)	9 (6.82)	0.005[d]	7 (6.42)	9 (17.31)	0.031[d]
≥T-Score	145 (90.06)	22 (75.86)	123 (93.18)		102 (93.58)	43 (82.69)	

[a]Data are expressed as mean and standard deviation.
[b]Wilcoxon Test
[c]Fisher's exact test.
[d]Chi-squared.
[e]Divorced Widow Widower.
MSD, Musculoskeletal Disorders; <p50, less than 6 painful regions; ≥p50, 6 or more painful regions.
PCS, Physical Component Summary; MCS, Mental Component Summary; T-Score, 50 indicate good QoL perception while scores below 50 indicate poor QoL perception.
$p < 0.05$.

researchers, as well as being totally without remuneration, compensation, or economic incentives in any part of the study. This study was approved by the Ethics Committee at Pontificia Universidad Católica de Valparaíso (BIOEPUCV-H 393–2021).

2.3 Instruments

The descriptive variables gathered included gender, age grouped into two categories (≤44 years and ≥45 years) according to the cutoff points used in the Chilean National Health Survey (29), marital status (single, married/cohabitating, divorced/widowed), number of children, school-age children, type of school where they taught by funding category (public, private, charter) (30) and contract type (fixed term or indefinite). The dependent variable was QoL, and the independent variable was the presence of MSD.

QoL perceptions were evaluated with the Short-Form 12 Health Survey (SF-12), validated for the Chilean population (31). The survey consists of 12 Likert-type personal appreciation questions grouped into two summary measurements: the Physical Health Component (PHC) and the Mental Health Component (MHC). Participants' scores for each scale and summary measurement were transformed into a 0–100 scale, followed by calculating a z-score and t-score value for PHC and MHC using internationally standardized methods (32, 33). Values above T-Score 50 indicated good QoL perceptions, while scores below T-Score 50 indicated poor QoL perceptions.

For MSD evaluation, we used the Standardized Nordic Questionnaire for Musculoskeletal Symptoms, validated for the Chilean population (34) and previously used among Chilean schoolteachers (16, 17). The survey comprises a graphic representation of a human body's posterior view, divided into nine different anatomical regions including neck, shoulders, upper back,

lower back, elbows, wrists/hands, hips/thighs, knees, ankles/feet. For each of these areas, there is a "yes" or "no" question that assesses the prevalence of self-reported musculoskeletal symptoms experienced by the respondents over the last 12 months (At any time during the last 12 months, have you had problems (pain, aches, discomfort) in the following parts of your body?). The symptoms may include aches, pain, or discomfort in these body segments. The prevalence rates were calculated based on the proportion of teachers who reported MSDs in any body part to the total number of respondents. In addition, the segments have been grouped to analyze major body segments, generating the following analysis segments: neck/shoulder, back, upper limb, and lower limb. Therefore, Standardized Nordic Questionnaire was crafted to evaluate issues related to the musculoskeletal system within a specific population, focusing on identifying the body parts where these problems are concentrated.

2.4 Statistical analyses

Data analyses were done using STATA v16 software for Windows (StataCorp. 2019. Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC). Descriptive statistics were processed using medians with standard deviations (M ± SD) for continual variables, and frequencies with percentages for categorical variables (*n*, %). Sociodemographic variables were compared between teachers by gender. MSD rates were presented as frequency and percentage (n, %) and evaluations were done on subjects with the greatest number of painful regions grouping them into percentile 50 according to the previous 12 months (p50: ≥ 6 regions). Sociodemographic characteristics, QoL, and MSD were compared between the PHC and MHC QoL categories according to the standardized t-score (< 50 and ≥ 50 respectively). QoL was also compared in each of its components (PHC and MHC), among teachers with 6 or more painful regions (≥ p50). Median comparisons were done according to data distribution according to the Shapiro–Wilk normality test (*t*-test: parametric; Mann–Whitney: non-parametric). Chi-squared and Fisher's Exact tests were used to analyze categorical variables. A logistic regression was also done to analyze the association between the most prevalent cases of MSD (≥ p50), with QoL in its PHC and MHC summary measures, adjusted by age, gender, and contract type. Finally, to evaluate the models' goodness of fit, a Hosmer-Lemeshow test was used where values above 0.05 indicated that the model fit the data. The significance alpha value was 0.05.

3 Results

3.1 Sociodemographic characteristics of the study group

Table 1 presents the sociodemographic characteristics, MSD prevalence, and teachers' QoL by gender and age category. We can observe a significant association in the gender and MHC categories for QoL ($p < 0.01$) where over 90% of women were below the *T*-Score. On the other hand, the age categories allow us to distinguish significant associations in marital status ($p < 0.001$), contract type ($p < 0.05$), number of children ($p < 0.001$) and the MHC area on QoL ($p < 0.05$) where 94% of teachers aged 44 or less fell below the *T*-Score.

3.2 MSD prevalence

MSD rates by age and gender appear in Table 2, indicating that the body regions with the highest MSD rates regardless of age or gender are the lower back and neck, at 83.85 and 83.23%, respectively. Along with this point, having 6 or more body regions with MSD occurred among 63.98% of respondents, while Any MSD stood at 98.14% of respondents. We can also observe that teachers over 45 years old and female teachers reported a higher rate of general MSD compared to younger teachers and male teachers.

3.3 Association between MSD and QoL

The association between sociodemographic characteristics and MSD with teachers' QoL appears in Table 3. The PHC on QoL has a significant association with the p50 of MSD ($p = 0.023$). On the other hand, in the MHC of QoL, there are significant associations in age, contract type, and p50 category ($p < 0.01$). Significant associations allow us to observe that most teachers below the *T*-Score for MHC are those age 44 or less and indicating that they had 6 or more body regions with MSD. Teachers with indefinite work contracts also had better mental health (87%).

Finally, Table 4 reports the results of the logistic regression done between the MHC and PHC areas for QoL with MSD rates and work characteristics by gender and age. This table shows that the p50 category for MSD is associated with worse scores on both the physical and mental domains (OR = 2.160; $p = 0.029$ and OR = 4.857; $p = 0.011$), while being female (OR = 3.417; $p = 0.041$) is also a risk factor for the QoL MHC. Finally, after incorporating age as a continuous variable within the model, we can observe a trend whereas teachers' age increases, there is a proportional decrease in the odds of having worse scores in the mental health component for QoL (OR = 0.946; $p = 0.043$).

4 Discussion

The study evaluated the relationship between MSD and QoL in a sample of teachers in Chile during the end of the academic period during the COVID-19 pandemic. The presence of 6 or more regions with MSDs seems to be an important risk factor for poor QoL, considering its physical and mental components, independent of age, gender, and type of contract. In our study, the prevalence of MSD in any part of the body was 98.1%, and for 6 or more parts of the body was 64.0%, these results show an increase in the prevalence of musculoskeletal disorders in teachers compared to previous studies carried out both inside and outside the country (16, 17, 35, 36). For example, while the prevalence of musculoskeletal disorders in 6 or more parts of the body in our results was 64.0%, the Solis-Soto study carried out prior to the pandemic in Bolivia reported a prevalence of 47.8% and only considering 3 or more body parts

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TABLE 2 Prevalence of musculoskeletal disorders according to age and gender in Chilean teachers.

Variables	Musculoskeletal disorders				
	Total sample	Age		Gender	
		≤44	≥45	Male	Female
Neck	134 (83.23)	87 (79.82)	47 (90.38)	21 (72.41)	113 (85.61)
Shoulders	112 (69.57)	72 (66.06)	40 (76.92)	19 (65.52)	93 (70.45)
Neck/Shoulders	143 (88.82)	94 (86.24)	49 (94.23)	26 (89.66)	117 (88.64)
Elbows	70 (43.48)	41 (37.61)	29 (55.77)	9 (31.03)	61 (46.21)
Wrist/Hands	118 (73.29)	78 (71.56)	40 (76.92)	20 (68.97)	98 (74.24)
Any upper limb	155 (96.27)	104 (95.41)	51 (98.08)	28 (96.55)	127 (96.21)
Upper back	119 (73.91)	81 (74.31)	38 (73.08)	19 (65.52)	100 (75.76)
Low back	135 (83.85)	94 (86.24)	41 (78.85)	20 (68.97)	115 (87.12)
Any back	148 (91.93)	101 (92.66)	47 (90.38)	24 (82.76)	124 (93.94)
Hips/Thigs	89 (55.28)	60 (55.05)	29 (55.77)	10 (34.48)	79 (59.85)
Knees	82 (50.93)	48 (44.04)	34 (65.38)	15 (51.72)	67 (50.76)
Ankles/Feet	62 (38.51)	36 (33.03)	26 (50.00)	9 (31.03)	53 (40.15)
Any lower limb	124 (77.02)	80 (73.39)	44 (84.62)	20 (68.97)	104 (78.79)
Any MSD	158 (98.14)	107 (98.17)	51 (98.08)	28 (96.55)	130 (98.48)
≥p50	103 (63.98)	67 (61.47)	36 (69.23)	15 (51.72)	88 (66.67)
Without MSD	3 (1.86)	2 (1.83)	1 (1.92)	1 (3.45)	2 (1.52)

Data are expressed as frequency (percentage).
Musculoskeletal Disorders; ≥p50, 6 or more painful regions.

(35). Other previous studies also carried out on Chilean teachers during the pandemic present lower prevalences than those reported in this study, for example, Vega-Fernandez reported only a 28.9% prevalence of MSD in 6 or more parts of the body, a much lower value compared with our results (16), which could mean a progressive increase in teachers' musculoskeletal disorders as the pandemic progressed.

Although the prevalence of MSD in the back, neck, and upper limbs has been previously reported as the most affected, our results suggest that its prevalence has increased during the period of the COVID-19 pandemic. Compared to one study before the pandemic, including rural and urban areas in Chile, and using the same questionnaire, it shows that any upper limbs discomfort increased by 20% (from 76 to 96.3%), back by 21% (from 71 to 92%) and neck/shoulders by 22% (from 62 to 89%). At the same time, slight variation was reported in other parts of the body, such as knees, which reported an increase of 5% (from 46 to 51%), and ankles/feet by 3% (from 36 to 39%) (16). This difference could be explained due to the change in class modality from face-to-face to virtual learning. Zyznawska and Bartecka reported that the average degree of declared back pain is significantly associated with the number of hours spent at the computer (37). Possibly during the pandemic, pre-existing complaints have intensified and become more persistent. Likewise, the most common discomforts in the body are related to the type of work and common postures exercised in the virtual classes of most schools. Sitting for long hours in front of the computer, inappropriate rest breaks, increased and inappropriate use of smart devices, improper keyboard and mouse position, uncomfortable table and chair for work, and the physical and environmental conditions of the room have been related to the increased MSD in employees using a computer (19–22, 38). Additionally, before the pandemic, most teachers did not have training in ergonomics for working in front of the computer, which could cause rapid MSD due to inadequate postures.

On the other hand, women presented higher prevalences in all parts of the body. It is consistent with other studies, which generally reported a higher prevalence and severity of MSD in women, partly explained by the higher overload of domestic tasks (36). However, during the pandemic, this difference may have deepened and decreased the work–non-work balance, especially at the beginning of the health crisis (39, 40). To those mentioned above it is essential to add that, during the study, Chilean teachers were at the end of the academic period and in the first steps toward the return to face-to-face teaching, so the amount of telework may have decreased, but the traditional work and the time dedicated to it were still at the worrying levels that have been described for years (41–44), or could even be higher, due to the greater effort required for end-of-semester activities (23).

Our study also found differences in MSD by age. People over 45 years of age have reported higher prevalences of MSD in different body parts, which may have a direct relationship with the human body's aging process (45). However, our study found a higher prevalence in the lower and upper back areas in younger people (under 45 years of age), which could be related to lifestyle changes due to the lockdown imposed during the pandemic. Restriction on social gatherings, financial problems, and housing conditions seems particularly stressful for younger adults (46). On the other hand, younger teachers could face a career shock at the beginning of their working life (47).

TABLE 3 Sociodemographic characteristics and prevalence of musculoskeletal disorders according to physical and mental health components of quality of life.

Variables	Quality of Life					
	PCS			MCS		
	<*T*-Score	≥*T*-Score	*p*	<*T*-Score	≥*T*-Score	*p*
Age[a]	39.196 ± 10.216	42.296 ± 12.826	0.258[b]	39.448 ± 10.911	47.375 ± 11.769	0.009[b]
≤44	77 (71.96)	32 (59.26)	0.104[d]	102 (70.34)	7 (43.75)	0.031[d]
≥45	30 (28.04)	22 (40.74)		43 (29.66)	9 (56.25)	
Marital status						
Single	46 (42.99)	20 (37.04)	0.640[c]	61 (42.07)	5 (31.25)	0.660[c]
Married/partnered	53 (49.53)	28 (51.85)		72 (49.66)	9 (56.25)	
DWW[e]	8 (7.48)	6 (11.11)		12 (8.28)	2 (12.50)	
Type of contrat						
Fixed-term	41 (38.32)	20 (37.04)	0.874[d]	59 (40.69)	2 (12.50)	0.027[d]
Indefinite-term	66 (61.68)	34 (62.96)		86 (59.31)	14 (87.50)	
Type of school						
Public (state)	38 (35.51)	16 (26.93)	0.647[c]	50 (34.48)	4 (25)	0.753[c]
Private (subsidized)	55 (51.40)	32 (59.26)		77 (53.10)	10 (62.50)	
Particular (non-subsidized)	14 (13.08)	6 (11.11)		18 (12.41)	2 (12.50)	
Number of child						
Without	47 (43.93)	20 (37.04)	0.403[d]	62 (42.76)	5 (31.25)	0.375[d]
With	60 (56.07)	34 (62.96)		83 (57.24)	11 (68.75)	
School child						
Yes	38 (35.51)	19 (35.19)	0.967[d]	54 (37.24)	3 (18.75)	0.142[d]
No	69 (64.49)	35 (64.81)		91 (62.76)	13 (81.25)	
P50						
<6 painful regions	32 (29.91)	26 (48.15)	0.023[d]	47 (32.41)	11 (68.75)	0.005[d]
≥6 painful regions	75 (70.09)	28 (51.85)		98 (67.59)	5 (31.25)	

[a]Data are expressed as mean and standard deviation.
[b]Wilcoxon Test.
[c]Fisher's exact test.
[d]Chi-squared.
[e]Divorced Widow Widower.
MSD, Musculoskeletal Disorders; p50, 50 % MSD.
PCS, Physical Component Summary; MCS, Mental Component Summary; *T*-Score, 50 indicate good QoL perception while scores below 50 indicate poor QoL perception.
$p < 0.05$.

TABLE 4 Logistic regression for the association between physical and mental health components of quality of life with prevalence of musculoskeletal disorders and work characteristics adjusted for gender and age.

Variables	PCS (T-Score)		MCS (T-Score)	
	OR [95% CI][a]	*p*	OR [95% CI][a]	*p*
≥p50 MSD	2.160 (1.084–4.304)	0.029	4.857 (1.446–16.308)	0.011
Gender (female)	1.527 (0.656–3.555)	0.326	3.417 (1.049–11.129)	0.041
Age[b]	0.975 (0.947–1.005)	0.106	0.946 (0.897–0.998)	0.043
Type of contrat (Fixed-term)	-		0.389 (0.076–1.988)	0.257
Hosmer-Lemeshow	0.568		0.670	

[a]OR, Odds Ratios [Confidence interval].
[b]Variable 'Age' was included in the model as a continuous variable.
Physical Component Summary; MCS, Mental Component Summary; *T*-Score, 50 indicate good QoL perception while scores below 50 indicate poor QoL perception.
≥p50 MSD, 6 or more regions with MSD.
$p < 0.05$.

In consistency with previous studies in Chile (16), our results show a significant association between MSD and QoL, both for its physical and mental components. In our study, QoL scores, especially for the mental component, have been reported to be significantly lower in women and younger people. Female teachers showed higher fatigue and anxiety with using technology for education during the Covid-19 pandemic (48–50). On the other hand, work-family and domestic and professional task conflicts could influence QoL and explain the higher techno-overload, techno-invasion, techno-complexity, and role overload reported more frequently in women than men (10, 51). Younger people have also reported lower QoL scores. It could be explained by the economic impact of the pandemic, uncertainty, and loneliness, as previously reported (52). In this sense, our results found that young teachers with more than six body regions with MSD are more at risk to have worse QoL in their mental component. In this line, by incorporating Age as a continuous variable in our regression models, it can be observed that as the teacher's age increases, there is a proportional decrease in the probability of having worse scores in the mental health domain of QoL, reinforcing the results of previous studies mentioned above on a greater impact of teleworking on younger teachers.

5 Limitations and strengths

Several limitations of the study can be identified. One of them refers to the cross-sectional design of the study. For this reason, it is impossible to ensure a causal association since it is impossible to guarantee the temporality criterion. It is possible that the sample needs to be representative of teachers in Chile. As we implemented an online survey, some teachers with limited internet access or use of digital tools may have yet to be able to participate in the study, possibly in rural areas or more peripheral to the city. However, the characteristics of the sample, in general, are similar to those of a previous study where randomized sampling and face-to-face surveys were carried out in various regions of Chile (16). On the other hand, the number of responses has been lower than initially expected. This may be due to non-response survey fatigue, which has been reported before and has been more significant during the pandemic due to limitations in face-to-face activities (53). To minimize response fatigue and improve the quality of the information, the implemented survey has paid particular attention to factors that have been reported to be essential for response fatigue, such as survey length, question complexity, and question type (54).

Additionally, some variables not considered in the analysis, such as socioeconomic level, hours of work per week, and teaching level, could be potential confounders in the relationship studied and could explain some of the results.

Among the strengths of the study, we highlight in the first place the simultaneous approach to the impact of the COVID-19 pandemic and the end of the academic semester on teachers' health. This issue is relevant to developing public and labor policies adapted to the current circumstances. Second, the study highlights the identification of particularly critical groups, such as women and younger teachers, highlighting the need to design specific and targeted interventions for these subgroups to address the challenges faced by teachers effectively.

6 Conclusion

This study provides insight into the impact of the COVID-19 pandemic during the end of the academic year on the health of teachers in Chile, specifically focusing on the prevalence of MSDs and their association with HRQoL. Our results indicate that working conditions during the critical period for COVID-19 at the end of the academic year have contributed to the increase of work stress and MSDs among teachers, negatively affecting their physical and mental health. The prevalence of MSDs is alarmingly high, with a marked prevalence in women and younger teachers, underscoring the need to consider gender and age dynamics in policy and public health responses.

Furthermore, this study highlights the direct relationship between MSDs and decreased HRQoL, suggesting that interventions to improve working conditions and ergonomics in telework settings are crucial. Public health policies and work practices must be adjusted to address these challenges, especially in health emergencies like the COVID-19 pandemic.

Finally, the results highlight the importance of conducting additional research to understand how working conditions during critical periods (e.g., remote work) effect teachers' health and to develop effective strategies to improve their quality of life. This study provides valuable evidence that can inform policy decisions and institutional practices to support teacher health and well-being in times of crisis and increased workload, such as the end of the academic year.

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 humans were approved by Ethics Committee at Pontificia Universidad Católica de Valparaíso (BIOEPUCV-H 393-2021). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

GV-F: Writing – review & editing, Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. CG-T: Writing – review & editing, Writing – original draft, Formal analysis, Data curation. MS-S: Investigation, Writing – original draft, Writing – review & editing. PL: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Writing – original draft, Writing – review & editing.

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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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Heterogeneous trajectories of perceived stress and their associations with active leisure: a longitudinal study during the first year of COVID-19

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Introduction: There is a plethora of literature on the dynamics of mental health indicators throughout the COVID-19 pandemic, yet research is scarce on the potential heterogeneity in the development of perceived stress. Furthermore, there is a paucity of longitudinal research on whether active leisure engagement, which typically is beneficial in reducing stress, might have similar benefits during times of major disruption. Here we aimed to extend previous work by exploring the dynamics of change in stress and coping, and the associations with active leisure engagement over the first year of COVID-19.

Methods: Data from 439 adults (M_{age}=45, SD=13) in Estonia who participated in a longitudinal online study were analyzed. The participants were assessed at three timepoints: April–May 2020; November–December 2020; and April–May 2021.

Results: Mean stress and coping levels were stable over time. However, latent profile analysis identified four distinct trajectories of change in stress and coping, involving resilient, stressed, recovering, and deteriorating trends. Participants belonging to the positively developing stress trajectories reported higher active leisure engagement than those belonging to the negatively developing stress trajectories.

Discussion: These findings highlight the importance of adopting person-centered approaches to understand the diverse experiences of stress, as well as suggest the promotion of active leisure as a potentially beneficial coping resource, in future crises.

KEYWORDS

perceived stress, coping, active leisure, person-centered approach, COVID-19 pandemic

1 Introduction

It is accepted that COVID-19 and the circumstances surrounding the pandemic exacerbated mental health around the world. The COVID-19 pandemic spread in many waves, and this was accompanied by varying levels of social and economic restrictions and the accumulation of potentially stressful life circumstances (1). The pandemic outbreak constitutes an acute, large-scale, and uncontrollable stressor with a long-term impact. The detrimental

impact of the pandemic on mental health has primarily been documented through the population-level increase in depression and anxiety symptoms (2, 3). The origin and the development of such mental health problems are consistently related to excessive stress [e.g., (4)], and these associations are aligned with the stress-vulnerability models of psychopathology (5, 6). These models explain the possible ways in which stressful experiences may trigger the onset of a mental health disorder, whether an individual is predisposed (i.e., vulnerable) to a mental health condition, and what role protective factors may play in these interactions. Numerous research evidence have linked high perceived stress not only to emotional disturbances such as anxiety (7) but also to physical health [e.g., hypertension, cardiovascular diseases (8)]. Identification of sub-populations with high risk of stress and interventions to reduce stress levels can potentially help to prevent later mental disorders (9).

The transactional stress model (10, 11) posits that a person's capacity to cope and adjust to life challenges is a consequence of interactions that occur between a person and their environment. The ability to cope with stress depends on how an individual evaluates the relevance of the stressors (primary appraisal) and whether a person believes to hold sufficient resources to relieve or remove the stressor (secondary appraisal). In line with the transactional stress model, Cohen et al. (12) argue that a psychological state of perceived stress (hereafter stress) occurs when a situation in a person's life is appraised as threatening or demanding and at the same time resources are insufficient to cope with the situation. However, this approach does not assume that certain life situations are inherently stressful but refers to the cognitive appraisal process where the cognitively mediated emotional response is given to the situation [e.g., (13)].

Several longitudinal studies among different age groups have investigated how stress levels may have changed during the pandemic. Most of these studies demonstrated a stable course of stress levels irrespective of the pandemic situation (14–16). Such findings have been explained considering the significant social and economic challenges (e.g., financial insecurities, changes in the working modalities, disruptions in the social life) that the pandemic brought in addition to the health crisis, and which together prolonged the risk of chronic stress. Salfi et al. (17) reported that stress levels even increased after the first lockdown period in the spring of 2020 and further plateaued by the second wave of the pandemic. They suggested that, in addition to a continuous societal and economic crisis, the lifting of restrictions in between the waves raised the perception of risk and thereby affected stress levels. Controversially, Gallagher et al. (18) demonstrated decreasing stress levels as the course of the pandemic continued and ascribed such findings to the presupposition that individuals become more resilient to the repercussions of the pandemic over time [see (19)].

Most of the previous longitudinal studies on the development of stress among adults during the COVID-19 pandemic have focused on the average changes (i.e., variable-centered approach), but the distinct courses of the stress over time (e.g., increasing for some, while decreasing for others) may bias the results and can obscure heterogeneous patterns (i.e., person-centered approach) of experiences. There is no reason to doubt that all the scenarios explained by the above-cited studies may have partly affected stress response throughout the pandemic but depended on many contextual and person-centered factors. A meta-analysis of the impact of COVID-19 on mental health indicators showed substantial heterogeneity among the findings of longitudinal studies (20), which suggests that there were no ubiquitous effects on mental health. Several longitudinal studies (21–23) have scrutinized the possibility of distinct courses of the change in symptoms of mental disorders (e.g., depression and anxiety). These studies found heterogeneous trajectories of symptoms during the pandemic, showing that approximately 70–80% of the population consistently reported no symptoms of mental disorders. They concluded that for smaller groups in the population symptoms of mental disorders increased, or in contrast decreased, as the pandemic continued its course. These findings add to evidence that lockdowns did not have evenly detrimental effects on mental health and that a certain proportion of people were psychologically resilient to the circumstances, or some might have even benefitted from the new work and life patterns.

A few studies have also employed a person-centered approach to examining perceived stress and stressor exposure based on cross-sectional data from the beginning of COVID-19. These studies have identified distinct profiles of pandemic-related exposure to stressors in adults (24) and heterogeneous profiles of stress and coping levels among pregnant women (25). However, such cross-sectional studies do not allow the examination of potentially distinct trajectory groups of stress developments over time. To our knowledge, the only published longitudinal investigation employing a person-centered approach for the examination of changes in perceived stress levels during the pandemic has been conducted among adolescents [age 12–15 years, (16)]. This study found no support for distinct trajectories of perceived stress. Adolescents (ages 12–15 years) were characterized by homogeneously stable and moderate stress levels during the first year of the pandemic. The authors explained this finding by assuming that adolescents commonly experience stress regardless of the pandemic, and thus pandemic-related stressors did not greatly affect their normative stress levels. To the best of our knowledge, no studies have scrutinized in adults the potential heterogeneity of trajectories (i.e., change over time) of perceived stress during the pandemic, and the findings of the previous variable-centered longitudinal studies on perceived stress are inconsistent (14, 15, 17, 18).

An all-embracing socio-historical event such as the COVID-19 pandemic provides a unique occasion to identify different paths of adaptation or maladaptation to persistent stressors and to examine coping resources that help individuals manage the effects of such drastic circumstances. Engagement in leisure activities is one such behavioral coping resource. Exploring how leisure contributes to relieving and counteracting stress has been studied for decades. Coleman and Iso-Ahola (26) first proposed in their theory that leisure facilitates social support and generates enduring beliefs of self-determination, which buffers the negative impact of stress on mental and physical health. In addition, Iwasaki and Mannell (27) described how leisure may act also as a strategy for palliative coping (i.e., temporarily diverting from stressful events to regroup and gain perspective) and mood enhancement (i.e., reducing negative mood and enhancing positive mood). Empirical studies have shown evidence that when people under stressful circumstances are engaged in leisure activities, the stress is reduced and therefore the negative impact of the stress on health is also reduced (28–31). Zawadzki et al. (32) have also identified the real-time within-person processes such that when individuals reported engaging in leisure, they had lower stress compared to when not engaged in leisure activity. Iwasaki (33, 34) has shown that leisure coping predicted positive coping outcomes even beyond the effects of general coping strategies (e.g., problem-focused coping unrelated to leisure).

Although no consensus definition of leisure engagement is imposed, prior research has mostly treated it as a behavioral

concept—defined as the frequency or the amount of time in which one participates in leisure activities outside work duties, personal maintenance, and other obligations (35). The classification of leisure activities has neither been consistent in the literature. Leisure activities have been divided either as passive (also referred to as "low-demand" or "time-out" leisure) or active (also referred to as "high-demand" or "achievement" leisure) (36–38). Prior research has shown that engagement in active leisure activities (e.g., hobbies, physical, and nature-based activities) is more consistently linked with the benefits of stress reduction (30, 39, 40). Caltabiano (41) identified that outdoor activities/sports and hobbies were the most significant leisure activities to reduce stress. Such activities often involve using both physical and mental energy and often happen with other people. Iwasaki et al. (42) have emphasized that active leisure is more than just physical activities, and less physically active forms of leisure should not be undervalued in leisure coping processes. It can be assumed that active leisure activities involve ingredients (e.g., social interaction, creative expression, cognitive stimulation) to stimulate a wider range of mechanisms (e.g., psychological, biological, social) which may simultaneously play a role in alleviating stress [see (43)].

However, it has been shown that paradoxically people tend to reduce their participation in active leisure when they are stressed, which can be caused by an intuitive preference for passive leisure during hectic times or by a not deliberate reaction to the levels of stress (44). Thus, the relationship between active leisure and stress could be bidirectional, with stress also affecting motivation to engage in active leisure. At the same time, the options for active leisure were often restricted during the pandemic, possibly further limiting the engagement in active leisure. Previous studies have reported that the number of leisure activities people engaged in decreased (45), and engagement in physical and outdoor activities was reduced (46) during the first year of COVID-19.

Several studies have examined leisure engagement as a potential coping resource also during COVID-19. Based on the ecological momentary assessment data, it has been shown that engaging in free time was associated with lower stress levels during the pandemic (47). Existing findings also suggest that changes in leisure engagement (compared to pre-COVID) were related to poorer mental health (46, 48) and people who felt their current leisure engagement level fell below their desired level reported lower mental well-being (46). Takiguchi et al. (45) have shown in their longitudinal study that engaging in a larger number of leisure activities during the pandemic reduced depressive symptoms through resilience. However, longitudinal research is scarce on whether active leisure engagement, which is usually beneficial for stress reduction, might have similar benefits in times of major disruptions of the pandemic. It can be assumed that heterogeneous trajectories (if they emerged as such) of perceived stress during the pandemic were characterized by distinct levels of active leisure engagement. As engagement in active leisure is linked with the benefits of stress reduction (30, 39–41), it can be further assumed that higher engagement in active leisure was associated with positively developing (i.e., decreasing) stress trajectories. It can be expected that lower engagement in active leisure was related to negatively developing (i.e., increasing) stress trajectories.

The present study aims to explore the dynamics of change in stress and its associations with active leisure engagement as a stress coping resource over the first year of the COVID-19 pandemic. The study seeks to expand previous research by examining varying trajectories of change in stress (i.e., differences in the level, and the direction of change) and the interplay between the changes in stress and active leisure engagement over time. By doing this, we could gain a more differentiated understanding of the pandemic's complex impact on stress levels and contribute to formulating guidance for stress-relieving behaviors in potential future lockdowns and pandemics.

As this study is exploratory by nature, to achieve the aim of the study, the following research questions are examined:

(1) How did perceived stress change over the first year of COVID-19?
(2) Can distinct trajectories be identified based on perceived stress levels over the first year of COVID-19?
(3) How was active leisure engagement related to belonging to a certain stress trajectory over the first year of COVID-19?

2 Materials and methods

2.1 Procedure and sample

This study is part of a longitudinal investigation that focuses on the dynamics of mental health and well-being during the COVID-19 pandemic in Estonia. Approval for conducting the research was granted by the Tallinn University ethics committee (April 15, 2020; decision no 6). Voluntary participants were recruited for the survey via online ads (with the link to the survey) in news portals (e.g., Delfi.ee), and social media channels (e.g., Facebook). The entire study was conducted online using the SurveyMonkey platform. Estonian-speaking adults aged 18 or older currently residing in Estonia were eligible to participate. No compensation was offered as an incentive to participate. After reading an information page and confirming their informed consent, participants completed the survey. The datasets across three assessments were merged based on unique anonymized identification numbers (using SPSS). The data was collected over three timepoints across the first year of the COVID-19 pandemic: at Time 1 (T1 – April 20th until May 11th, 2020); at Time 2 (T2 – November 9th until December 6th, 2020); and at Time 3 (T3 – April 27th until May 23rd, 2021).

At T1, 530 participants were recruited for the longitudinal study, of whom 257 responded at T2 and 249 responded at T3. An additional 212 participants were recruited at T2 (via a similar strategy as at T1), of whom 142 responded also at T3. Two hundred participants responded to the survey at all three timepoints. To be able to analyze potential changes, those who had responded to the survey at least twice were included in the data analysis. This strategy resulted in a sample size of 448, which was predominantly composed of females (92.4%). Participants' ages ranged from 18 to 81 ($M = 45.37$, $SD = 12.97$). 98.2% of the participants reported their native language as Estonian. In terms of relationship status, 31% were single (including widowed, divorced) and 69% were in a relationship (including married, cohabitation, civil partnership). 82.1% of the participants were employed, and 17.9% were not employed (including students, and pensioners).

Figure 1 shows the pandemic situation in Estonia during the three data collection periods. In spring 2020, while the first measurement (T1) occurred, the State of Emergency was in effect in Estonia, which

meant that the availability of medical services was decreased. Students were transferred to distance learning; public gatherings were banned. Along with restrictions in traveling, all leisure facilities were closed, excluding parks and recreational trails if following the "2 + 2 rule" (i.e., a maximum of two people together at one time, keeping a minimum distance of two meters apart from others). In autumn 2020 (T2), after a relatively virus- and restriction-free summer, the second wave of the virus arrived, and the number of new cases was rising rapidly. However, by that time, lighter restrictions (compared to T1) were only being gradually re-introduced—schools were still open and leisure facilities were so far mostly available. The third data collection, in spring 2021 (T3), followed a period in which the numbers of new cases and hospitalizations had been the highest observed throughout the pandemic, and the government had re-imposed stricter restrictions lasting until May 2021. Widespread vaccination against COVID-19 in the general population (age groups below 60 years) did not start until mid-May 2021 in Estonia (49) when our third data collection (T3) was ending.

2.2 Measures

2.2.1 Perceived stress

Perceived stress was assessed using the Estonian version of the 10-item Perceived Stress Scale [PSS-10; (50)]. Participants were asked to indicate on a five-point scale (0 = never, 4 = very often) how often they felt or thought a certain way during the last 4 weeks (e.g., "How often did you feel unable to control the important things in life?"). Originally, this self-reported questionnaire was designed to measure "the degree to which situations in one's life are appraised as stressful" [(12), p. 385], consisting of six positively (items 1, 2, 3, 6, 9, 10) and four negatively (items 4, 5, 7, 8) worded items.

Although the scale was developed to capture stress as a single latent factor, following empirical studies in different contexts and languages using confirmatory factor analysis (CFA) techniques have predominantly shown that a two-factor model fits the data better than a unidimensional model (51–53). These two related factors have been described as (a) *perceived stress* (or helplessness; negatively worded items) and (b) *perceived coping* (or self-efficacy; positively worded items). In favor of the two-factor solution, authors have pointed out that the content of positively phrased and negatively phrased items do not coincide (54); and the two factors have shown distinct predictive qualities (55). For the Estonian version of the PSS-10, only the preliminary psychometric properties have been previously reported, based on principal component analysis and internal reliability coefficients for the unidimensional solution of the scale (56). Thus, CFA was conducted for the PSS-10 to examine whether a one- or two-factor solution fits the data best. Our data supported the two-factor model of the Estonian version of the PSS-10. Hence, the current study treated perceived stress as a two-dimensional construct of stress and coping. Longitudinal measurement invariance (MI) analysis was also conducted to ensure whether comparisons of stress and coping scores across the three timepoints were meaningful (57). Our data showed configural invariance and partial scalar and metric invariance in three timepoints, as factor loadings and item intercepts were allowed to vary for two items. The detailed results of CFA and MI are provided in Supplementary material. Cronbach's alphas showed good internal consistency for both the stress and coping items at each time point (α = 0.83–0.88). Mean values were calculated for both scales at each timepoint and used in further analyses.

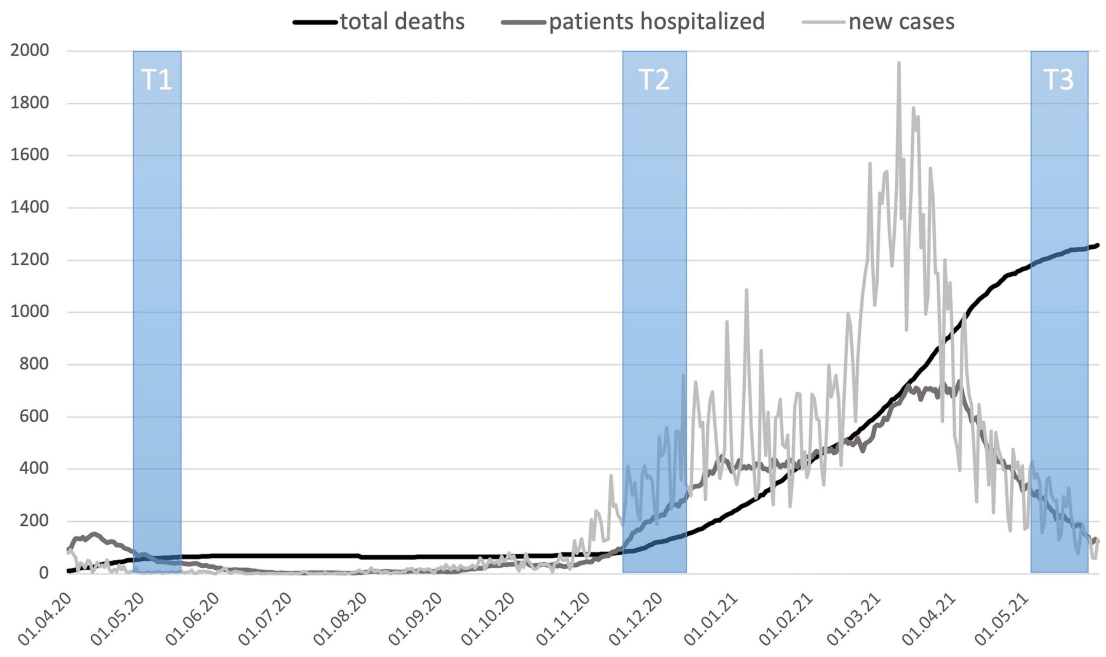

FIGURE 1
Situation during three data collection time windows (T1–T3): the number of COVID-19 deaths, patients hospitalized, and new cases per day. Source: Compiled by authors based on data provided by TEHIK (49).

2.2.2 Active leisure

Active leisure engagement was measured with a formative scale, comprising the frequency of respondents' participation in three leisure activities: (1) *engaging in physical activities* (e.g., sports, walking); (2) *spending time in natural settings* (e.g., parks, forests); (3) *participating in main hobby/pursuit*. A similar aggregation approach has been used by numerous previous studies when the goal has been to capture a broader leisure activity domain with one indicator [e.g., (36, 46, 58)]. The three active leisure activities were selected based on literature: their stress-alleviating qualities have been widely described (30, 39, 40); and they have been consistently linked with better mental health, both before (59) and during the pandemic (48). Although our choice of leisure activity items was not all-inclusive, it tapped major active leisure engagement facets relevant to this study (39–43). Participants were asked to rate how often they spent time doing each of the activities during the last month. Response options were: 1 = "less than once a week or never"; 2 = "1–2 times a week"; 3 = "3–4 times a week"; 4 = "5–6 times a week"; 5 = "every day"; and 6 = "2 or more times a day." The mean aggregation of the three activities was used, which weights each activity equally. Higher scores indicate higher active leisure engagement.

2.3 Statistical analyses

Since the final sample also included those participants who had missed one of the data collection points, the dataset had missing values of perceived stress, perceived coping, and active leisure engagement at different timepoints (31.7% of cases at T1; 10.9% at T2; 12.7% at T3). Regression imputation was used to preserve all cases and to fill in the missing values (60). For the imputation models of stress and coping, available scores of both constructs of the other two timepoints were used as predictors. In the regression imputation models for active leisure engagement, available scores of the other two timepoints of the same construct were used as predictors. Next, the stress and coping variables were scrutinized for the absence of multivariate outliers. Nine cases were eliminated as multivariate outliers, which resulted in the final sample size of 439. Further, repeated measures analysis of variance (ANOVA) controlling for covariates (age and gender) was used to examine changes in stress and coping over time. Violations of sphericity were addressed using Greenhouse–Geisser corrections.

Next, exploratory latent profile analysis (LPA) was used to identify distinct trajectories of perceived stress across the three timepoints. LPA as a person-centered technique allows the identification of heterogeneous subpopulations comprising distinct response patterns across time. Deciding the number of subgroups (i.e., trajectories) is based on the grouping precision and the comparative fit indices, as well as the interpretability of subgroups (61). Both stress and coping factors were modeled in one LPA with the variances allowed to vary between groups. Also, the covariance between stress in three timepoints and the covariance between coping in three time points were allowed to vary between groups. The fit of models with the different number of profiles was compared using the Akaike information criterion (AIC), the Bayesian information criterion (BIC), the sample-size adjusted Bayesian information criterion (aBIC), the Vuong-Lo-Mendell-Rubin likelihood ratio test (VMLR), bootstrapped likelihood ratio test (BLRT), a measure of entropy, interpretability of the observed trajectories, and the size of the profiles (61). After model selection, participants were classified according to their most likely profile membership.

Finally, a mixed ANOVA model controlling for age was run to examine the interaction between changes in active leisure engagement (time as a within-subjects factor) and trajectories of stress and coping (as a between-subjects factor). Gender was not included as a covariate due to the low number of men (<5) in some of the stress trajectory groups found with LPA. The assumption of homogeneity of variances was tested by Box's M test. Violations of sphericity were corrected by applying a Greenhouse–Geisser correction. For *post hoc* multiple comparisons, Bonferroni adjustment was used.

CFA and invariance tests were performed in R version 4.1.3 (62), using *lavaan* package (63). Regression imputations were performed in R package *mice* (64). LPA was conducted using Mplus 8.8 (65). ANOVAs were performed in SPSS version 28.

3 Results

The means, standard deviations, ranges, Cronbach's alphas, and bivariate correlations for all the study variables are shown in Table 1.

3.1 Changes in stress and coping: variable-centered approach

First, changes in average perceived stress and perceived coping during the first year of the pandemic were investigated using repeated measures ANOVA. There were no significant changes found across three timepoints in mean scores of stress, F (1.88, 818.60) = 0.83, $p = 0.43$, $\eta_p^2 = 0.002$, nor in mean scores of coping, F (2, 872) = 0.84, $p = 0.43$, $\eta_p^2 = 0.002$.

3.2 Distinct trajectories of stress and coping: person-centered approach

To identify potential distinct trajectories of stress during the first year of the pandemic, a latent profile analysis was conducted on perceived stress and coping scores measured at three timepoints. Six sets of LPA-s were compared. The drop of AIC and aBIC values decelerated, and BIC value did not further decrease, after the four-trajectory solution (see Table 2 for the fit indices, entropy, and group sizes). The five-trajectory solution did not reveal any new patterns of change, and the more parsimonious four-trajectory model was chosen as it had the best interpretability.

Figure 2 presents the stress and coping trajectories over three timepoints for four groups identified in the LPA model. The first trajectory, labeled as '*Stressed*' (15%, $N = 66$), was characterized by a high stress level and a low coping level throughout the study. In the second trajectory, labeled as "*Deteriorating*" (27%, $N = 120$), the participants had relatively low stress and high coping at the beginning of the pandemic, but it was followed by a sustained incline in stress and decline in coping throughout the first year of the pandemic. The largest proportion of participants (33%, $N = 144$) belonged to the third trajectory labeled as "*Resilient*." The participants in this group had consistently low stress and high coping across the first year of the

TABLE 1 Means (M), standard deviations (SD), ranges, Cronbach's alphas (α), and correlations between study variables.

	M	SD	Range	*α*	1	2	3	4	5	6	7	8
1. Perceived stress T1[a]	1.75	0.76	0.17–4	0.86	–							
2. Perceived stress T2[a]	1.74	0.79	0–4	0.88	0.54	–						
3. Perceived stress T3[a]	1.73	0.80	0–4	0.88	0.52	0.70	–					
4. Perceived coping T1[a]	2.53	0.66	0–4	0.87	−0.71	−0.50	−0.50	–				
5. Perceived coping T2[a]	2.49	0.71	0–4	0.83	−0.42	−0.72	−0.59	0.61	–			
6. Perceived coping T3[a]	2.48	0.74	0–4	0.86	−0.37	−0.55	−0.71	0.66	0.70	–		
7. Active leisure engagement T1[b]	3.34	1.07	1–6	–	−0.19	−0.22	−0.21	0.23	0.19	0.20	–	
8. Active leisure engagement T2[b]	3.00	1.12	1–6	–	−0.13	−0.23	−0.25	0.17	0.21	0.22	0.70	–
9. Active leisure engagement T3[b]	3.17	1.15	1–6	–	−0.14	−0.26	−0.27	0.17	0.23	0.28	0.64	0.69

$N = 439$; all correlations were statistically significant at $p < 0.01$.
[a]Scale from 0 to 4.
[b]Scale from 1 to 6.

TABLE 2 Fit statistics for comparison of different longitudinal latent profile models of perceived stress and coping.

Number of profiles	*N*	AIC	BIC	aBIC	Entropy	VLMR *p*-value	BLRT *p*-value
1	439	4,886	4,959	4,902	–	–	–
2	191/248	4,624	4,775	4,658	0.74	0.04	<0.01
3	215/120/104	4,522	4,751	4,573	0.76	0.16	<0.01
4	**66/120/144/109**	**4,426**	**4,732**	**4,494**	**0.78**	**0.03**	**<0.01**
5	104/70/52/85/128	4,363	4,747	4,448	0.81	0.27	<0.01
6	83/105/94/28/73/56	4,339	4,800	4,442	0.82	0.76	0.14

N, group sizes; AIC, Akaike information criterion; BIC, Bayesian information criterion; aBIC, sample-size adjusted Bayesian information criterion; VLMR, Vuong-Lo-Mendell-Rubin likelihood ratio test; BLRT, bootstrapped likelihood ratio test. Estimates of the chosen four-trajectory solution are bolded.

pandemic. In the fourth trajectory, labeled as "*Recovering*" (25%, $N = 109$), the participants reported relatively high levels of stress at the beginning of the pandemic. However, these participants "bounced back" over time, as indicated by a decline in stress and an incline in coping throughout the next two timepoints.

Next, we tested if the four groups identified in the LPA were characterized by differences in age, relationship status, or work status. A one-way ANOVA was used to compare the mean age between four stress and coping groups. There was no statistically significant difference in age between the four groups [$F(3, 435) = 2.36$, $p = 0.07$]. Chi-square tests were used to examine if the group membership was related to relationship status or work status. Relationship status was dichotomized into "single" (incl. Widowed, divorced) and "in a relationship" (incl. Married, cohabitation, civil partnership). Work status was dichotomized into "employed" and "not employed" (incl. Student, pensioner). Group membership was neither related to relationship status [$X^2(3, N = 439) = 1.39$, $p = 0.71$] nor to work status [$X^2(3, 439) = 3.57$, $p = 0.31$].

3.3 Changes in active leisure engagement in relation to distinct trajectories of stress and coping

Changes in active leisure engagement were investigated in relation to distinct trajectories of stress and coping. Specifically, a 4 (trajectories) X 3 (timepoints) mixed ANOVA model controlling for age was run to examine the interaction effect between trajectories of stress and coping (group membership as a between-subjects factor) and time (as a within-subjects factor) on active leisure engagement. The mixed ANOVA results are illustrated in Figure 3.

There was a main effect of time on active leisure engagement, $F(1.96, 850.85) = 9.68$, $p < 0.001$, $\eta_p^2 = 0.02$. Bonferroni adjusted pairwise comparisons showed a quadratic effect such that active leisure engagement decreased ($p = 0.001$) from spring 2020 to autumn 2020, and then increased ($p = 0.001$) from autumn 2020 to spring 2021 (see Table 1 for means and SDs). There was a main effect of stress and coping trajectory membership on active leisure engagement, $F(3, 434) = 12.18$, $p < 0.001$, $\eta_p^2 = 0.08$. Bonferroni adjusted pairwise comparisons revealed that participants belonging to the "Resilient" ($M = 3.46$, SD = 0.94) trajectory reported higher active leisure engagement than those in the "Stressed" ($M = 2.93$, SD = 0.93) and "Deteriorating" ($M = 2.83$, SD = 0.93) trajectories (both comparisons $p < 0.001$). In addition, participants belonging to the "Recovering" ($M = 3.30$, SD = 0.93) trajectory reported higher active leisure engagement than those in the "Deteriorating" ($M = 2.83$, SD = 0.93) trajectory ($p < 0.001$). The interaction between the stress trajectories and changes in active leisure engagement was not found, $F(5.88, 850.85) = 1.30$, $p = 0.26$, $\eta_p^2 = 0.009$, failing to prove that changes in active leisure engagement were related to distinct trajectories of stress and coping.

4 Discussion

The present study aimed to explore the dynamics of change in stress and its associations with active leisure engagement as a stress coping resource during the first year of the COVID-19 pandemic. Our

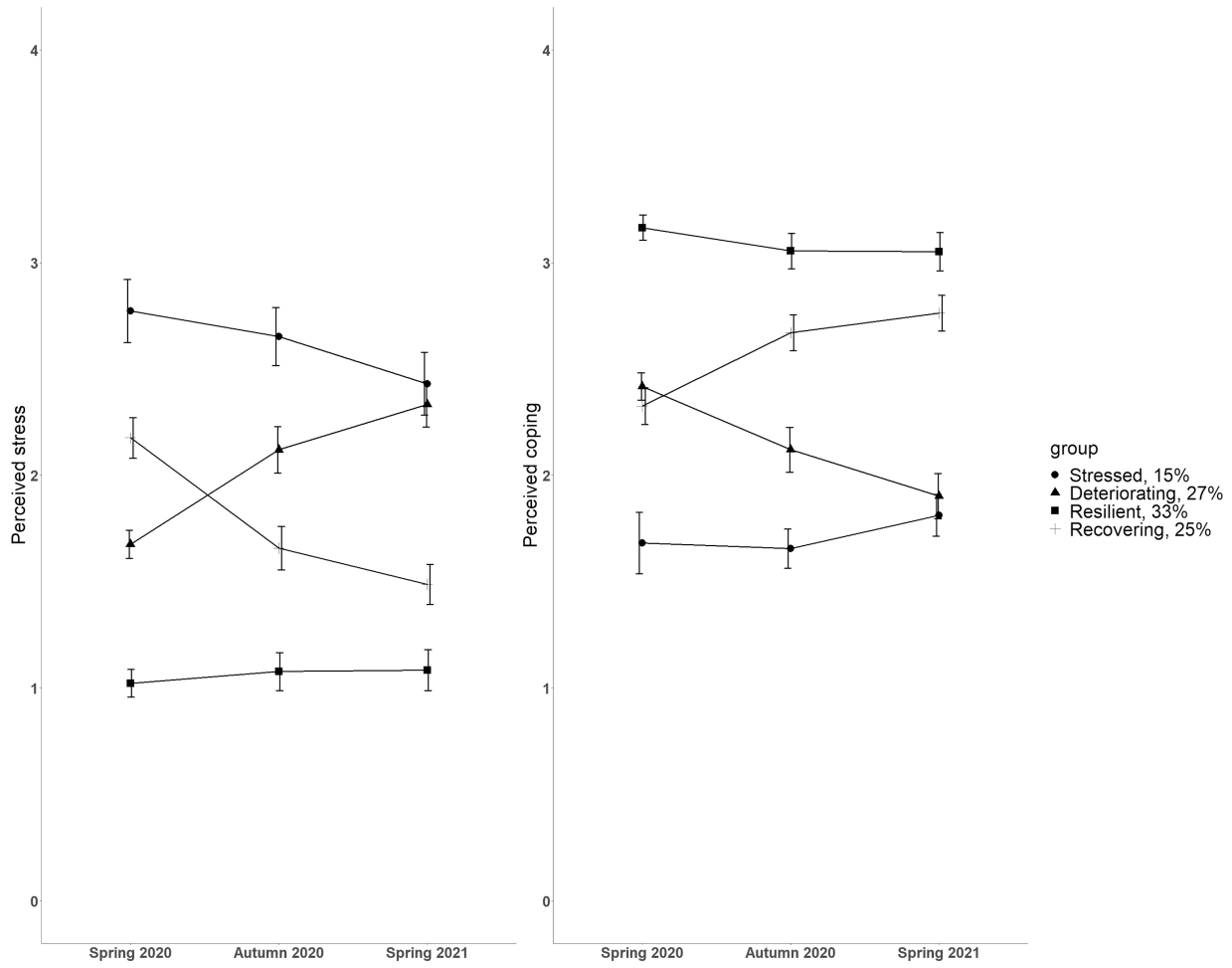

FIGURE 2
Estimated mean perceived stress (left) and perceived coping (right) scores from the four-trajectory solution of the latent profile analysis across three timepoints. Each group indicates a distinct trajectory during the first year of the pandemic. Both scales from 0 to 4. Error bars represent 95% confidence intervals.

person-centered analytical approach with longitudinal data adds to previous research by identifying heterogeneous trajectories of change in stress among adults. In addition, the current study extends previous research by demonstrating how stress trajectories were characterized by distinct levels of active leisure engagement in times of major social and economic disruptions of the pandemic.

Addressing the first research question, the results from variable-centered analyses indicated that perceived stress and coping levels were stable irrespective of the situation over the first year of the pandemic. Such finding coincides with many of the longitudinal studies on stress levels during the pandemic (14–16). However, as our subsequent person-centered analyses showed, the depiction obtained through the conventional variable-centered approach failed to capture the complexity of the situation.

Our second research question aimed at identifying potentially distinct stress trajectories. The person-centered (latent profile) analyses, based on perceived stress and coping scores measured at three timepoints, revealed a more nuanced understanding of temporal stress dynamics during the first year of the pandemic among adults. Four heterogeneous trajectories of change in stress and coping were identified.

The largest proportion of the sample belonged to the *Resilient* group (33%), with consistently stable low stress and high coping across the year. This group was composed of individuals who tended to appraise the circumstances as not harmful for them and/or perceived their resources as sufficient to cope with the demands, regardless of the varying conditions throughout the first year of the pandemic (11, 66). The clear emergence of such a group also supports Bonanno's (67) work on arguing how a substantial proportion of individuals endure aversive events with minor effects on their healthy functioning.

One-quarter of the sample consisted of *Recovering* individuals, who experienced relatively high levels of stress during the first spring of the pandemic, but "bounced back" during the following year. This favorable adaptation trajectory could be ascribed to novelty, unpredictability, and initial difficulties with new obligations that caused acute stress during the first wave of the virus, but over time adaptation to the conditions occurred and the situation was appraised as less threatening [see (19, 68)].

Over a quarter of our sample belonged to the *Deteriorating* trajectory, with relatively low stress and high coping at the beginning of the pandemic which was followed by a sustained incline in stress and decline in coping over the study period. A continuous societal and

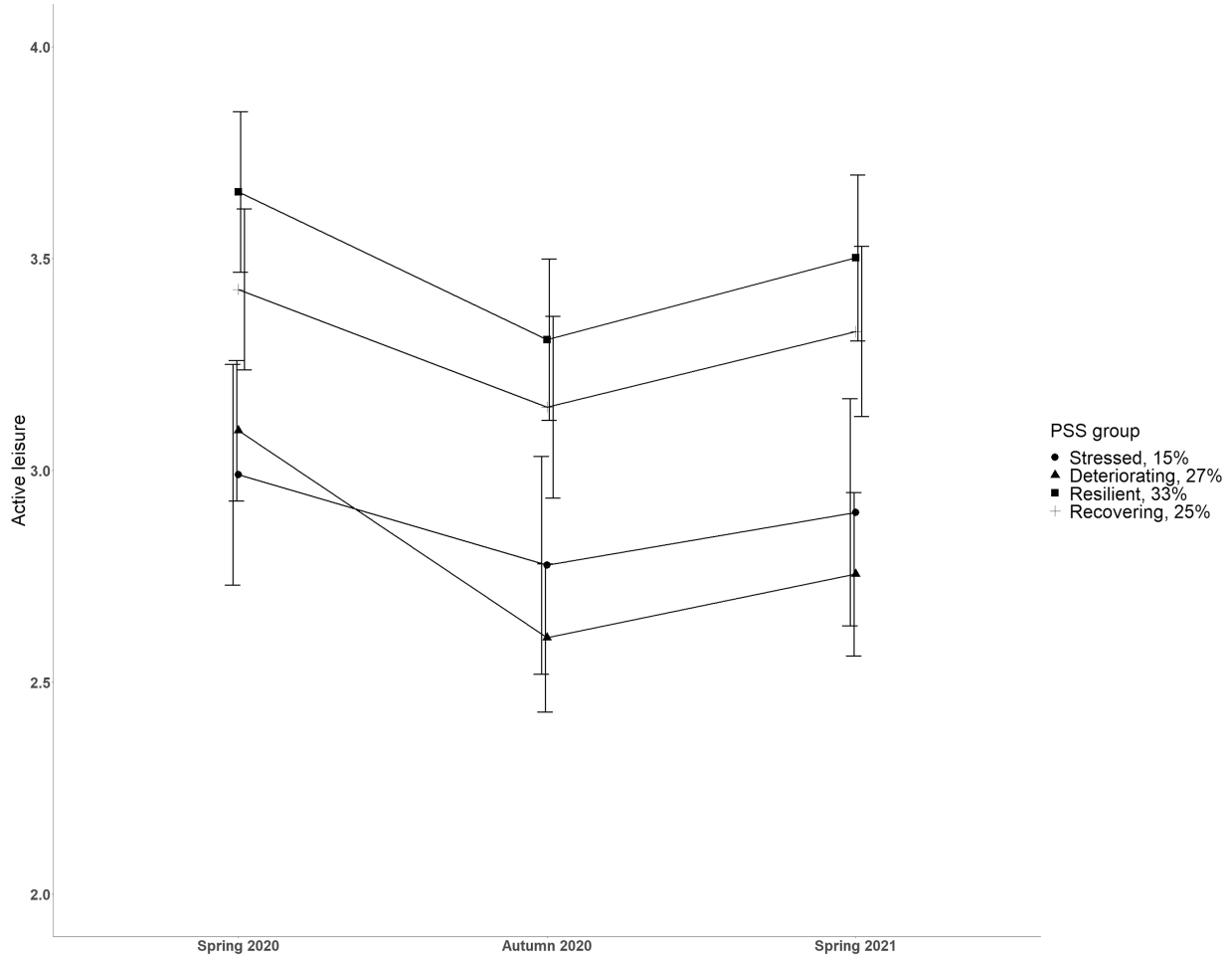

FIGURE 3
Estimated mean active leisure engagement scores across three timepoints according to four distinct stress trajectories. Scale from 1 to 6. Error bars represent 95% confidence intervals.

economic crisis, loss of hope for a quick end to the pandemic, and a possible increase in perception of health risks (17) may have played a role for the individuals in the deteriorating trajectory.

The smallest proportion of our sample belonged to the *Stressed* group, who experienced high stress and low coping levels throughout the study period. Since we did not possess pre-pandemic data on our sample, it is not possible to credibly attribute high stress levels to the pandemic. Nevertheless, these patterns of increasing or persistently excessive stress levels call for particular attention.

Our analyses demonstrated that focusing only on the average changes (i.e., variable-centered approach) obscures the variability of the temporal changes in stress during the pandemic and could lead to oversimplified inferences. As opposed to the assumption of uniform effects of the varying circumstances of the pandemic on stress levels (14, 17, 18), our study highlights that there was a clear heterogeneity of temporal changes in perceived stress across the first year of the pandemic. More generally, this means that the identification of different subgroups in the temporal process of stress provides an opportunity to describe differences in the details of effective coping with stress. Contrary to our results, a study conducted among adolescents found no evidence of heterogeneity in stress trajectories during the first year of the pandemic (16). We assume that the different target populations of these studies explain the discrepancy in findings. One possible explanation is that changes in the daily routine of adults were more heterogeneous compared to adolescents (e.g., interruptions in the typical school routines were similar for all students). Among adults, previous studies on mental disorder symptoms during the pandemic that employed a person-centered approach, have consistently shown distinct trajectories of the symptoms' development (21–23) and thus, support our findings considering the link between stress and psychopathology (6). Interestingly, the four trajectories also overlap with the prototypical outcome trajectories of human stress responses after potentially traumatic life events [see (68)]. It seems that continuous and potentially stressful conditions of the pandemic (i.e., chronic events) were followed by a similar heterogeneity of stress responses across time, as have been observed after short-term aversive life events (i.e., acute events). When considering the socio-demographics potentially associated with the four stress trajectories, our analysis indicated that the distinct trajectories could not be attributed to age, being single (vs. in a relationship), or being employed (vs. not employed). This partially contradicts previous findings which have consistently shown that younger age is related to a higher risk for negatively developing mental health trajectories (21–23, 68).

Addressing our third and final research question, active leisure engagement across three timepoints was investigated in relation to distinct trajectories of stress and coping. We found that the data collection period had a small effect on average active leisure engagement levels. Even though in the autumn of 2020 there were fewer restrictions on leisure activities than in the rest of the data collection periods, in the autumn of 2020 our study participants were less engaged in active leisure, compared to the spring of 2020 or the spring of 2021. Thus, this finding can be attributed rather to a seasonal effect, as inclement and uncomfortable weather conditions in north temperate zones in autumn have been shown to reduce the frequency of active leisure engagement (69).

The participants' active leisure engagement levels were found to differ according to their stress trajectories membership irrespective of the timepoint of assessment. As it was assumed, participants belonging to the positively developing stress trajectories reported higher active leisure engagement than those belonging to the negatively developing stress trajectories (specifically, *Resilient* compared to *Stressed* and *Deteriorating*; *Recovering* compared to *Deteriorating*). Thus, our findings not only support existing studies (30, 39, 40, 47) but also extend previous studies by indicating a potentially preventive effect of active leisure engagement on perceived stress during times of crises (while options for leisure are often limited). Importantly, we cannot rule out the possibility of a bidirectional relationship between stress levels and active leisure engagement. It has been previously shown that perception of stress may negatively affect motivation to engage in active leisure (44). The interaction effect between the changes in active leisure engagement across time and the stress trajectories was not found in our study, indicating that distinct developments in stress during the pandemic were not attributable to the addition of, or shrinkage in, active leisure. However, a slight tendency toward such an effect was noticeable (Figure 3), where individuals in the *Deteriorating* stress trajectory tended to decrease their active leisure engagement between spring and autumn 2020 more than individuals in other trajectories; and it warrants attention in future research.

5 Limitations

Despite our contributions to a better understanding of the complex temporal dynamics of stress and its longitudinal associations with active leisure engagement in times of major social and economic disruptions, our research has several limitations. First, based on our observational data, we cannot be sure of the direction of associations, and intervention studies are needed to infer causality. A clear limitation is the absence of pre-pandemic data on our sample that would have facilitated a more detailed interpretation of the stress trajectories, and their associations with active leisure engagement. Caution should be taken when interpreting stress levels as 'due to the pandemic' since such a supposition remains speculative. Second, we cannot rule out self-selection bias that may have occurred using an online survey; health-conscious people may have been more interested in participating in a mental health study. Most concerning is the underrepresentation of males (7.6%) in our sample. Thus, we must be especially careful when making inferences about men. Challenges with male recruitment are widely documented, especially in online public health surveys (70). Still, we could not overcome this issue because the data collection needed to be urgently started to study this unpredictable period of the pandemic. Third, additional person-related confounders (e.g., health status, contracting the virus, job insecurity, social support, personality traits) and environmental factors such as season might have influenced our findings. These variables were not included in our study, and we recommend accounting for them in future research. Finally, a rather broad measure of active leisure engagement (i.e., aggregation of three activities) was used in our study, and future research should consider scrutinizing the possible differential and additive effects of specific leisure activities.

6 Conclusion

Our findings indicate substantial variabilities in the level and in the direction of change in stress during an all-embracing socio-historical crisis. The study highlights the importance of considering individual differences in stress appraisal and adopting person-centered approaches to understand the diverse experiences of stress and coping during future crises. Heterogeneous trajectories of perceived stress were characterized by distinct levels of active leisure engagement. Our findings extend previous studies by pointing to the stable link between higher active leisure engagement and lower perceived stress during the pandemic while options for active leisure were often limited. We highlight the importance of promoting and facilitating opportunities for active leisure as a potentially beneficial coping resource during times of crisis. As male participants were underrepresented in our study, special caution should be taken when generalizing the findings to men.

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 study involving humans was approved by Tallinn University ethics committee. The study was conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

KKu: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing, Visualization. A-LJ: Conceptualization, Data curation, Formal analysis, Visualization, Writing – review & editing. AP: Conceptualization, Methodology, Writing – review & editing. KKa: Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Writing – review & editing.

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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.2024.1327966/full#supplementary-material

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Psychological status of medical security teams in Winter Olympic Games and Paralympics under COVID-19

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Background: Medical security work for the 2022 Beijing Winter Olympic and Paralympics faced enormous challenges under COVID-19. This study aimed to investigate the mental status of those medical team members to provide a reference for scientifically implementing medical security services for large-scale events.

Methods: In this prospective cohort study, the Patient Health Questionnaire-9, Self-rating Anxiety Scale, General Self-Efficacy Scale, and Psychological Questionnaire for Emergent Events of Public Health (PQEEPH) were administered to 145 members of the medical team. A generalized mixed linear model was used to analyze the impact of work duration, position, on/off rotation, and gender on psychological status.

Results: Work duration significantly impacted depression, anxiety, self-efficacy, and all dimensions of PQEEPH. Women scored higher than men in the PQEEPH dimensions of depression, neurasthenia, fear, and total score. Working status affected the dimensions of depression, neurasthenia, and total score. Deterioration in emotional state became apparent in the fourth week and recovered 1 week after the task concluded, while self-efficacy decreased from beginning to end.

Conclusion: All the medical team members experienced emotional deterioration and decreased self-efficacy in medical security tasks. To maintain a medical team's psychological wellbeing during large-scale activities, rotation times should be set reasonably, and adequate mental health services should be provided.

KEYWORDS

anxiety, depression, emotional responses, mental health, public health emergencies, self-efficacy

1 Introduction

The Olympic Games are a major traditional international sporting event. Hosting the Games can not only spread the Olympic spirit and promote international exchanges, but also demonstrates the host country's soft power (1). However, the mass movement of people and large gatherings entail many challenges related to emergencies and public health issues (2).

Furthermore, the potential risk of spreading infectious diseases could endanger the health system of the city, country, or region where the event takes place (3). The COVID-19 outbreak in December 2019 caused a global pandemic. The uneven vaccination rate, declining immunity, and emergence of new COVID-19 variants have brought new challenges to hosting major international sporting events (4). The pandemic caused the Tokyo 2020 Summer Olympic and Paralympic Games to be postponed for the first time ever. In November 2021, the World Health Organization reported about the new "Omicron" variant of COVID-19 (i.e., variant B.1.1.529) (5) that had enhanced transmissibility, raising concerns for public health amid mass gatherings, including sporting events. This presented greater challenges to large-scale crowd movements, and research shows that the pandemic is a hybrid threat comparable in scope to terrorism (6). The Olympic medical service team has also faced challenges associated with the pandemic (3). The 2016 Rio Olympics medical security team shouldered heavy responsibility under the Zika virus epidemic (7), and the COVID-19 pandemic has been even more complicated. In China, the COVID-19 pandemic has fundamentally changed people's living conditions (8). Against such a grim backdrop, the 2022 Beijing Winter Olympics and Paralympics were held.

Even setting aside the challenges associated with the Olympic Games, in the case of infectious diseases, medical staff often face high-pressure and high-risk work situations and are more prone to various psychological problems (9). Working in isolation can also lead to negative psychological effects (10). Previous research during the Severe Acute Respiratory Syndrome (SARS) epidemic showed higher rates of mental health problems among medical staff (11–13). They were also more likely to experience traumatic experiences or symptoms of Post-Traumatic Stress Disorder (14) and had more severe symptoms of post-infection fatigue and anxiety (15). Multiple studies in China during the early stages of the 2020 COVID-19 pandemic revealed that medical staff, including non-frontline medical staff, exhibited significant vicarious traumatization and psychological problems (16, 17). Compared with non-clinical staff, front-line medical staff in the respiratory, emergency, infection, and intensive care units who had close contact with infected patients were twice as likely to experience anxiety and depression; and were 1.4 times more afraid of infection (18). A 2021 study conducted in Xinjiang, China, showed that under the normalized prevention and control policy, the prevalence of mental health problems among medical staff was as high as 20.25%, and nurses had a higher risk than doctors (19). In addition, studies have illustrated that the overall mental health of Chinese medical staff is poor (20).

Although the Beijing 2008 Olympic team provided medical security services that were acclaimed worldwide, they also had organizational and operational experience that provided a reference for the 2022 Winter Olympics and Paralympics (21). During a pandemic, the work of medical security is obviously more difficult. Providing good medical care in such situations requires a healthy medical team. The psychological health of medical staff is often undervalued compared with their physical health. This study aimed to explore the psychological status of the Beijing 2022 Winter Olympics medical team through evaluation indicators such as depression, anxiety, self-efficacy, and emotional responses to public health events, and to provide a reference for the deployment of medical services for large-scale events.

2 Materials and methods

2.1 Study design

This is a prospective cohort study.

2.2 Participants

In view of the ongoing COVID-19 pandemic, the International Olympic Committee announced on September 29, 2021, that all athletes and the medical team must remain inside the biosecurity bubble as part of the biosecurity protocol for the Olympic Games. This closed-loop management system included daily COVID-19 testing and restricted contact areas. Only travel to and from Olympic-related venues was allowed. The medical team was divided into two groups: an in-group and an out-group. The in-group was directly responsible for the medical security of Olympic-related personnel, whereas the out-group was responsible for rest in designated areas, handling paperwork, and emergency backup forces. Members of the medical team would take turns entering the in-group or out-group as needed, and have the opportunity to change group every 2 weeks.

On January 10, 2022, the medical security team gathered at the Chongli Winter Olympic Medical Center for the first assessment and then subsequently gathered every 14 days (window period ± 2 days). The final assessment was completed on March 22, 2022. All competitions ended on March 13, 2022, and the members of the medical team left after 2 weeks of centralized isolation and observation.

2.3 Assessments

General information, group conditions, and psychological status assessments of the medical team were collected using an online questionnaire. The first page of the questionnaire introduced the research, and all subjects signed an informed consent form online after reading it. This study strictly complied with the Declaration of Helsinki and was approved by the ethics committee of our research institution.

Depression was assessed using the Patient Health Questionnaire-9 (PHQ-9). PHQ-9 was formulated with reference to the diagnostic items of depression in the DSM-5. The questionnaire consists of nine items, each of which is scored from zero to three. The higher the score, the more severe the depressive symptoms. PHQ-9 has widely been used to assess depression, and Cronbach's alpha was 0.86 (22).

Anxiety was assessed using the Self-rating Anxiety Scale (SAS). The SAS consists of 20 items scored on a scale of one to four, with higher scores indicating more severe anxiety symptoms. SAS has widely been used to assess anxiety, and Cronbach's alpha was 0.93 (23).

Self-efficacy was assessed using the General Self-Efficacy Scale (GSES). The questionnaire consists of 10 items, and each item is scored from one to four. The higher the score, the higher one's self-efficacy. Cronbach's alpha was 0.91 (24).

Emotional responses to public health emergencies were assessed using the Psychological Questionnaire for Emergent Events of Public Health (PQEEPH). The PQEEPH consists of 25 items, which are grouped into five dimensions: depression, neurasthenia, fear, obsessive-compulsive anxiety, and hypochondria. Cronbach's alpha

was 0.692. This questionnaire can be used to assess the psychological responses of people over 16 years of age to public health emergencies. It was used in China during the SARS epidemic (25).

The study collected data by repeatedly measuring the same individual and utilized the self-control effect to control for bias.

2.4 Statistical analysis

All data analyses were performed using the IBM Statistical Product and Service Solutions (SPSS) data analysis software package (IBM Corp., Armonk, NY, United States, version 22.0). A generalized mixed linear model was used to evaluate the influence of various factors on the mental status of the medical staff. All tests were two-sided, and the significance level was set at 5%.

3 Results

3.1 Composition of the medical service team

The 2022 Winter Olympics medical service team had 145 members (43.4% male), including doctors ($n = 49$, 65.3% male), nurses ($n = 43$, 18.6% male), administration staff ($n = 12$, 66.7% male), technical (ECG, B-ultrasound, laboratory physician; $n = 30$, 36.7% male), and rear-service personnel positions ($n = 11$, 36.4% male).

3.2 Depression, anxiety, and self-efficacy

Work duration significantly impacted the depression, anxiety, and self-efficacy levels of medical staff, although position and work group had no significant impact on their anxiety and self-efficacy levels. In contrast, sex and work group had significant effects on depression (Table 1).

Depressed mood among medical staff increased significantly at weeks four, six, and eight compared to baseline. Men had lower depression scores than women, and members of the out-group had significantly lower depression scores than the in-group. Regarding anxiety scores, although there was an increasing trend from baseline for all participants from weeks 2 to 10, this was not statistically significant. Compared with the baseline, self-efficacy decreased significantly during the entire Winter Olympics support work period and failed to return to the baseline level 1 week after the mission ended (Figure 1).

TABLE 1 The influence of various factors on PHQ-9, SAS, and GSES.

		Time	Sex	Position	Group
PHQ-9	F	9.825	5.003	1.088	6.249
	p	<0.001*	0.026*	0.361	0.013*
SAS	F	3.460	1.777	1.042	3.683
	p	0.004*	0.183	0.385	0.055
GSES	F	4.648	1.149	0.799	1.839
	p	<0.001*	0.284	0.526	0.176

*$p < 0.05$.

3.3 Emotional responses to public health events

Work duration significantly affected all dimensions of the emotional responses of the medical staff to public health events. Women exhibited higher total scores than men in the dimensions of depression, neurasthenia, fear, and emotional response. The in-group scored higher than the out-group in the dimensions of depression, neurasthenia, and total score. Position had no significant impact on the scores for each dimension or total score (Table 2).

The results for the depression dimension were consistent with those of the PHQ-9. The neurasthenia scores of the medical staff were significantly higher in the fourth week than the baseline, although changes in neurasthenia in men were milder than in women, and the neurasthenia score of the out-group was lower than that of the in-group. Compared with baseline, the medical staff showed significant fear and hypochondria at work weeks four and eight, with men having lower fear scores than women. At weeks four, six, and eight, the medical staff scored significantly higher than baseline on the obsessive-compulsive anxiety dimension. Overall, the total scores of emotional responses to public health events were significantly higher at weeks four, six, and eight than at baseline, with women and the in-group exhibiting more severe scores (Figure 2).

3.4 Statistical power

The statistical power of this study was calculated and found to be 0.868. This indicates a high probability that the study has correctly identified true effects and minimizes the risk of Type II errors.

4 Discussion

During an infectious disease epidemic, medical staff are more likely to come into contact with the source of the disease and face a higher risk of infection. Subhealthy and fatigued staff members may be more susceptible to the virus, leading to increased levels of anxiety related to uncertainty and fear of contagion (11, 26). Although medicine and medical management have undergone more than 10 years of development since the end of the original SARS epidemic, this is still not enough to relieve the psychological pressure on medical staff. A 2021 study conducted in Singapore showed that more than half of healthcare workers felt safer (54.8%), better equipped (72.1%), and better able to manage their workload (58.9%) during the current pandemic than during the SARS epidemic, and 77% believed that authorities and healthcare leaders were doing a better job now than they had before. However, less than half (47.3%) felt less stressed now compared to their past SARS experiences (27).

Unlike ordinary medical staff, the Winter Olympics medical team had to simultaneously deal with participating teams from different regions of the world. Medical conditions and equipment had more limitations, and medical care was performed in an isolated environment, creating more challenges.

Our study found that during the 10-week healthcare mission, healthcare workers in all positions, not just doctors and nurses but also administrative, technical, and support staff, experienced emotional deterioration and decreased self-efficacy.

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During the service, the Winter Olympic medical team experienced persistent depression, increased anxiety, and emotional reactions such as neurasthenia, fear, obsessive-compulsive anxiety, and hypochondria. Most of the above changes did not recover after 2 weeks in the external group, suggesting that the deterioration of the mood of the medical staff was not entirely due to their current working status and infection risk, but might also be related to accumulated fatigue, limited range of activities, and pressure from future tasks. The final assessment occurred at the end of week 10, when the team completed all Olympic medical work, took a week off, and knew they would be able to return home in another week, yet their emotional status did not differ significantly from the baseline. Female members of medical teams experienced more severe symptoms of depression, fear, and neurasthenia.

TABLE 2 The influence of various factors on PQEEPH.

		Time	Sex	Position	Group
Depression	F	7.750	5.820	0.742	6.143
	p	<0.001*	0.016*	0.563	0.013*
Neurasthenia	F	2.571	6.330	0.651	6.484
	p	0.026*	0.012*	0.626	0.011*
Fear	F	3.721	5.019	1.904	3.251
	p	0.003*	0.025*	0.108	0.072
Obsessive	F	4.062	1.675	0.735	3.382
	p	0.001*	0.196	0.568	0.066
Hypochondria	F	2.497	1.175	0.817	1.571
	p	0.030*	0.279	0.515	0.211
Total score	F	3.921	4.509	0.929	5.417
	p	0.002*	0.034*	0.447	0.020*

In addition to emotions, self-efficacy is worth noting. Self-efficacy is a core concept in Bandura's social cognitive theory (28). A good sense of self-efficacy can prompt individuals to cope with difficulties, while a poor working environment may destroy one's sense of self-efficacy; this reduced self-efficacy will negatively impact the individual's psychological status and work engagement (29, 30). We found that the self-efficacy of the medical team (regardless of position or sex) decreased significantly by the end of week two and had not yet recovered to baseline levels at the final assessment.

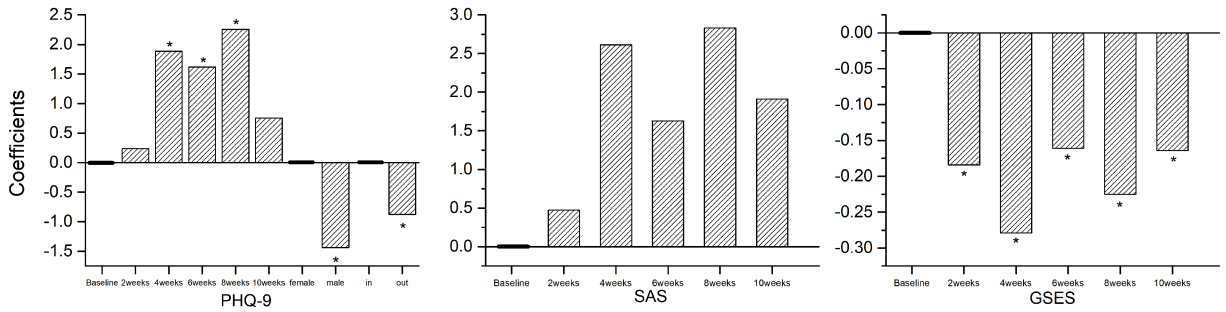

FIGURE 1
Coefficient of factors affecting PHQ-9, SAS, and GSES (*$p < 0.05$).

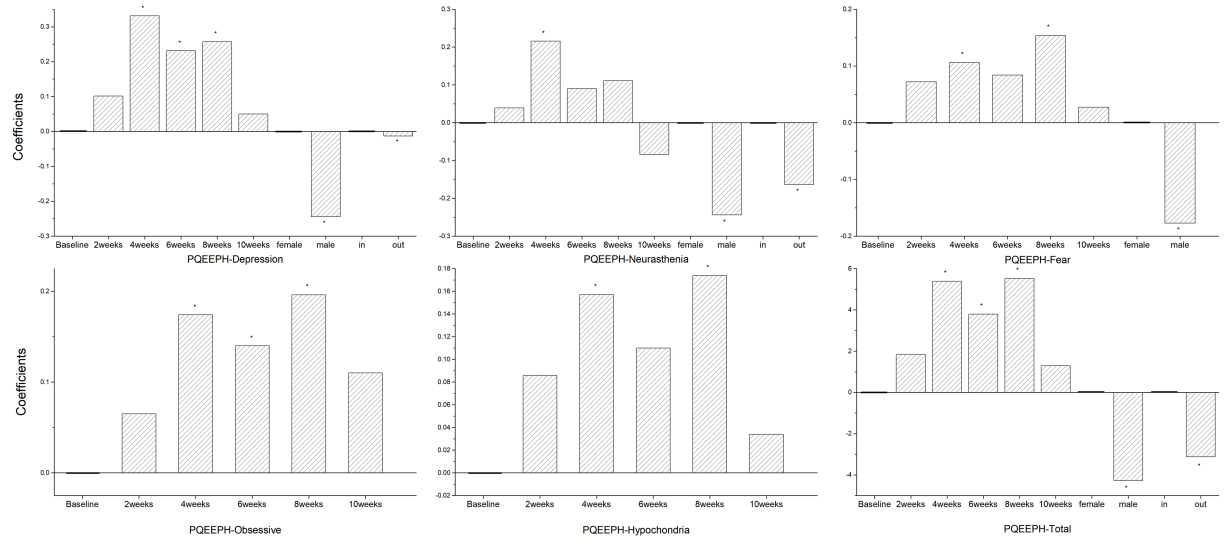

FIGURE 2
Coefficient of factors affecting PQEEPH (*$p < 0.05$).

According to this study, the emotional status of most medical team members did not differ significantly from baseline at 2 weeks on the job, but significantly worsened after 4 weeks on the job. This deterioration persisted, indicating that 2–4 weeks is the time period that requires particular attention when deploying medical teams under public health pressure. The team can basically maintain its mental status within the first 2 weeks. If conditions permit, staff rotation for about 4 weeks may stabilize the emotional status and work efficiency of the medical team.

Regarding the effects of breaks, our research shows that taking either 2 weeks of rest when knowing they needed to keep on task or 1 week of rest after the task was completed did not reverse the deterioration in mental status associated with sustained high workload. Limitations in the range of movement during rest may have also decreased the effectiveness of rest. This suggests that longer rest or rotation schedules should be considered when deploying medical services for major events.

The strength of this study is that it focuses on the psychological wellbeing of medical teams at major events, an important but often neglected issue. The study offers a new perspective and provides valuable insights for medical deployment in such events.

However, there are some limitations in this study. The assessment of the medical team's condition is restricted to scale-based evaluations. Including biological indicators would enhance the comprehensiveness of the assessment. Additionally, establishing the medical work group in its everyday state as a control group would enable a better comparison of the psychological states between large-scale event settings and routine medical work, highlighting their differences and influences in these contexts. From a research design perspective, this study primarily focused on observing the phenomenon of psychological deterioration among medical personnel. However, it did not incorporate intervention measures such as varying rest periods, relaxation training, or psychological interventions. As a result, the study missed the opportunity to identify effective methods for mitigating this deterioration. Furthermore, the study did not include an extended follow-up period to observe the complete recovery process of all indicators, thus failing to explore the recovery trajectory of the psychological state of medical personnel. Enhancing the research design in future studies could provide more practical and actionable guidance for managing similar scenarios in the future.

5 Conclusion

Medical team members at major events faced severe challenges during an infectious disease epidemic. These team members, especially women, experienced significantly deteriorated mental status with extended work duration. To address this situation, psychological support services should be considered for them. Less than 4 weeks of continuous work and more than 2 weeks of rest may be beneficial for them to maintain better wellbeing or to recover from poor wellbeing.

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 humans were approved by the Human Research Ethics Committee of Beijing Huilongguan Hospital. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

XZ: Conceptualization, Methodology, Writing – original draft. YZ: Data curation, Investigation, Writing – review & editing. ZQ: Data curation, Investigation, Writing – review & editing. RL: Data curation, Supervision, Validation, Writing – review & editing. YT: Methodology, Supervision, Validation, Writing – review & editing. ZY: Conceptualization, Project administration, Writing – review & editing.

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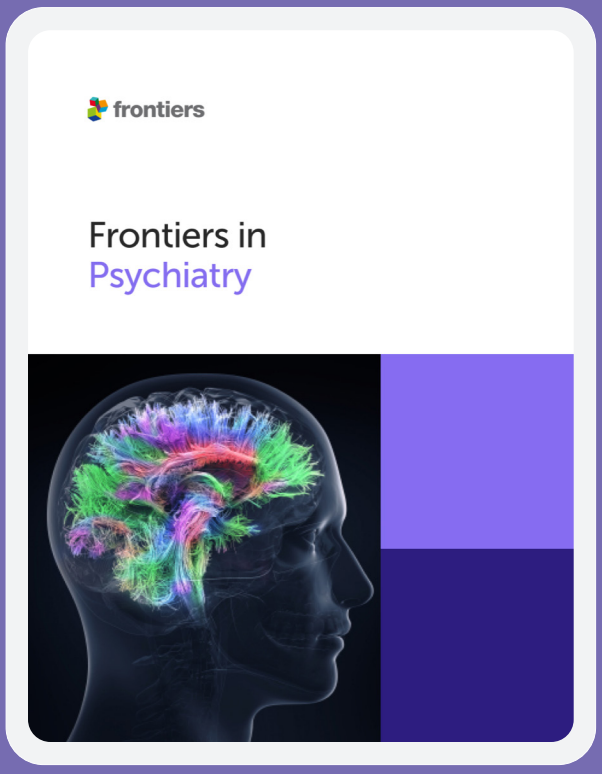

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