

Public risk perception in public health policies

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Ibrahim A. Elshaer, Abdalwali Lutfi, Adi Mohammad Alsyounf, Mahmaod I. Alrawad, Kingston Rajiah and Aidi Ahmi

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Public risk perception in public health policies

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Intention and practice on personal preventive measures against COVID-19 among older adults in the Kingdom of Saudi Arabia: an epidemiological study using the Theory of Planned Behaviour

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Introduction: Older adults aged 65 years and above are among the most vulnerable to adverse outcomes and death following a COVID-19 infection. The weekly epidemiological updates by the World Health Organisation show that the continued emergence of concerning subtypes of the virus indicates that the pandemic remains a public health concern and the public should continue to comply with personal preventive measures (PPMs). This study applies the Theory of Planned Behaviour (TPB) which is rooted in the field of Public Health, Epidemiology, and Preventive Medicine to Saudi older adults to predict their health behaviour.

Methods: This behavioural epidemiological study recruited older adult participants aged 65 years of age and above. A tool which consisted of sociodemographic and health-related questions, as well as questions regarding the components of the TPB, namely, Attitude, Subjective Norm, Perceived Behavioural Control was used. Bivariate analyses, followed by unadjusted and adjusted multivariable logistic regression analyses were performed to derive odds ratios and 95% confidence intervals.

Results: The total number of participants was 502. The mean age was 70.34 years, with similar distributions between males and females. In total, 52.2% intended to practice PPMs, whereas only 48% had a good practice. Also, 56% had a favourable Attitude towards PPMs, 61.4% had a positive Subjective Norm and 39.8% had perceived they had a high control over their behaviour. Females, and high educational status were predictors for high intention to practice PPMs (OR = 1.59, 95% CI = 1.01–2.52 and OR = 2.72, 95% CI = 1.44–5.16 respectively). Further predictors included Attitudes, Subjective Norm and Perceived Behavioural Control. Results also show that intention to practice was significantly associated with a lower odd of practicing PPMs (OR = 0.06, 95% CI = 0.04–0.10).

Conclusion: Current findings highlight the need to continue with public health efforts targeting vulnerable older adults. Also, the fact that intention negatively predicted practice highlights the need for further behavioural epidemiological studies addressing the intention-behaviour gap.

KEYWORDS

public health, epidemiology, the Theory of Planned Behaviour, older adults, COVID-19

Introduction

Disease prevention is crucial in various aspects of life and health. Ever since the emergence of the coronavirus disease – 2019 (COVID-19) in late December of 2019, and it being announced as a pandemic in March of 2020, over 770 million confirmed cases and almost 7 million deaths have been registered (1, 2). This disease originates from a single-stranded RNA virus that is able to cause respiratory, gastrointestinal and central nervous system infections in its host (3). Due to the virus's ability to rapidly spread and evolve, it remains a public health priority to this day.

Very early on, specific groups of people were understood to be at a higher risk of mortality after a COVID-19 infection. These groups include older adults aged 65 years of age and above, patients with comorbidities as well as immunocompromised patients (4, 5). Therefore, preventive measures have been put in place, with the World Health Organisation (WHO) leading global efforts by setting up periodic bulletins with guidelines, as well as establishing the COVID-19 dashboard, and the United Nations supporting national preparedness and response plans to countries worldwide (1, 6). During the early stages of the pandemic, and while vaccines were still under development, the primary focus was on non-pharmaceutical interventions (7). These were steps that could be taken to mitigate and control the spread of the disease, and consequently alleviate its burden and allow time to develop the much-needed vaccines and treatments.

The Kingdom of Saudi Arabia (KSA) was among the first countries to proactively implement preventive measures that were – in those early stages – considered unprecedented. For example, two months before the detection of any cases in the country, a national committee with members from different governmental agencies had been entrusted with overseeing global updates and providing recommendations in preparing for the possibility of cases locally (8). Upon the discovery of the first case, all entry points to the two holy cities of Makkah and Madinah were suspended and international flights were cancelled, shifting schools and other educational institutions to remote learning as well as nationwide curfews (8, 9). Furthermore, health campaigns over official governmental social media accounts and text messages were streamed daily to raise public awareness and to remind everyone to abide by national preventative measures (8, 10). These measures have greatly assisted in reducing and controlling the spread and potential further burden of the disease (9).

The Theory of Planned Behaviour (TPB) is a theory that attempts to draw the framework for predicting adherence and compliance to preventive measures (11). This theory is a conceptual model that was established in 1980 as an extension of the Theories of Reasoned Action to explain the effect of information and motivation on behaviours (12).

Even though this theory has been extensively studied in several countries, very few studies within the KSA are found, and none have studied older adults specifically and/or preventive measures in general. For example, it has been applied to dental healthcare workers to examine the factors associated with infection control behaviour (13), as well as among the general public to study their intent to receive the

COVID-19 vaccine alone (13, 14). Although on the 5th of March of 2022, all restrictions have been scraped, the continued emergence of concerning subtypes of COVID-19 and the fact that older adults remain at risk of complicated outcomes and death compounded by the lack of research on this specific vulnerable population has given rise to this research.

Therefore, this study will first provide a theoretical foundation for the TPB within the context of COVID-19, and subsequently apply the components of the theory to Saudi older adults to examine their intention to practice personal preventive measures (PPMs) as set out by the Saudi health authority guidelines. The study will also discuss the study's findings and provide implications for public health policy.

Theoretical foundation

Several theories that attempt to predict health behaviours are available in the medical literature. These include – but are not limited to – the Health Belief Model, Technology Acceptance Model, and the TPB (11, 15, 16). The TPB argues that behaviour is driven by the intention to perform that particular behaviour forming what is known as the individual's "belief structure" (11). In the case of COVID-19 preventive measures, this structure would be comprised of Attitude towards preventive measures (i.e., their perceived necessity), Subjective Norms (i.e., whether others support and perform these measures), and Perceived Behavioural Control (i.e., the extent of which the preventive measures are within the individual's control).

The TPB is related to the science of behavioural epidemiology which has been emerging since the late 1970s (17, 18). Behavioural epidemiology is under the umbrella of Public Health and consists mainly of two concepts, the first is to identify the epidemiological relationship between individual behaviour and disease occurrence, and the second is the epidemiological study of the actual behaviour itself (19). There is a vast literature supporting the application of this theory to predict health behaviour in general and for COVID-19 specifically (12, 18, 20–22).

Materials and methods

Study design, setting, and study participants

This behavioural epidemiological study employed a cross-sectional design and was conducted in the Eastern region of the KSA. The study setting were community health centres where older adult participants attended routine physical examinations. Eligibility for inclusion included both male and female participants who were aged 65 years and above, and that they were clear from any neurocognitive disorders such as Parkinson's disease and dementia and were capable of communicating verbally.

Ethical considerations

The Imam Abdulrahman Bin Faisal University's Institutional Review Board approved the study (IRB-2022-01-294). The participation was voluntary and there was no requirement to obtain personally identifiable information. Consent to participate was obtained from all participants. The study complied with the principles of the Declaration of Helsinki.

Sample size and sampling technique

The minimum required sample size was 383. This was based on a previous study in which the intention to practice PPMs was 52% (22), with a precision of 5% and at an alpha level of 0.05. The Epi info software version 7.0 was used for sample size calculations. Since the study targets a delicate population, a non-probability sampling technique was used to recruit participants.

Data collection tool and processes

The questionnaire was adapted from the WHO Survey tool and guidance and incorporated recent international literature that had also used the TPB within the context of COVID-19 (14, 20–24). Since these studies were either on the general population or on specific health workers, the authors had to adapt the tool to better represent the older adults' population who are the focus of this work. Three experts namely, a geriatrician, preventive medicine consultant and a public health consultant had reviewed the tool to check for its clarity and appropriateness. Then, a pilot study was performed on a sample of 10 participants aged 65 years and above, all questions were clear and the average time to complete the tool was 8 min.

The first set of variables in the tool included questions on sociodemographic and health-related characteristics. Also, the tool asked whether the participants knew of a previous COVID-19 infection, and if yes, the perceived severity level of that infection (mild, moderate or severe, i.e., hospitalised). The second set of variables were pertaining to the TPB. These included questions on the three main elements of the theory, namely, Attitude towards PPMs, Subjective Norm and Perceived Behavioural Control. Attitudes may be defined as the degree to which an individual holds a favourable or unfavourable assessment of a particular behaviour. Subjective Norm is the belief of whether other people within the community approve or disapprove of a particular behaviour, whereas Perceived Behavioural Control is the perceived difficulty or easiness of performing that behaviour (11). PPMs against COVID-19 may be defined as those measures that are known to protect and prevent infection and which included the following six preventive recommendations; handwashing with soap and water for a minimum of 20s, avoid touching eyes, mouth, and nose when hands are not washed, staying at home if sick, covering mouth and nose when coughing and sneezing, physical distancing and self-isolation. Furthermore, the tool asked the participants on their intention to practice these PPMs and whether they already do so in the present time.

Data were collected through an online tool which allowed the team to share the link within themselves during the data collection period. In order to protect both the older adult participants and the

team, guidelines were followed in terms of respiratory etiquette and distancing.

Measurements

The Attitude to practice PPMs was measured using the six main recommendations stated above on a five-point Likert's scale. The mean score was computed for each participant, and those who score the overall mean and above were considered as having a good Attitude, whereas those who scored below the mean were considered to have a poor Attitude. As for Subjective Norm, it was based on two questions, namely, if you were infected with COVID-19, would you let people know? and how much do you trust the prevention information issued by the MoH? These were both measured on the five-point Likert's scale. Similar to Attitude, participants scoring above the mean were considered to have a positive Subjective Norm and participants scoring below the mean were considered to have a negative Subjective Norm. The Perceived Behavioural Control construct was similarly computed and was based on three questions, namely, do you think COVID-19 would have a serious impact on you and your family? Are you still worried about COVID-19 and other large infectious diseases? And do you have the confidence to protect yourself and your family against COVID-19 and other large scale infectious diseases? (22, 24).

Intention to practice PPMs was measured based on the above six PPM questions, and further questions were added that included the use of antibiotics to prevent and treat COVID-19. These were measured on a Likert's scale and those who were intending had scored above the mean. The current practicing of PPMs was a simple yes/no response. This allowed us to differentiate between the intention and actual practicing of these measures.

Data analyses

Descriptive statistics were computed as frequencies and percentages for categorical variables and means \pm standard deviations for continuous variables. The study had two outcomes, the first was intention to practice PPMs and the second was the current practice. Bivariate associations were performed to study the associations between these outcomes and all elements of the TPB as well as sociodemographic and health-related characteristics. Both unadjusted and adjusted binary logistic regression analyses were performed for the two outcomes of the study to compute the Odds Ratios (ORs) and their accompanying 95% confidence intervals (CIs). The level of significance was set at 0.05. All analyses were performed in Stata Statistical Software version 15.0 (Stata Corp) (25).

Results

Sociodemographic and health characteristics of study participants

The study included 502 participants. The mean age was 70.34 years \pm 5.85 years. The distribution of males and females were very similar (49 and 51% respectively). The majority of participants (44.40%) had

TABLE 1 Sociodemographic and health characteristics of the older adult participants.

Characteristics	N (%)
Age (μ, α)	70.34 (5.85)
Sex	
Males	246 (49.00)
Females	256 (51.00)
Level of education	
Read and write	145 (28.90)
High school	223 (44.40)
University graduate	126 (25.10)
Postgraduate	8 (01.60)
Health care professional	
Yes	14 (02.80)
No	488 (97.20)
Chronic disease conditions	
Yes	378 (75.30)
No	124 (04.70)
Living circumstances	
Alone	23 (04.60)
With a family	479 (95.40)
Perceived financial status	
Bad	10 (02.00)
Fair	196 (39.00)
Good	229 (45.60)
Excellent	67 (13.30)
Know someone previously infected with COVID-19	
Yes	438 (87.30)
No	64 (12.70)
Know someone who had died from COVID-19	
Yes	215 (42.80)
No	287 (57.20)
History of previous COVID-19 infection	
Yes	239 (47.60)
No	263 (52.40)
Severity of previous COVID-19 infection^a	
Mild	102 (42.70)
Moderate	100 (41.80)
Severe (Hospitalised)	37 (15.50)
Test confirmed previous infection^a	
Yes	201 (84.10)
No	38 (15.90)

^aFrequencies and percentages are based on the 239 participants who had reported a previous COVID-19 infection.

a high school degree and only 1.60% were postgraduates. Only 2.80% reported that they once were healthcare professionals. With regards to their health status, 75.30% reported the presence of a chronic disease condition. Also, 4.60% were living alone and 45.60 of the total sample

reported a “good” financial status, compared to only 2% who had reported a bad financial status.

In total, 87.30% had known people who were previously infected with COVID-19, and 42.8% had known someone who had died from it. With regards to personal history, 47.60% reported a previous COVID-19 infection, of those sub-sample of participants, 15.5% were hospitalised due to the severity of the infection (Table 1).

Subjective Norm and Perceived Behavioural Control and Attitude of the study participants

The mean score for the Subject Norm was 8.44 ± 1.68 (range 2–10). In total, 61.4% had a positive Subjective Norm. As for the Perceived Behavioural Control, the mean was 8.33 ± 2.01 (range 3–13) and 39.8% perceived that they had a higher control in their behaviour. Whereas for the Attitude, the median score was 25.51 ± 4.83 (range 6–30) and 56% were found to have a favourable Attitude (Table 2).

Likewise, along the range of the five degrees of Attitudes towards the PPMs, over half the participants (50.00 to 64.30%) strongly agreed to most of them, except for physical distancing which showed the least amount of agreement (43.60%). Physical distancing also showed a higher proportion of strong disagreement compared to other statements (05.20%).

Intention and practice on PPMs against COVID-19

The mean score for the intention to practice PPMs was 29.44 ± 8.56 (range 10–50). In total, 52.2% had intended on practicing the stated preventive measures. Along the range of the five degrees of intention, 50.8% had very likely intended to practice washing hands with soap and water for at least 20s. Participants reported lesser percentages of being very likely intending to avoid touching eyes, mouth, and nose with unwashed hands (44.20%), as well as for using disinfectants to clean hands when soaps are unavailable (35.3%). A large proportion of participants exhibited being very unlikely to intend to use antibiotics to prevent or treat COVID-19 (62.70 and 59.40% respectively) (Table 3).

With regards to the actual practice of PPMs, the analysis found that the mean practice score was 15.62 ± 2.58 (range 10–20) and the proportion of participants who had good practice were 48.0%. Hand washing with soap and water for at least 20 min was reported among 80.1%, avoid touching eyes, nose, and mouth with unwashed hands was stated among 71.1%. The least commonly reported practice was using antibiotics to prevent COVID-19 (7.0%).

Factors associated with the intention to practice PPMs against COVID-19 infection

Results shows statistically significant differences in the intention to practice PPMs in relation to age, level of education, Attitude towards PPMs, Subjective Norm, and Perceived Behavioural Control ($p < 0.05$). Given these results, Table 4 shows unadjusted and adjusted logistic regression analyses of participants' characteristics in relation to intention to practice PPMs. The odds of intention were significantly

TABLE 2 Attitude towards personal preventive measures against COVID-19 among older adult participants.

Personal preventive measures (PPMs)	Attitude N (%)				
	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
Washing hands with soap and water for at least 20 s	15 (03.00)	39 (07.70)	28 (05.60)	150 (29.90)	270 (53.80)
Avoid touching eyes, mouth and nose with unwashed hands	12 (02.40)	35 (07.00)	22 (04.40)	162 (32.20)	271 (54.00)
Staying at home (sick or having cold)	21 (04.10)	40 (08.00)	31 (06.20)	159 (31.70)	251 (50.00)
Covering mouth and nose when coughing or sneezing	8 (01.60)	15 (03.00)	14 (02.80)	151 (30.10)	314 (62.50)
Keep physical distancing	26 (05.20)	71 (14.10)	47 (09.40)	139 (27.70)	219 (43.60)
Self-Isolation	12 (02.40)	27 (05.40)	13 (02.60)	127 (25.30)	323 (64.30)
Overall Attitude towards PPMs					
Favourable			281 (56.00)		
Unfavourable			221 (44.00)		

TABLE 3 Intention and practice of personal preventive measures against COVID-19 among older adult participants.

Personal preventive measures (PPMs)	Intending to practice N (%)					Practice N (%)	
	Very unlikely	Unlikely	Not sure	Likely	Very likely	Yes	No
Wash hands with soap and water for at least 20 s	19 (03.80)	75 (11.40)	21 (04.10)	150 (29.90)	255 (50.80)	402 (80.10)	100 (19.90)
Avoid touching eyes, mouth and nose with unwashed hands	32 (06.40)	81 (16.10)	15 (03.00)	152 (30.30)	222 (44.20)	357 (71.10)	145 (28.90)
Use disinfectants to clean hands when soaps are unavailable	83 (16.50)	93 (18.50)	18 (03.60)	131 (26.10)	177 (35.30)	284 (56.60)	218 (43.40)
Disinfecting touchable surfaces	103 (20.50)	101 (20.10)	26 (05.20)	140 (27.90)	132 (26.30)	333 (66.40)	269 (53.60)
Wearing masks in public places	85 (16.90)	96 (19.10)	18 (03.60)	153 (30.50)	150 (29.90)	284 (56.60)	218 (43.40)
Avoid social gathering	148 (29.50)	159 (31.70)	32 (06.40)	104 (20.70)	59 (11.70)	182 (36.30)	320 (63.70)
Ensure physical distance in public places	80 (15.90)	121 (24.10)	18 (03.60)	141 (28.10)	142 (28.30)	288 (57.40)	214 (42.60)
Staying at home (when sick or with a cold)	179 (35.70)	171 (34.10)	27 (05.40)	79 (15.60)	46 (09.20)	111 (22.10)	391 (77.90)
Use antibiotics to prevent COVID-19	315 (62.70)	128 (25.50)	30 (06.00)	16 (03.20)	13 (02.60)	21 (04.20)	481 (95.80)
Use antibiotics to treat COVID-19	298 (59.40)	123 (24.40)	28 (05.60)	31 (06.20)	22 (04.40)	35 (07.00)	467 (93.00)

lower among the ≥ 70 -year age group, although this was not significant in the adjusted model. Sex arose as a factor where females were 59% more likely to exhibit intention to practice PPMs (95% CI = 1.0–2.52). Also, the results show that the odds of intention increased with higher education. With respect to the studied four components of the TPB, it was observed that participants who had a favourable Attitude were 4.41 times more likely intending to practice PPMs (95% CI = 2.89–6.73). Also, higher odds were seen among participants who had a positive Subjective Norm (95% CI = 1.53–3.65). Similarly, the odds of intention were 72.3% times higher among those participants with a high Perceived Behavioural Control compared to their counterparts.

Factors associated with current practicing of PPMs

Results show that there were statistically significant differences in the current practicing of PPMs in relation to the level of education, having been a healthcare professional, Attitude towards PPMs,

Subjective Norm, and Perceived Behavioural Control and the intention to practicing PPMs ($p < 0.05$).

Given these results, Table 5 shows unadjusted and adjusted logistic regression analyses of participants' characteristics in relation to the current practicing of PPMs. In the adjusted model, only three of the four components of the TPB were statistically significant. Firstly, participants with a favourable Attitude were 62.10% less likely to report practicing PPMs (95% CI = 0.22–0.63). For Perceived Behavioural Control, participants who had reported a high Control were 40% less likely to practice PPMs (95% CI = 0.36–0.98). As for the intention, participants who were intending to practice PPMs were 93.4% less likely to currently practice them (95% CI = 0.04–0.10).

Discussion

Despite all scientific evidence, epidemiologically or biologically, on the positive effects of preventive measures against COVID-19, compliance with these measures remains variable. Cultural and

TABLE 4 Unadjusted and adjusted binary logistic regression analyses of older adult participants predictors of the intention to practice personal preventive measures against COVID-19 infection.

Predictors	Intention to practice PPMs		Unadjusted OR	95% CI	Adjusted OR	95% CI
	Not Intending <i>N</i> (%) 240 (47.80)	Intending <i>N</i> (%) 262 (52.20)				
Age						
< 70	120 (42.40)	163 (57.6)	Ref			
≥70 years	120 (54.80)	99 (45.20)	0.60	0.42–0.86	0.76	0.49–1.16
Sex						
Males	119 (49.58)	126 (51.20)	Ref			
Females	121 (50.42)	136 (53.10)	1.07	0.76–1.53	1.59	1.01–2.52
Level of education						
Read and write	85 (58.60)	60 (41.40)	Ref			
High school graduate	104 (46.60)	119 (53.40)	1.62	1.06–2.47	2.17	1.28–3.70
University/Postgraduate	51 (38.10)	83 (61.90)	2.36	1.42–3.72	2.72	1.44–5.16
Health care profession						
Yes	5 (37.70)	9 (51.30)	Ref			
No	235 (48.20)	68 (54.80)	1.67	0.55–5.06	1.02	0.24–4.30
Chronic diseases						
Yes	184 (48.70)	194 (51.30)	Ref			
No	56 (45.20)	68 (54.80)	0.86	(0.57–1.30)	0.93	0.57–1.52
Attitude towards PPMs						
Unfavourable	154 (69.70)	67 (30.30)	Ref			
Favourable	86 (30.60)	195 (69.40)	5.21	3.55–7.64	4.41	2.89–6.73
Subjective Norm						
Negative	128 (66.00)	66 (34.00)	Ref			
Positive	112 (36.40)	196 (63.60)	3.39	2.32–4.94	2.30	1.53–3.65
Perceived Behavioural Control						
Low	166 (55.00)	136 (45.00)	Ref			
High	74 (37.00)	126 (63.00)	2.07	1.44–2.99	1.72	1.13–2.61

behavioural factors play an important role in this variability. To the best of our knowledge, this is the first study to apply the TPB to predict adherence to public health preventive measures against the COVID-19 infection in the older adults' vulnerable population. We examined both the intention as well as the actual current practicing of PPMs. It is also important to note that the collection of the data was past the date at which the government had scraped all restrictions, hence the results presented here show the attitudes and beliefs of the participants long after the extensive health campaigns and the COVID-19 public concern. Several important findings have been found regarding the intention and practice towards PPMs among the older adult Saudi population.

In our study, we found that over half the participants had intended to practice PPMs. These figures are very similar to those of studies in parts of Africa (22, 26), but are in stark contrast to those in the US where the national average intent to comply with four recommendations, namely, washing hands, social distancing, cough etiquette and stay at home was over 80% (27). These differences may be due to fatality differences between the two regions which may have played a role in the increased intention in the US.

Factors associated with the intention to practice PPMs against COVID-19

Our study analysed factors predicting older adults' intention to practice PPMs. We found that females were more likely to intend to practice PPMs, and those with higher education had an even greater odd of intention. This aligns with another that showed that women, and those with higher educational attainment, were more likely to adopt preventive measures (28). Rooted within the TPB, our findings also revealed that participants with a favourable Attitude were more likely to intend to practice PPMs. This underlines the impact of personal Attitudes on health behaviours, as confirmed by multiple studies, which found that positive Attitudes towards preventive measures significantly increased their adoption (29, 30). The role of social factors was also highlighted in our study. Participants with positive Subjective Norms were more likely to intend to practice PPMs against COVID-19, supporting the findings of a previous study which reported that positive social norms significantly influenced the uptake of preventive measures (31). Lastly, our study showed that older adults with high Perceived Behavioural Control were more likely to intend

TABLE 5 Unadjusted and adjusted binary logistic regression analyses of older adult participants predictors of the current practicing of personal preventive measures against the COVID-19 infection.

Predictors	Currently practicing PPMs		Unadjusted OR	95% CI	Adjusted OR	95% CI
	Not Practicing <i>N</i> (%) 261 (52.0)	Practicing <i>N</i> (%) 241 (48.0)				
Age						
< 70	157 (55.50)	126 (44.50)	Ref			
≥70 years	104 (47.50)	115 (52.50)	1.37	0.96–1.96	0.89	0.53–1.48
Sex						
Males	124 (50.40)	122 (49.60)	Ref			
Females	137 (53.50)	119 (46.50)	0.88	0.62–1.25	0.69	0.40–1.20
Level of education						
Read and write	62 (48.80)	83 (57.20)	Ref			
High school graduate	113 (50.70)	110 (49.30)	0.72	0.47–1.10	0.77	0.41–1.44
University/Postgraduate	86 (64.20)	48 (35.80)	0.41	0.25–1.04	0.49	0.23–1.05
Health care profession						
Yes	11 (78.60)	3 (21.40)	Ref			
No	250 (51.20)	238 (48.80)	0.28	0.07–1.04	0.17	0.02–1.14
Chronic diseases						
Yes	191 (50.50)	187 (49.50)	Ref			
No	70 (56.50)	54 (43.50)	0.78	0.52–1.18	1.20	0.66–2.18
Attitude towards PPMs						
Unfavourable	68 (30.80)	153 (69.20)	Ref			
Favourable	193 (68.70)	88 (331.30)	0.20	0.13–0.29	0.37	0.22–0.63
Subjective Norm						
Negative	73 (37.60)	121 (62.40)	Ref			
Positive	188 (61.00)	120 (36.00)	0.38	0.26–0.55	0.88	0.51–1.46
Perceived Behavioural Control						
Low	133 (44.00)	169 (56.00)	Ref			
High	128 (64.00)	72 (36.00)	0.44	0.30–0.63	0.60	0.36–0.98
Intention to practice						
Not intending	45 (18.80)	195 (81.20)	Ref			
Intending	216 (84.20)	46 (17.60)	0.04	0.03–0.07	0.06	0.04–0.10

to practice PPMs against COVID-19, indicating the importance of individuals' confidence in their ability to perform preventive behaviours. This complements the findings of a local study which found that perceived control significantly impacted the adoption of preventive measures (32). Overall, our findings confirm and expand upon existing literature, emphasizing the role of sex, education, Attitudes, social norms, and perceived control in influencing older adults' intention to practice PPMs against COVID-19.

Factors associated with the current practice of PPMs against COVID-19

With regards to the current practicing of PPMs, we found that, among the study participants, those with a favourable Attitude towards PPMs were about two-thirds less likely to practice PPMs. This contradicts the findings of previous studies, which demonstrated a

positive correlation between Attitudes towards PPMs and their adoption (28, 31). We also found that participants who had a Perceived Behavioural Control were less likely to practice PPMs. This is in stark contrast to the findings of previous studies which highlighted that Perceived Behavioural Control was a significant predictive factor in the adoption of PPMs (30, 33). These studies suggested that individuals who believe they have the skills and resources to perform PPMs are more likely to do so. Interestingly, our study showed that participants who reported intending to practice PPMs were almost two times less likely to actually practice PPMs against COVID-19. This divergence between intention and behaviour contradicts the findings of a Turkish study which found a strong positive correlation between intentions and subsequent behaviour, particularly around health-related actions (34). It is interesting to find that in an Ethiopian study, although those who intended to practice PPMs were more likely to actually practice it, this association was not significant in their adjusted model (22). It is important though to note that the mean age in the first study was only

38.76 years, and in the second study it was 42.67 years, whereas in our study the mean age was 70.36 years. Notably, this divergence between intention and practice is not unheard of, the intention-behaviour gap is a phrase that describes the failure of intentions to be translated into actions (26). It maybe that the older adult population as a defined group possess specific behavioural characteristics unique to all other age groups. Overall, our unexpected findings highlight a complex interaction between Attitudes, Perceived Behavioural Control, intentions, and actual behaviour in the practice of PPMs among older adults. These findings suggest that other factors might be influencing the adoption of PPMs and that further research especially in the intention-practice gap is needed to fully understand these dynamics.

Implications and future directions

Although literature focusing on the role of the TPB during the pandemic is flourishing, there is a lack of research focusing on the older adult population. The current finding in that intention does not necessarily mean practice is extremely important to investigate in further epidemiological studies for this particular vulnerable population. Public health agencies within the KSA should continue its efforts to raise awareness through communication plans regarding the importance of adopting these preventive measures even long after lifting all restrictions. These communication plans should incorporate the role of friends and family especially since social constructs have been found to be associated with adoption of preventive measures. Furthermore, epidemiologists should further conduct behavioural epidemiological studies that would further suggest practical recommendations for public health agencies and health authorities in the KSA. Funded national surveys managed by experienced epidemiologists would be particularly helpful in order to reach sample sizes of sufficient and generally representative quality. Also, given the current focus on the practice of Family and primary care physicians, particularly with the expansion in preventive clinics, the role of these healthcare practitioners is crucial in increasing both awareness and promoting the health of older adults and other vulnerable groups.

Strengths and limitations

This is the first study to apply the TPB to the older adult population in the KSA within the context of preventive measures against COVID-19. However, the cross-sectional nature and the fact that both the intention and the actual practice were taken at the same time does not allow for any temporal associations to be made. Furthermore, the non-probability sampling technique, albeit consciously chosen due to the sensitive nature of our population, limits the generalisability of our results.

Conclusion

This study has shown that long after lifting all restrictions against COVID-19 in the KSA, a little over half the older adult participants intend to practice PPMs. It also showed that females, participants with a higher education level, those with a favourable Attitude towards preventive measures, positive Subjective Norm and high Perceived Behavioural Control exhibited a higher odd of intending to practice

PPMs. Most importantly, that intending to practice does not necessarily mean actual practicing. We recommend that public health agencies, health authorities and primary care physicians in the country to continue the efforts to raise awareness of proper preventive measures through customised communication plans. Also, the role of epidemiologists in terms of behavioural epidemiological studies should not be neglected.

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 of Imam Abdulrahman Bin Faisal University (IRB-2022-01-294). 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

RA: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. AmA: Conceptualization, Data curation, Project administration, Validation, Visualization, Writing – original draft, Writing – review & editing. LA: Conceptualization, Data curation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. SA: Conceptualization, Data curation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. ZA: Conceptualization, Data curation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. HA: Conceptualization, Data curation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. FA: Conceptualization, Data curation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. MA-S: Conceptualization, Data curation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. NoA: Conceptualization, Formal analysis, Methodology, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. MS: Formal analysis, Investigation, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing. AsA: Conceptualization, Formal analysis, Project administration, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. NiA: Conceptualization, Formal analysis, Methodology, Supervision, Validation, Visualization, 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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Determining the nurses' perception regarding the effectiveness of COVID-19 protocols implemented in Eastern Province: Saudi Arabia

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Background: The global impact of Coronavirus Disease 2019 (COVID-19) has been profound, affecting public health, the global economy, and overall human life. Past experiences with global pandemics underscored the significance of understanding the perception of HCWs and hospital staff in developing and implementing preventive measures. The World Health Organization (WHO) provided protocols to manage the spread of COVID-19 and assist healthcare workers and health systems globally in maintaining high-quality health services.

Objective: This study aims to assess nurses' perception, awareness, and compliance regarding the implementation of COVID-19 protocols and explore factors influencing their perception.

Methodology: A quantitative cross-sectional survey-based study was conducted, distributing a constructed survey among nurses in the Eastern Province of Saudi Arabia.

Results: Out of 141 participants, most adhered to protocols such as hand sanitization, social distancing, and proper personal protective equipment (PPE) usage. The predominant age group among respondents was 31 to 40 years ($n = 71$, 50%). A significant portion of participants reported holding a bachelor's degree ($n = 86$, 61%), with only 14% possessing advanced degrees ($n = 19$). Nearly a third of the nurses in the study had accumulated 6 to 10 years of professional experience ($n = 49$, 34.8%). A noteworthy percentage of nurses were engaged in daily shifts exceeding 8 h ($n = 98$, 70%). Gender differences were observed, with females exhibiting a higher tendency to avoid shaking hands and social gatherings. Saudi nationals were more inclined to shake hands and engage in gatherings. Non-Saudi nurses and those aged between <25 to 40 years demonstrated proper donning/doffing practices. Nurses with over 6 years of experience avoided social gatherings, while those working >8 h adhered better to PPE usage, proper donning/doffing, and disposal of PPE in designated bins.

Conclusion: Understanding COVID-19 protocols is crucial for tailoring interventions and ensuring effective compliance with COVID-19 preventive measures among nurses. More efforts should be made toward preparing the healthcare nursing to deal with the outbreak. Preparing healthcare nursing

with the right knowledge, attitude, and precautionary practices during the COVID-19 outbreak is very essential to patient and public safety.

KEYWORDS

nurses, perception, COVID-19, protocols, preventive measures, PPE, hand hygiene

Introduction

The global impact of Coronavirus Disease 2019 (COVID-19), stemming from severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), has left an indelible mark on the world economy, public health, and individuals' quality of life. In a brief span, it has placed an unprecedented burden on the global healthcare industry, necessitating every healthcare worker (HCW) to be at the forefront in managing the disease (1). The response to previous global pandemics underscored the pivotal role of HCWs and hospital staff perception in shaping and implementing protocols to address health crises (2).

In response to the COVID-19 outbreak, international health organizations like the World Health Organization (WHO) issued protocols to guide the management of COVID-19, aiding health systems and HCWs worldwide in maintaining the delivery of high-quality health services (3). Additionally, governments around the world implemented national protocols to contain the spread and impact of the pandemic. The global management of COVID-19 highlighted the effectiveness of a combination of non-pharmaceutical interventions, including lockdowns, school closures, restrictions on social gatherings and international travel, and robust information campaigns (4, 5). However, despite their effectiveness in curbing infections, these foundational protocols and policies fell short of completely halting the virus's spread and containing the disease (6).

The timing of protocol implementation was crucial, with evidence demonstrating that earlier implementation significantly influenced virus control (7). HCWs exhibited outstanding performance in executing preventive protocols while addressing the clinical demands of the pandemic. Notably, there was a significant increase in HCWs' adherence to preventive measures such as hand hygiene and the proper use of personal protective equipment (PPE) (8, 9). However, the swift adoption of protocols brought about various challenges.

HCWs, lacking prior experience in handling such diseases, faced high levels of stress, mitigated to some extent by protocols such as "disinfection efforts and isolation measures" that facilitated their work and maintained focus (10). PPE and resource shortages emerged as primary concerns, particularly in developing countries where these shortages hindered the implementation of preventive protocols (11, 12). Poorly designed infrastructure, including overcrowded Emergency Rooms (ER), hindered hospitals from implementing preventive measures such as social distancing (13, 14). Inadequate training, especially for redeployed HCWs facing increased workloads or requiring proficiency in using PPE, added to the challenges of managing the pandemic (2, 9, 11).

The spread of the pandemic has created drastic challenges and changes in all aspects of life, especially in health professionals' education. One of the most important challenges is the preparedness and willingness of health professional nursing to work in infectious disease outbreaks (13, 14).

Therefore, assessing knowledge, attitude, and practices of health professionals regarding any infectious outbreak has become a fundamental step to setting an effective plan related to their preparedness. The initial research on COVID-19 has demonstrated that during unexpected natural crises and infectious diseases, health-care professionals will make every effort to participate in the efforts to control the outbreak and reduce the complications, but the less consciousness of the risk of the infection.

Constant changes in suggested preventive guidelines and protocols further complicated matters, causing confusion among HCWs about which protocol to adopt and how to implement it, leading to potential errors in handling cases (2). Nurses in Madrid emphasized the importance of hospital management and leadership considering feedback from frontline HCWs during the COVID-19 pandemic (15). Effective communication emerged as a crucial factor in clarifying applied preventive measures, ensuring proper implementation, avoiding misconceptions, and supporting HCWs through this challenging period (1, 2, 15, 16).

Nationally, Saudi Arabia implemented extraordinary and stringent preventive measures to safeguard citizens, ensure well-being, and enhance awareness, influencing a strong commitment to applying preventive measures (17). Papers highlighted that HCWs in Saudi Arabia possessed sufficient knowledge and skills to manage the COVID-19 outbreak (18, 19). Effective communication, leadership coordination, proactive planning, HCWs training, skill development, and the implementation of strict policies contributed to enhancing HCWs' attitudes toward controlling the pandemic (20).

While published papers worldwide shared experiences in managing the COVID-19 outbreak, shedding light on various protocols advised and implemented by national and international agencies, including WHO and local governments, there remains a gap in research focusing on the perception of healthcare workers regarding the implementation of COVID-19 protocols in hospitals, particularly in Saudi Arabia. This paper seeks to address this gap by determining nurses' perception, awareness, and compliance regarding the implementation of COVID-19 protocols and exploring the factors influencing their perception.

Methodology

Research design

This is a quantitative, survey-based, cross-sectional study among nurses in the Eastern Province in Saudi Arabia. The survey used a validated survey developed by Agarwal et al. (21). The survey measures the nurses' perception, awareness, and compliance regarding the COVID-19 protocols and define the barriers in implementing them at the hospital. Survey results were analyzed using Statistical

Package for Social Sciences (SPSS) to test the association between nurses' socio-demographics and their awareness and perception of COVID-19 protocols.

Study setting

Healthcare organizations operated during the pandemic of COVID-19 in Saudi Arabia.

Participants

The participants were nurses who worked during the pandemic of COVID-19 in hospitals located in Eastern Province, Saudi Arabia. The sample size was 240. We distributed the survey through public social media accounts, also public nurses' WhatsApp groups. Due to the scope of the study, we specifically targeted the nurses who faced or contacted the patients during that time as they always have direct contact with the patients and therefore, might be more exposed to get the infection compared to other healthcare workers.

Instruments

An online survey was constructed based on a published validated survey done by Agarwal et al. (21) to evaluate the implemented preventive measures against COVID-19 among healthcare workers in India. It has two sections starting with Section A, which assesses the awareness and compliance toward the preventive measures. In addition, Section B cover the barriers to implementing these measures. Both sections cover the following elements: "hand hygiene, social distancing, personal protective equipment (PPE), gadgets/fomites, lifestyle, and exposure." The elements of interest in this study are hand hygiene, social distancing, and PPE, which are implemented as COVID-19 protocols in hospitals in Saudi Arabia.

Ethics and limitations

The ethical approval was obtained from the Institutional Review Board of Imam Abdulrahman Bin Faisal University; IRB-PGS-2021-03-443. The main limitation of the study journey was its short period as the study was conducted in one semester, which consequence in a small sample size.

Analysis

Statistical Package for the Social Sciences (SPSS) software analyzed numerical data. Descriptive analysis was performed to present the participants' characteristics, their reported practices in implementing the COVID-19 preventive protocols (Section A), and their perceived barriers toward implementing them (Section B). Furthermore, due to the small sample size (22), bivariate analysis was done using Fisher's Exact test to assess the association between the participants' characteristics and their perception and attitudes regarding the

implemented COVID-19 protocols. Lastly, the significance of the results were based on the value of p (value of $p < 0.05$).

Results

Out of the 141 nurses who completed the survey, 118 were females (83.7%), almost half of the participants were Saudis ($n = 73$). The majority of respondents were between the age of 31 to 40 years ($n = 71$, 50%). Most of the participants indicated that they have a bachelor's degree ($n = 86$, 61%), while only 14% had higher degrees ($n = 19$). Almost third of the nurses in the study had 6 to 10 years of experience ($n = 49$, 34.8%). A remarkable number of nurses worked more than 8 h a day ($n = 98$, 70%).

Section I: adherence to prevention practices against COVID-19 infections among healthcare workers

Half of the nurses in the study indicated that they rarely shook hands when encountering a colleague ($n = 73$); on the other hand, 22% of them always or mostly did ($n = 31$). Most nurses in the study adhered to sanitizing their hands after meeting patients or touching their surroundings ($n = 120$, 85%), compared to only 5% who occasionally or rarely did ($n = 7$). Additionally, more than two thirds of the nurses followed the appropriate steps when washing or sanitizing their hands ($n = 112$, 79%).

A considerable number of nurses kept at least 1 meter when communicating with their colleagues ($n = 96$, 68%). Similarly, when asked about meeting colleagues at work for lunch gatherings, almost half of the nurses in the study mentioned that they occasionally or rarely did ($n = 68$), while 35% always or mostly did ($n = 49$).

Most of the nurses in the study (more than 80%) followed the proper steps for donning and doffing the PPE as per the guidelines, wore adequate PPE during duty, wore masks inside the hospital premises, cover both their nose and mouth with a mask while wearing it, and indicated that they dispose of PPE in specified colored dustbins after use according to guidelines (Table 1). More than half of the nurses in the study mentioned that they changed their PPE and did not reuse them in a single shift ($n = 70$, 50%). More than third of the nurses in the study mentioned that they always or mostly carry their face shields/gowns/PPE to their duty room in the ward before completely doffing ($n = 55$, 39%).

Several variables are significantly associated with the participants adherence to Hand Hygiene. Saudis have significantly higher average adherence score to hand hygiene regulations compared to non-Saudis ($t = 2.54$, $p = 0.012$). Younger participants have significantly better hand hygiene adherence score compared to older participants ($f = 3.085$, $p = 0.049$). Further, participants with less than 6 working hours are more adherent to hand hygiene compared to more than 8 working hours ($t = 2.76$, $p = 0.006$, Table 2).

None of the variables in the study influence the adherence to social distancing except the nationality. The results show that Saudis are significantly more adherent to social distancing compared to non-Saudis ($t = 3.72$, $p < 0.001$, Table 2).

In addition, Saudi participants in the study appear to be significantly more adherent to Personal Protective Equipment

TABLE 1 Frequency (%) of responses to the adherence questionnaire.

Domain	Questions	Always	Mostly	Commonly	Occasionally	Rarely
Hand hygiene	I shake hands while meeting colleagues.	21 (14.9)	10 (7.1)	16 (11.3)	21 (14.9)	73 (51.8)
	I sanitize my hands after contact with each patient and/or his/her surroundings.	104 (73.8)	16 (11.3)	14 (9.9)	4 (2.8)	3 (2.1)
	I properly follow the steps of washing/sanitizing hands.	97 (68.8)	15 (10.6)	13 (9.2)	11 (7.8)	5 (3.5)
Social distancing	I maintain at least 1 m distance with coworkers at the hospital.	66 (46.8)	30 (21.3)	24 (17)	10 (7.1)	11 (7.8)
	I have attended social gatherings (meetings, lunch gatherings, visiting other coworkers' offices, etc.) in the past two months.	27 (19.1)	22 (15.6)	24 (17.0)	29 (20.6)	39 (27.7)
Personal protective equipment (PPE)	I follow the steps of donning and doffing properly.	89 (63.1)	30 (21.3)	15 (10.6)	6 (4.3)	1 (0.7)
	I wear adequate PPE during duty (according to guidelines for my ward and patients).	103 (73.0)	17 (12.1)	8 (5.7)	10 (7.1)	3 (2.1)
	I wear a mask inside hospital premises.	106 (75.2)	12 (8.5)	10 (7.1)	8 (5.7)	5 (3.5)
	I cover both nose and mouth with a mask while wearing it	109 (77.3)	15 (10.6)	5 (3.5)	9 (6.4)	3 (2.1)
	I reuse my gowns/PPE during my single-duty shift.	28 (19.9)	13 (9.2)	14 (9.9)	16 (11.3)	70 (49.6)
	I carry face shields/gowns/PPE to my duty room in the ward before completely doffing.	30 (21.3)	25 (17.7)	19 (13.5)	15 (10.6)	52 (36.9)
	I dispose of PPE in specified colored dustbins after use according to guidelines.	93 (66)	22 (15.6)	18 (12.8)	2 (1.4)	6 (4.3)

compared to non-Saudis ($t=3.720$, $p<0.001$), and younger participants show significantly better adherence to PPE compared to older ones ($f=3.227$, $p=0.043$, [Table 2](#)).

Section II: reasons for adherence or non-adherence to preventive practices from COVID-19 infection among healthcare workers

In this section, most nurses chose “not applicable,” which indicates that they did not face any difficulty or had any reason for not adhering to the applied COVID-19 protocols. Thus, the primary reported barriers/reasons are presented below.

Hand hygiene

Out of the 141 nurses, 17.7% were unaware that COVID-19 spread through handshaking, and 11.3% were not convinced that it does. Others felt it was inappropriate to refuse to shake another's hand (17.7%), and some had difficulty changing their habits (12.8%). Moreover, 25.6% of respondents either were tired of continuously

sanitizing their hands or did not have time due to their workload, whereas 10.6% faced a lack of sanitizers at their organizations. About following the sanitizing/handwashing steps, 17.7% did not find it crucial, 13.5% felt it was exhausting, and 12.1% did not have to follow all the steps ([Table 3](#)).

Social distancing

14.2% of the nurses pointed out that lack of space hindered their ability to apply social distancing in hospitals and public places, and 17.0% found it hard to speak to others in public places. Additionally, 14.2% found it difficult to change their habits in the hospital, and equally, 14.2% did not see the necessity to keep a 1-meter distance for they wear their PPE all the time ([Table 3](#)).

Personal protective equipment (PPE)

Reasons for not wearing all the required PPE varied, starting with unavailability of PPE (10.6%), nurses feeling uncomfortable while wearing them (12.8%), or being unaware of the PPE guidelines (7.8%), and 8.5% were not convinced that the required PPE safeguard against COVID-19. Regarding wearing masks, 12.8% could not breathe easily, specifically when covering their nose and mouth (22.0%), 9.2% felt hot

TABLE 2 Association between the participants' characteristics and their perception toward the implemented COVID-19 protocols.

Variables	Freq. <i>n</i> = 141 (%)	Nurses' adherence					
		Hand hygiene		Social distancing		Personal protective equipment (PPE)	
		Mean (SD)	Test (<i>p</i> -value)	Mean (SD)	Test (<i>p</i> -value)	Mean (SD)	Test (<i>p</i> -value)
Gender							
Male	23 (16.3)	6.2 (2.2)	<i>t</i> = 1.74 (0.084)	5.5 (1.5)	<i>t</i> = 2.021 (0.050)	5.5 (1.5)	<i>t</i> = 2.021 (0.050)
Female	118 (83.7)	5.2 (2.6)		4.7 (2.1)		4.7 (2.1)	Alth
Nationality							
Saudi	73 (51.8)	5.8 (2.3)	<i>t</i> = 2.54 (0.012)	5.4 (1.8)	<i>t</i> = 3.72 (<0.001)	5.4 (1.8)	<i>t</i> = 3.720 (<0.001)
Non-Saudi	68 (48.2)	4.8 (2.7)		4.0 (2.0)		4.2 (2.0)	
Age							
< 25–30	40 (28.4)	6.0 (2.7)	<i>f</i> = 3.085 (0.049)	5.1 (2.0)	<i>f</i> = 1.605 (0.205)	14.5 (5.4)	<i>f</i> = 3.227 (0.043)
31–40	71 (50.4)	5.3 (2.7)		4.9 (2.1)		12.0 (5.3)	
41 and above	30 (21.3)	4.5 (1.9)		4.3 (1.9)		12.8 (3.9)	
Education level							
Diploma	36 (25.5)	5.8 (2.5)	<i>f</i> = 0.1168 (0.314)	5.1 (1.8)	<i>f</i> = 0.304 (0.738)	13.6 (4.8)	<i>f</i> = 0.503 (0.606)
Bachelor	86 (61.0)	5.1 (2.7)		4.8 (2.1)		12.6 (5.3)	
Higher education (MSc/PhD)	19 (13.5)	5.5 (2.1)		4.8 (2.0)		12.7 (5.1)	
Years of experience							
< 1–5 years	47 (33.3)	5.5 (2.4)	<i>f</i> = 0.574 (0.565)	5.4 (1.8)	<i>f</i> = 3.018 (0.052)	13.3 (4.4)	<i>f</i> = 0.250 (0.779)
6–10 years	49 (34.8)	5.5 (2.9)		4.5 (2.2)		12.6 (6.1)	
11 years or more	45 (31.9)	5.0 (2.3)		4.7 (1.9)		12.7 (4.7)	
Working hours							
< 8 h	43 (30.5)	6.2 (2.5)		5.3 (1.7)		5.3 (1.7)	
> 8 h	98 (69.5)	5.0 (2.5)	<i>t</i> = 2.76 (0.006)	4.7 (2.1)	<i>t</i> = 1.733 (0.086)	4.7 (2.1)	<i>t</i> = 1.73 (0.330)

Bold font indicates statistically significant results.

while wearing it, and 7.8% reported it sliding down from their nose. Moreover, nurses reused PPE due to its shortage in their organizations (19.9%) and long shifts (12.1%), whereas 14.2% did not see any risk in doing so (Table 3).

16.3% of nurses reported the unavailability of a designated area to doff, in addition to the need for an assistant or mirror to ensure proper doffing (11.3%) as barriers to applying the appropriate steps, and only 10.6% found it unnecessary to follow the steps of donning and doffing. When asked about PPE disposal, fatigue led 17.8% of nurses to not dispose of PPE/masks in their appropriate bins. Besides, 29.0% of the nurses pointed out the lack of designated bins. However, 13.5% were unaware that masks should be disposed of separately, and similarly, 24.8% were confused about which bin they should throw the PPE in Table 3.

Eighty-three percent of the respondents were female, in line with other studies (23) which indicate that 90% of the workforce during this COVID-19 crisis was female.

In the present study 69.5 of nurses spend longer working hours (> 8 h) might affect the efficiency and effectiveness of the workforce in delivering high-quality, safe care. A recent study in China about

healthcare providers working longer hours due to the spread of COVID-19 conveyed high symptom rates of depression, insomnia, and work stress (24). An international study reported that when nurses wear personal protective equipment (PPE), they usually take 4–6 working hours without a break. This is very critical to nurses' well-being, since longer hours wearing PPE can cause fatigue, stress, and exhaustion, making healthcare providers prone to causing medical errors (25). Hence, nursing administration should organize staffing and scheduling to avoid mental and physical health impairment.

Interestingly, in this study, demographics and work-related issues mattered. Female nurses had better preventive behaviors than male nurses as shaking hands with their colleagues. This distinction can be attributed to the fact that, in Saudi tradition and culture, females are more inclined to be healthcare providers than men (26). This result is consistent with a United Nations policy brief that women are more confident and have higher self-awareness about the impact of COVID-19 on women. Caution should be taken in interpreting this study, since only 16.3% of participants were male nurses, which means the findings cannot be generalized.

TABLE 3 Reasons for preventive practices among healthcare workers.

What is/are the reason(s) for not being able to don and doff properly?	
I do not know/remember the steps.	10 (7.1)
I believe they do not matter.	15 (10.6)
There is no dedicated doffing area.	23 (16.3)
There is a lack of helping people/mirrors to help in doffing.	15 (11.3)
There is a lack of sanitizers.	8 (5.7)
What is/are the reason(s) for not wearing adequate PPE?	
I do not know about guidelines for wearing PPE.	11 (7.8)
I do not believe adequate PPE protects me against COVID-19.	12 (8.5)
There are no guidelines for wearing PPE.	10 (7.1)
There is a lack of availability of PPE.	15 (10.6)
I find it uncomfortable to wear.	18 (12.8)
My long duty hours prevent its use.	9 (6.4)
I do not get time to wear PPE.	3 (2.1)
What is/are the reason(s) for not wearing a mask on the hospital premises?	
I do not know if masks are protective against COVID.	6 (4.3)
I do not find it useful.	8 (5.7)
I do not require it as I work in the administrative section.	7 (5.0)
There is a lack of availability.	9 (6.4)
I do not feel comfortable wearing it.	9 (6.4)
I have difficulty breathing while wearing it.	18 (12.8)
It gets hot while wearing them.	13 (9.2)
I do not look good wearing it.	1 (0.7)
Other reasons (Kindly specify):	1 (0.7)
What is/are the reason(s) for not covering both nose and mouth while wearing masks?	
I do not know if both nose and mouth have to be covered.	9 (6.4)
I do not find it useful.	9 (6.4)
I have difficulty breathing while wearing it.	31 (22.0)
I do not feel comfortable wearing it.	13 (9.2)
It slides down due to a loose fit.	11 (7.8)
Other reasons (Kindly specify):	1 (0.7)
What is/are the reason(s) for not disposing of masks properly in waste-bin/separate bags?	
I do not know if it should be kept properly in a waste bin/ separate bag.	19 (13.5)
I do not feel it is important to keep it properly.	9 (6.4)
I get too tired after work.	13 (9.2)
I do not find a suitable place to dispose of the mask.	27 (19.1)
What is/are the reason(s) for reusing gowns/PPE during a single shift?	
I do not know that I should not reuse the same gown/PPE.	13 (9.2)
I believe reusing them is not harmful.	20 (14.2)
There is a lack of availability of gowns/PPE.	28 (19.9)
I have long duty hours.	17 (12.1)
What is/are the reason(s) for not disposing of PPE in specific bins?	
I do not know how to dispose of PPE.	9 (6.4)
I believe proper disposing of PPE does not matter.	8 (5.7)
There is a lack of doffing area/dustbins.	14 (9.9)
I get confused regarding which PPE to dispose of in which bin.	35 (24.8)
I get too tired after duty hours.	8 (5.7)

Discussion

In this study, we found that, nationality, age, and working hours influence nurses' different perceptions regarding the effectiveness of COVID-19 protocols. Based on the perception of the nurses regarding the COVID-19 protocol, we found that 79.4% of the respondents followed the appropriate steps in washing their hands, and 85.1% wore their PPE according to their guidelines as compared with Social Distancing wherein only 16.1% of the participants keep at least a meter when communicating. This means that participants perceive both hand washing and wearing PPE as effective protocols against the pandemic. Previous studies have concluded that nurses have demonstrated outstanding performance in conducting preventive protocols to meet the demands of the pandemic. Notably, nurses increasingly adhere to preventive measures such as hand hygiene and wearing PPE (8, 9).

Furthermore, the study reveals that more than 10 % of the participants are not wearing all the required PPE because of its unavailability. Previous researchers also noted that the shortage in PPE and resources is a major concern for healthcare workers (11, 12). In other words, one of the main reasons nurses are not wearing their PPE despite having a positive perception of the protocol is because there is a shortage of this resource.

The earliness of implementation determines the effectiveness of COVID-19 protocols implemented in 2020 to 2021 in response to the pandemic. We found that nurses trust PPE use as an effective COVID-19 protocol; once they wear it, they do not see the need to keep a 1-meter distance or have social distancing anymore. Researchers have proven that the earlier the protocols are implemented, the more remarkable the impact (27). In addition, COVID-19 protocols are more effective by combining non-pharmaceutical interventions such as lockdowns, restricting social gatherings and international travels, school closures, and strengthening information campaigns. As for healthcare workers, previous studies noted that effective communication between HCWs, patients, leadership, and team coordination and implementing strict policies to avoid errors and control the pandemic are effective COVID-19 protocols (21).

After comparing the social demographic with the nurse's perception of COVID-19 protocol, the education factor was found not to influence nurses' different perceptions regarding the effectiveness of COVID-19 protocols. This finding is consistent with Olum et al. (28) study, which revealed that there is no association between level of education and compliance with COVID-19 protocols. This can be justified by the fact that the level of knowledge about COVID19 precautions the level of knowledge about COVID-19 might be similar irrespective of level of education of healthcare workers (28).

Although the gender is not significantly associated with social distance practice in the present study females are more cautious about shaking hands with their colleagues, which means that they are more likely to social distance than their male counterparts. This can be supported by another study which revealed that female nurses had significantly higher good hand hygiene practice than male nurses (24). It was justified that the higher compliance rate of hand hygiene among females may also be associated with their propensity to practice socially acceptable behaviors (25).

Moreover, non-Saudi nurses had more tendencies to shake hands and attend gatherings with their colleagues than Saudi nurses.

Therefore, non-Saudi nurses are more likely to not adhere to social distancing protocols than Saudi nurses. In addition, Saudi nurses are more likely to follow the proper steps in hand hygiene compared with non-Saudis.

Nurses who are 25 to 40 years of age avoid entering their duty rooms with their face shields and are more likely to perform appropriately donning than nurses 40 years of age and above and Nurses who were 31 years and above are less likely to reuse their PPE for a single shift. Moreover, younger participants have significantly better hand hygiene adherence scores compared to older participants. We also found that the more experienced the nurses are, the more they comply with the COVID-19 protocols. This finding is supported by another study that has been conducted in Nigeria which revealed that compliance with the preventive measure significantly increased as nurses' years of experience increased (29).

We also found that compared to nurses who worked more than 8 h, those who worked for less than 8 h adhered more to hand hygiene. This shows that nurses who are overburdened are less likely practicing proper handwashing. Previous studies showed that not having previous experience handling certain diseases impacted the HCWs' perception and behavior on COVID-19 protocols; thus, experience influences how nurses handle the pandemic (29).

In the present study, the overall compliance with PPE usage and IPC measures in the nurses was 85.1%. However, the discrepancy in compliance rates reported in different studies might be attributed to the time factor. Some studies were conducted during the first wave of the COVID-19 pandemic (30, 31).

High perception, good level of knowledge, and high compliance rate reported among nurses in this study. Similar findings were reported in Abdel Wahed et al. study conducted among HCWs in Egypt (32).

Nurses in this study reported higher preventive practices in dealing with COVID-19. These findings affirm a previous study among healthcare workers in Saudi, and a recent study about COVID-19 in India among students and health care workers, in which, due to constant exposure and previous outbreak experience with similar coronavirus disease, this nurses were able to practice in their full clinical capacity and use preventive measures (25).

This study revealed that good compliance with PPE usage, hand hygiene, and IPC measures was independently predicted by nurses' risk perception and knowledge about PPE usage and hand hygiene. Likewise, Brooks et al. (33) review studied 56 papers and revealed evidence that staff with higher concern about the risk of infection were more likely to comply with the recommended measures. Similarly, Webster et al. (34) review found that accurate knowledge about the recommended performances, perception of susceptibility and severity of being infected, and perception of benefits of compliance would facilitate compliance.

The nurses did not see "availability of incorrect PPE sizes, feeling uncomfortable and irritable when wearing PPE, as factors that influence their practice of preventive measures against COVID-19. It is vital to the importance to apply preventive measures and comply with PPE usage, hand hygiene, and IPC measures that could minimize the spread of the disease (35). Despite that negative influence of PPE on nurses and some other psychological factors were reported by Chan (36) in their study, which is not the case in the present study, there is a need for improved knowledge through sufficient training in

order to enhance compliance to the preventive measures to COVID-19 and stop all the improper practices that may spread the infection.

In accordance with the present study, the study of Al-Rawajfah et al. (37), revealed that the overall knowledge of the health-care students about the current COVID-19 is not optimal, as only about one-quarter of the sample scored more than 75% of the maximum score.

Variation in compliance rates reported in studies could also be explained by the disparity in the studies' methodology. Self-reporting might overestimate the real compliance rate unlike assessing an observed practice. Similar results revealed from the study of Al-Mugheed et al. (26) who investigated the acceptance and attitudes of nursing students toward the COVID-19 vaccine booster dose in two Gulf Cooperation countries and showed that the total attitude scores for the students ranged from 28 to 35, with a mean score of 15.8 (SD = 2.5), representing 73% of the highest possible score, with 79.3% classified as 'positive attitude toward booster dose of COVID-19' as vaccine booster might cause infection, vaccine booster ineffective, worried about adverse effects and not safe were major barriers influencing the acceptance of the COVID-19 vaccine booster. However, preparing nursing students with positive attitude of COVID-19 vaccine booster is very important to patient and community safety.

Conclusion

The purpose of the current research is to define the nurses' perception, awareness, and compliance regarding COVID-19 protocols implementation and explore the factors influencing their perception. Through a quantitative, survey-based, cross-sectional study, we identified the nurse's perception regarding COVID-19 protocol, determined the effectiveness of COVID-19 protocols implemented from 2020 to 2021, and compared nurses' social demographic with their perception toward COVID-19 protocols. As a result, we found out that nurses perceive hand hygiene and wearing of PPE as effective COVID-19 protocols and that, nationality, age, and working hours influence nurses' different perceptions regarding the effectiveness of COVID-19 protocols.

These findings suggest that different social demographic factors influence how nurses perceive COVID-19 protocols. Healthcare providers should consider these differences in training nurses and healthcare workers in adhering to COVID-19 protocols. For example, since non-Saudis are less likely to social distance than Saudis, more informative training should be given to non-Saudi nurses regarding the importance of social distancing. Since nurses who are working for more than 8 h a day are less likely to follow the protocols, they should be given more training and their perceptions should be considered while implementing COVID-19 protocols in hospitals and healthcare centers, in order to assure better adherence in their busy schedule.

The project's strong points include filling in the research gap on the perception of healthcare workers regarding the implementation of the COVID-19 protocol in hospitals, especially in Saudi Arabia. Moreover, we found social demographics that affect nurses' perceptions of the protocols. However, the paper was based on a structured survey; thus, presenting a limitation in the study. Future researchers can conduct interviews to confirm the study's findings and

find a more in-depth explanation of why nurses provided the answers they gave. Indeed, further study is required to understand nurses' perceptions regarding the effectiveness of COVID-19 Protocols implemented in Saudi Arabia.

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 participants provided written informed consent to participate in this study. The ethical approval was obtained from the Institutional Review Board of Imam Abdulrahman BinFaisal University; IRB-PGS-2021-03-443.

Author contributions

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Research on online public opinion dissemination and emergency countermeasures of food safety in universities—take the rat head and duck neck incident in China as an example

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In recent years, food safety accidents have occurred frequently in colleges and universities, and students are prone to emotional resonance with food safety. It triggered heated discussions among the whole society and gradually formed a unique online public opinion on food safety in universities. After food safety incidents broke out in universities, some universities deliberately avoided responsibility or made mistakes in handling the incidents, which will create greater risks of online public opinion. Therefore, this paper takes the “Rat Head and Duck Neck” incident at Jiangxi Institute of Technology in China as an example. The purpose is to study the dissemination of public opinion on food safety online in universities and propose emergency countermeasures. Above all, the food safety online public opinion is divided into five stages: incubation period, burst period, spreading period, recurring period and dissipation period. Then, methods such as text mining and cluster analysis were used to deeply analyze the influencing factors at each stage of the development of food safety online public opinion. And analyze the role of different subjects in the development of public opinion based on the perspective of stakeholders. Finally, this paper provides corresponding countermeasures for different stages of online public opinion on food safety in universities, which provides suggestions and references for university governance. This study found that: (1) The resonance effect of online public opinion media on food safety in universities is significant. (2) Public opinion on food safety in universities is repetitive. (3) Improper response to food safety incidents in universities can easily trigger negative secondary public opinion.

KEYWORDS

university food safety, rat head duck neck, life cycle theory, online public opinion, emergency measures

1 Introduction

Currently, with the improvement of the economy and living standards, people pay more and more attention to healthy diets. In public health, foodborne diseases have become one of

the threats to public health security. Physiological diseases caused by unhealthy food are explosive and aggregated, especially in developing countries, bringing a heavy disease burden (1). As an important educational institution in the country, colleges and universities are the foundation for building an educational power and are responsible for cultivating a group of intellectuals for society (2). Therefore, the healthy development of students has become a common concern of society. However, in recent years, food incidents in colleges and universities have occurred frequently, causing concerns among students and their families (3). As a gathering place for students, colleges and universities will pose a threat to the lives and safety of many students once a food safety incident occurs. At the same time, students begin to fear performance in the cafeteria, which also brings great psychological harm to students (4). In 2022, hundreds of Iranian students suffered from food poisoning, which damaged the credibility of universities and the government.¹ There have also been many food safety incidents in universities in China. In September 2020, nearly a 100 students at Wuhu Vocational and Technical College in Anhui suffered from vomiting, diarrhea and other poisoning symptoms after eating in the canteen. This was caused by irregular food processing. Therefore, it can be seen that colleges and universities have become high-incidence areas for food safety accidents. For this reason, food safety in colleges and universities has also attracted much attention from the Chinese government. As early as 2003, China's former Ministry of Health issued the "Emergency Notice on Strengthening the Supervision and Management of School Food Hygiene during SARS Prevention and Control" Given the dire food safety situation in colleges and universities, health and education administrative departments at all levels are required to conduct safety inspections in college canteens. Hygiene problems discovered during inspections should be corrected promptly to help schools improve their food hygiene management levels. In 2023, the State Council of China revised the "Measures for Evaluation and Assessment of Food Safety Work." This aims to implement the "Four Strictest" requirements for food safety and strengthen local government territorial management responsibilities. Improve the ability to supervise the entire process from farmland to table, continuously improve the level of food safety throughout the chain, and ensure the health and life safety of the people.² However, compared with food safety problems in other fields, food safety problems in universities have more serious consequences. The reason is that this poses a threat to the life and health of the majority of students, and its impact is sudden and widespread, which may further lead to the occurrence of mass infectious diseases. Food safety in colleges and universities is directly related to the lives and health of students, and it also involves the concerns of countless students' families. At the same time, students, as the main active force on the Internet, will expose food safety accidents in school cafeterias and require schools to publicly solve food safety problems, thus forming a larger online public opinion on food safety in colleges and universities. After the outbreak of food safety accidents in universities, relevant departments intentionally avoided responsibilities or mishandled the incidents, thereby creating greater risks of public opinion on university food safety online.

Colleges and universities carry the important mission of "Educating Talents for the Country." Sudden food safety incidents in universities endangering the health of students are negative news, which is completely different from the mission of "Educating Talents for the Country." Negative news expresses stronger emotional energy on the Internet, directly contributing to the generation and development of online public opinion (5). Currently, with the advent of the 5G era, the Internet is gradually becoming more popular. According to the 52nd "Statistical Report on China's Internet Development Status," as of June 2023, the number of Internet users in China reached 1.079 billion, and the power of online public opinion is huge. After the outbreak of food safety incidents in colleges and universities, students, as the main force active on the Internet, actively discussed food safety incidents in colleges and universities. Students have a high degree of emotional resonance with emergencies in colleges and universities, so students will be exposed to food safety incidents in canteens around them on the Internet. Then the student union of our school forwarded and commented on the incident, which gradually attracted the attention and discussion of students from other schools and the whole society. People have condemned the school and asked officials to respond to the accident. As a result, the online public opinion on food safety in universities has been further fermented and developed. The outbreak of online public opinion on food safety in colleges and universities is sudden and spreading. This requires understanding the development rules of public opinion and responding in time. Otherwise, public opinion will develop in a bad direction and directly trigger mass incidents. At the same time, online public opinion on food safety brings harm to the reputation of universities and even threatens the normal teaching activities of schools. As the supervisor of universities, the government's credibility will also be questioned. However, there are currently few studies on public opinion on food safety in universities. On June 1, 2023, the "Rat Head and Duck Neck" incident broke out at Jiangxi Institute of Technology in China. The incident triggered extensive discussions and generated a large public opinion on the university's Internet. Therefore, based on the information life cycle theory and the perspective of stakeholders, this paper takes China's "Rat Head and Duck Neck" incident as an example to try to explain the propagation rules of public opinion on food safety in colleges and universities, and propose appropriate emergency countermeasures for each stage of public opinion development. In this way, we can effectively prevent and control online public opinions on food safety in universities. The innovation points of this paper: (1) Creatively combines university online public opinion with food safety online public opinion. Take China's "Rat Head and Duck Neck" incident as an example, which is very representative. It well explains the public opinion caused by food safety accidents in colleges and universities. (2) Using life cycle theory, the online public opinion on food safety in universities is divided into five stages. More importantly, text mining and cluster analysis methods are used to analyze the causes of online public opinion at different stages. On this basis, corresponding emergency countermeasures are given in a targeted manner.

2 Literature review

This paper focuses on the online public opinion on food safety in universities. However, there are few studies specifically studying

1 Data Sources: <https://www.universityworldnews.com/>.

2 Data Sources: <https://www.pkulaw.com/law>.

online public opinion on food safety in universities. Compared with other types of online public opinions in universities, online public opinions on food safety in universities are unique, their scope of influence is wider, and their consequences are more serious. Therefore, this paper needs to study the evolution of public opinion on food safety in universities. With the further popularization of the Internet, it has become more convenient for college students to use social media to surf. Post comments on the Internet anytime and anywhere to discuss current hot events, thereby promoting the generation of hot searches on the Internet (6). Online public opinion in universities affects the image of universities, and the guidance and management of public opinions has become one of the daily tasks of universities. First of all, in the research on the evolution and dissemination of online public opinion in colleges and universities, college students have integrated into the wave of the Internet. College students actively discuss various social events on the Internet and are deeply affected by the online public opinion field (7). The generation of online public opinion in colleges and universities comes from hot events in colleges and universities, especially negative information about colleges and universities, which are most easily spread, thus triggering larger online public opinion (8). In the development of each online public opinion, the focus of netizens' comments changes with the disclosure of information. It is very important to understand the themes of online public opinion at different stages, which has guiding significance for controlling the further expansion of public opinion (9). Therefore, using the Latent Dirichlet Allocation (LDA) topic model, based on the public opinion popularity index and time series-based trends, can perform a time series analysis of university online public opinions (6). Then, in order to resolve the crisis of online public opinion in universities, it is particularly important to explore the spread rules of online public opinion in universities. AnyLogic software was used to simulate the improved SNIDR infectious disease model, which can intuitively simulate the process of spreading public opinion on the university online (8). Of course, online public opinion in universities is often accompanied by rumors. In an environment with asymmetric information, rumors can easily spread. However, college students only pay attention to existing information on the Internet and comment on it, and do not know whether the incident is true and complete (10). The complex and ever-changing Internet environment challenges the moral concepts and values of college students. Especially for college students with immature physical and mental development, they are easily influenced by online public opinions. Among them, social motivations and information sources are the main factors affecting college students' online public opinion dissemination behavior (11). Therefore, ideological and political education in colleges and universities should be combined with big data to guide college students' outlook on life and values (12). In addition, colleges and universities should make full use of Internet tools to pay attention to student's physical and mental health and behavior (13), so as to effectively use online public opinion to educate and guide them (14). Then, in the research on prediction and early warning of online public opinions in colleges and universities, it is mainly used to track and predict public opinions in a big data environment. Through the collection of university public opinion data, the public opinion information is then cleaned and processed. Then machine learning to track the theme of public opinion to achieve the detection of public opinion (15). College students are greatly affected by external public

opinion and their self-awareness is not strong. Therefore, they need to increase their efforts to use big data to analyze the trend of public opinion to achieve early detection and early resolution (16). College students are independent individuals with high intellectual abilities. To demonstrate the spirit of individualism, it is very easy to express opinions and comments on hot social events, which has led to the emergence of online public opinions in colleges and universities (17). A multi-level and comprehensive dynamic detection system has been established using big data, which can effectively predict and process online public opinion in universities (18). Of course, the development of online public opinion in colleges and universities mainly includes three key entities: Internet media, college students, and management. Further analysis is the game between these three parties. The role of any party will affect the advancement of the entire public opinion (19). Among them, college students, as the core factor of online public opinion in colleges and universities, make inappropriate remarks on social platforms or become the disseminators of rumors. This directly leads to the generation and development of public opinion, for which it is necessary to establish a campus Weibo comment forwarding and comment prediction model based on neural networks (10). Schools pay attention to students' interactive content on social media, and then understand students' performance on online platforms, providing a basis for identifying and preventing potential problems (20). Finally, in the research on the processing and guidance of online public opinion in colleges and universities, for college students to develop healthily physically and mentally, it is very necessary to guide college students' public opinions on social media, thereby promoting the formation of students' correct values and outlook on life (21). Through semi-structured interviews with counselors, we can understand the factors that influence students' participation in online public opinion, mainly subjective, objective and peripheral factors (22). In addition to paying attention to the online public opinion of universities themselves, it is more important to use big data to analyze the mental health of college students and establish an emergency protection system for the mental health of college students (23). For this reason, some scholars have been able to analyze the emotional attitudes of comments in public opinion based on the improved text emotion learning model, thereby controlling the emotional response of the entire public opinion event process (24). From the perspective of schools' response to public opinion in colleges and universities, it is mainly divided into three stages: intervention beforehand, intervention during the incident and intervention after the incident. Topic guidance, rapid response and agenda-setting are more effective solutions (25). Universities can use smart campuses to establish public opinion platforms for monitoring and to analyze the generation and dissemination of public opinion (26). Of course, after online public opinion breaks out in universities, it will inevitably damage the image of universities, and repairing the image of universities is destined to be a long process (27). In particular, there are differences in the dissemination of online public opinion in different types of colleges and universities, and accordingly, targeted public opinion emergency countermeasures are needed.

So, this paper focuses on the online public opinion on food safety in universities. As the name suggests, it is the online public opinion caused by food safety accidents in university cafeterias. Compared with other types of online public opinions, online public opinions on food safety mainly involve conflicts between university cafeterias and

student groups. As a group public place, university cafeterias have indoor air quality, environmental sanitation, food material sources and operating procedures that may cause problems in cafeteria hygiene (28). However, many studies only focus on questionnaire surveys on food safety in colleges and universities, and the subjects are students, canteen staff, and managers (29), and few directly study the online public opinions caused by food safety in colleges and universities. In addition, some scholars are currently studying online public opinion on food safety. In most cases, the media exposes relevant reports on food safety, which triggers heated discussions. For example, food fraud (30), green organic rice (31), alternative meat (32), genetically modified soybeans (33), etc. will arouse social concern. The underlying reason behind this is the consideration of safe food.

Of course, there is no doubt that similar to other online public opinions, the development of online public opinions in universities also proceeds in stages. Currently, it is more common to use life cycle theory to analyze the stage division of public opinion. The information life cycle is developed from life cycle theory (34). As early as the end of 1950, the crisis theory on the human life course was proposed, which was the prototype of the original life cycle theory (35). Currently, according to the life cycle theory, academic circles divide online public opinion into three, four (36), five (37) and six stages. Among them, the third and fourth stages (38) are the main ones. The difference is due to the different types of Internet public opinions. Internet public opinions triggered by different types of events have their own operating mechanisms, and their cycles are naturally also quite different (39). However, it is generally consistent with the life cycle theory, from creation to dissipation. Any period division is inseparable from three basic stages, namely: the formation period, development period, and decline period (40).

Based on the above, there are currently many studies on online public opinion in colleges and universities. It mainly focuses on three aspects: the dissemination of university public opinion, the prediction and early warning of university public opinion, and the processing and guidance of university public opinion. However, it is regrettable that there are few research topics dedicated to online public opinion on food safety in universities. In addition, although there are a few studies on online public opinion on food safety, they are relatively broad and do not focus on schools as a public places. Therefore, this paper focuses on food online public opinion in universities. Apply life cycle theory and take the rat-headed duck-neck incident in China as an example. This paper provides a complete analysis of the development of public opinion on food safety accidents in colleges and universities. It aims to analyze the rules of the spread of public opinion on the Internet in colleges and universities and propose corresponding emergency countermeasures for each stage of public opinion. Before studying the online public opinion on food safety in universities, this paper puts forward the following assumptions. (1) The spread of online public opinions caused by food safety accidents in universities will not conflict with other types of online public opinions. (2) It is assumed that when discussing the role of each subject in public opinion, all factors considered have been comprehensive and other factors can be ignored. (3) This paper is based on Weibo data and ignores online public opinions on food safety in universities triggered by other platforms. The research framework of this paper (Figure 1).

3 Research methods and data sources

3.1 Cluster analysis method

This paper mainly uses text mining methods to analyze online public opinions on food safety in universities. Currently, cluster analysis is mostly used in text mining. Cluster analysis is a more advanced statistical method, and the most commonly used are hierarchical cluster analysis and K-means cluster analysis (41). The so-called cluster analysis is to divide the data set into several clusters according to the unsupervised principle, so that the subsets under the same cluster maintain a high degree of similarity (42). In text cluster analysis, the same cluster is a group containing similar topics, and objects in different clusters are as different as possible. This paper will use the FCM clustering algorithm. Compared with the hard ordinary C-means algorithm, the fuzzy C-means algorithm has been improved and is a soft clustering method. At the same time, this clustering method is clustering based on the objective function. In a given data set containing n data: $X = \{X_1, X_2, \dots, X_i, \dots, X_n\}$. X_i is the i -th feature vector. X_{ij} is the j -th attribute of X_i . The FCM algorithm divides the data set into K categories, and the cluster centers are $[V_1, V_2, \dots, V_n]$. The objective function of FCM is formula (1), and its constraint is Formula (2).

$$J(U, V) = \sum_{i=1}^n \sum_{j=1}^k u_{ij}^m d_{ij}^2 \quad (1)$$

$$\sum_{j=1}^k u_{ij} = 1, u_{ij} \in [0, 1] \quad (2)$$

In the above formula, u_{ij} is the membership degree between the sample point x_i and the cluster center V_m , m is the blur index. d_{ij} is the distance between the sample point x_i and the cluster center V_n .

$$u_{ij} = \frac{1}{\sum_{c=1}^k \left(\frac{d_{ij}}{d_{ik}} \right)^{\frac{2}{m-1}}} \quad (3)$$

$$v_j = \frac{\sum_{i=1}^n u_{ij}^m x_i}{\sum_{i=1}^n u_{ij}^m} \quad (4)$$

The fuzzy C-means algorithm obtains fuzzy classification of the sample set through iterative optimization of the objective function. To obtain the minimum value of the objective function J , the Lagrange multiplier method is used on the objective function under the condition that the constraints are met, and the membership matrix u_{ij} and the cluster center v_j are obtained (Formulas 3, 4).

3.2 Data sources

This paper focuses on the study of online public opinion on food safety in universities. The so-called online public opinion mainly

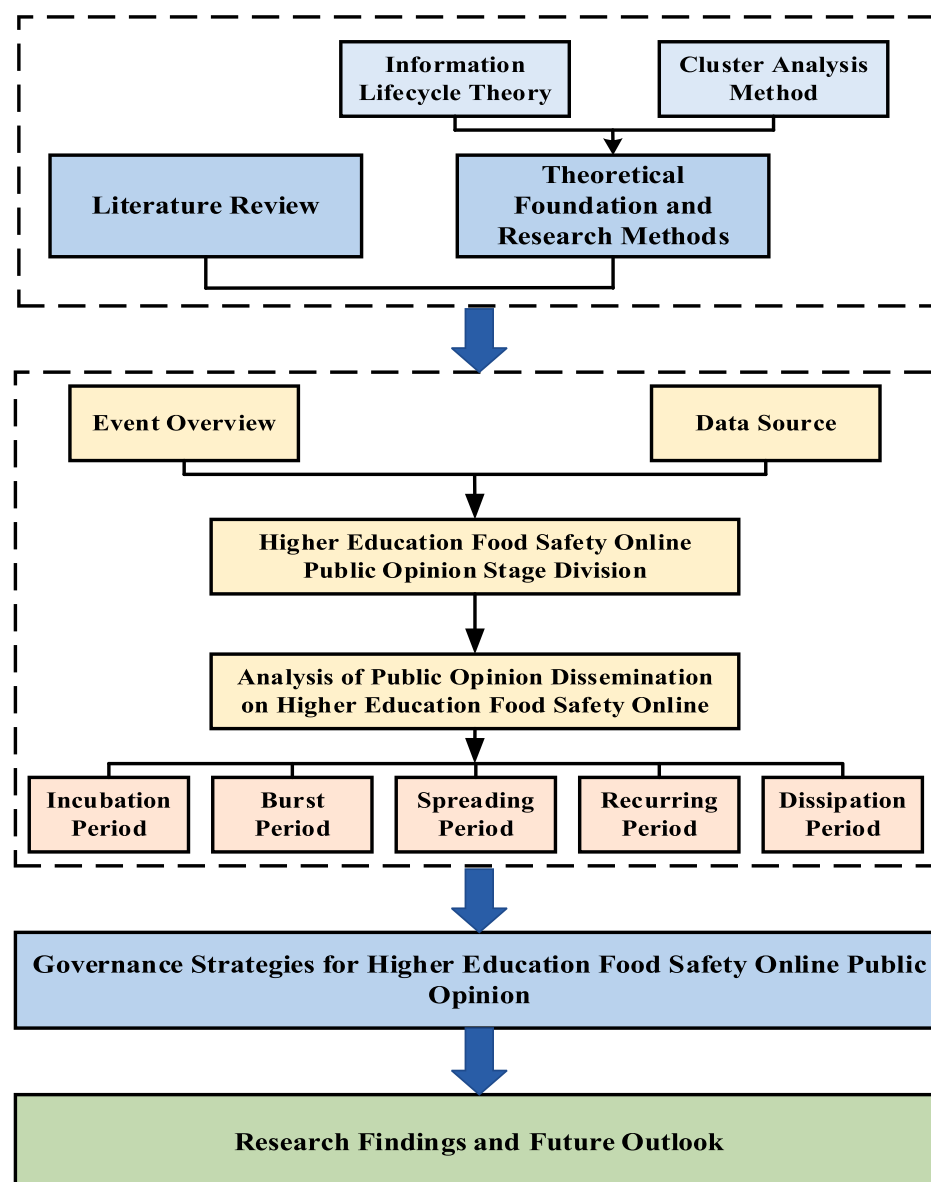


FIGURE 1
Research framework diagram.

refers to discussions on specific topics on major social platforms. Topic discussions eventually form larger online public opinions. Weibo is the most active platform on the Internet in China and has the widest audience. Therefore, this paper selects the Weibo platform as the data source for online public opinion on food safety in universities. Weibo topic popularity reflects the discussion and attention of Weibo users on a certain topic during a specific period. Generally, public opinion is intuitively evaluated from quantitative data such as the number of Weibo posts related to the topic, the number of forwards, the number of comments, and the number of likes (10). The number of retweets on Weibo is often used as a representation of the activity and popularity of Weibo. The higher the number of retweets, the higher the activity on Weibo (43). Therefore, in order to explore the evolution of online public opinion about the

rat-headed duck-neck incident in Jiangxi colleges and universities in China, the keyword “Rat Head and Duck Neck” was entered on the Weibo page and Python software was used to crawl the data. Finally, relevant data such as the number of Weibo posts, topics, content, forwarding volume, comments, and likes were obtained. The “Rat Head and Duck Neck” incident occurred on June 1, 2023. After many turning points, public opinion stabilized and gradually subsided by the end of June 2023. Therefore, this study limited the time range of the data search to June 1, 2023, to June 30, 2023. After excluding irrelevant data, a total of 33,778 valid original Weibo posts, 138,717 valid retweets, 252,181 valid comments, and 4,037,052 valid likes were mined. The crawling time is July 1st, which can effectively ensure that the Weibo topic data is crawled, so that the Internet public opinion of the Rat Head and Duck Neck incident can be completely reproduced.

4 Empirical analysis of online public opinion dissemination of food safety incidents in universities

4.1 Event overview

On June 1, 2023, a student at Jiangxi Institute of Technology in China was suspected of eating a foreign object in the cafeteria. Related videos were circulated on major platforms. The foreign object in the videos was highly similar to mice, which aroused social concern. The school and front-line law enforcement officers began to unanimously say that the foreign objects in the food were duck necks, which caused the Internet public opinion to reach a climax. Subsequently, a joint investigation team was established. After investigation and verification, the results showed that the conclusion given by the school was wrong. In the end, the school involved terminated its contract with the logistics group. After the entire incident was exposed that a student had eaten a foreign object, the university did not disclose the true situation truthfully, which made the public dissatisfied with the results of the report (Figure 2).

It can be seen from this that public opinion was not well handled in the initial stage, which made the online public opinion on food safety in colleges and universities reach a historical height. This public opinion lasted for a long time and aroused widespread concern from society. This has led the government to introduce a series of measures to control food safety in colleges and universities.

4.2 Stage division of online public opinion on food safety in universities

Different types of online public opinions have different evolution rules, and their peaks are also different. The same type of online public opinion will also be different due to the different progress of the event. With the continuous disclosure of information about the incident and the participation of different subjects of public opinion, public opinion will fluctuate. For example, some types of online public opinion are cyclical and will occur at every point in time. Some online public opinions are one-off and will only be generated when the event occurs. Of course, there are also Internet public opinions that will indirectly

affect the frequent occurrence of other public opinions of the same type. This is the domino effect (44). Although the development trajectory of online public opinion is relatively complex, it still essentially conforms to the characteristics of the information life cycle. The generation of online public opinion basically comes from the outbreak of social or natural events, but the premise is that the event can attract public attention.

The “Rat Head and Duck Neck” incident in this paper belongs to the topic of food safety in colleges and universities, and food safety in colleges and universities is related to the health issues of students. The main subject of this incident was the university cafeteria, which has a certain degree of sensitivity. In addition, the development process of the incident itself was tortuous and complicated. The incident was questioned by students and then denied by the school and front-line law enforcement officials. Finally, the authoritative agency issued a document confirming that the school and front-line law enforcement officials made wrong judgments and other tortuous processes. The “Rat Head and Duck Neck” incident spans a long time, and it takes a certain amount of time for schools and relevant government agencies to investigate and collect evidence. This has caused public opinion on this topic to reach peaks repeatedly within a month, showing an evolutionary trend of “Multi-peak Public Opinion.” However, it still essentially fits the cyclical and staged characteristics of the information life cycle. In order to carry out in-depth research, this paper is based on the information life cycle theory. Concerning the actual development of public opinion in the “Rat Head and Duck Neck” incident, the online public opinion of the “Rat Head and Duck Neck” incident is divided into five stages: the incubation period, the burst period, the spreading period, the recurring period, and the dissipation period. Specifically, the incubation period means that the incident has occurred and a certain amount of discussion has occurred, but it has not spread on a large scale. The burst period refers to the qualitative change or reversal of an event, or the event may be reported by the media, thereby attracting a large number of people to participate, and public opinion will spread rapidly in a short period, reaching the first peak of public opinion. The contagion period refers to that as information related to the incident continues to be disclosed, public opinion gradually deepens, and the number of subjects and content participating in the topic discussion continues to increase. This is manifested in the high growth rate of the number of Weibo posts,

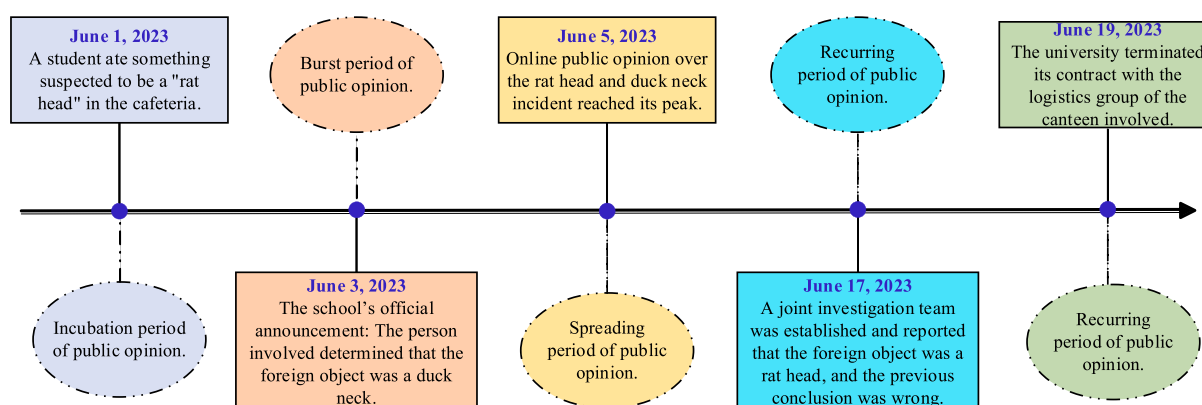


FIGURE 2

The development trajectory of the "Rat Head and Duck Neck" incident in universities in Jiangxi, China.

reposts, likes, and comments. The recurring period refers to the fact that after the first peak of public opinion appears, the public opinion does not completely subside, but peaks appear again as events evolve, or even multiple peaks appear. The dissipation period means that the issue of the public opinion incident is basically resolved and the official responds to the focus of public opinion. As time goes by, the discussion of the incident gradually decreases and the public opinion gradually dissipates.

According to the number of Weibo posts, reposts, comments and likes of the “Rat Head and Duck Neck” incident, and also with reference to important events that occurred in the public opinion process, the Rat Head Duck Neck online public opinion was divided into five stages (Figure 3). Incubation period: June 1 to June 2, 2023, burst period: June 3 to June 4, 2023, spreading period: June 5 to June 12, 2023, recurring period: June 13, 2023–June 20, dissipation period: June 21, 2023–June 30. From the perspective of the number of posts, the number of likes, the number of comments, and the number of retweets, public opinion is mainly concentrated in three stages: the burst period, the spreading period, and the recurrence period, while the value of public opinion is lower in the incubation period and the dissipation period. On the whole, the incubation period of public opinion is short, and the outbreak period is characterized by a rapid increase in attention in a short period. The incident involves multiple stakeholders, causing public opinion to fluctuate in cycles. The dissipation period lasts longer than the outbreak period. In other words, the occurrence of online public

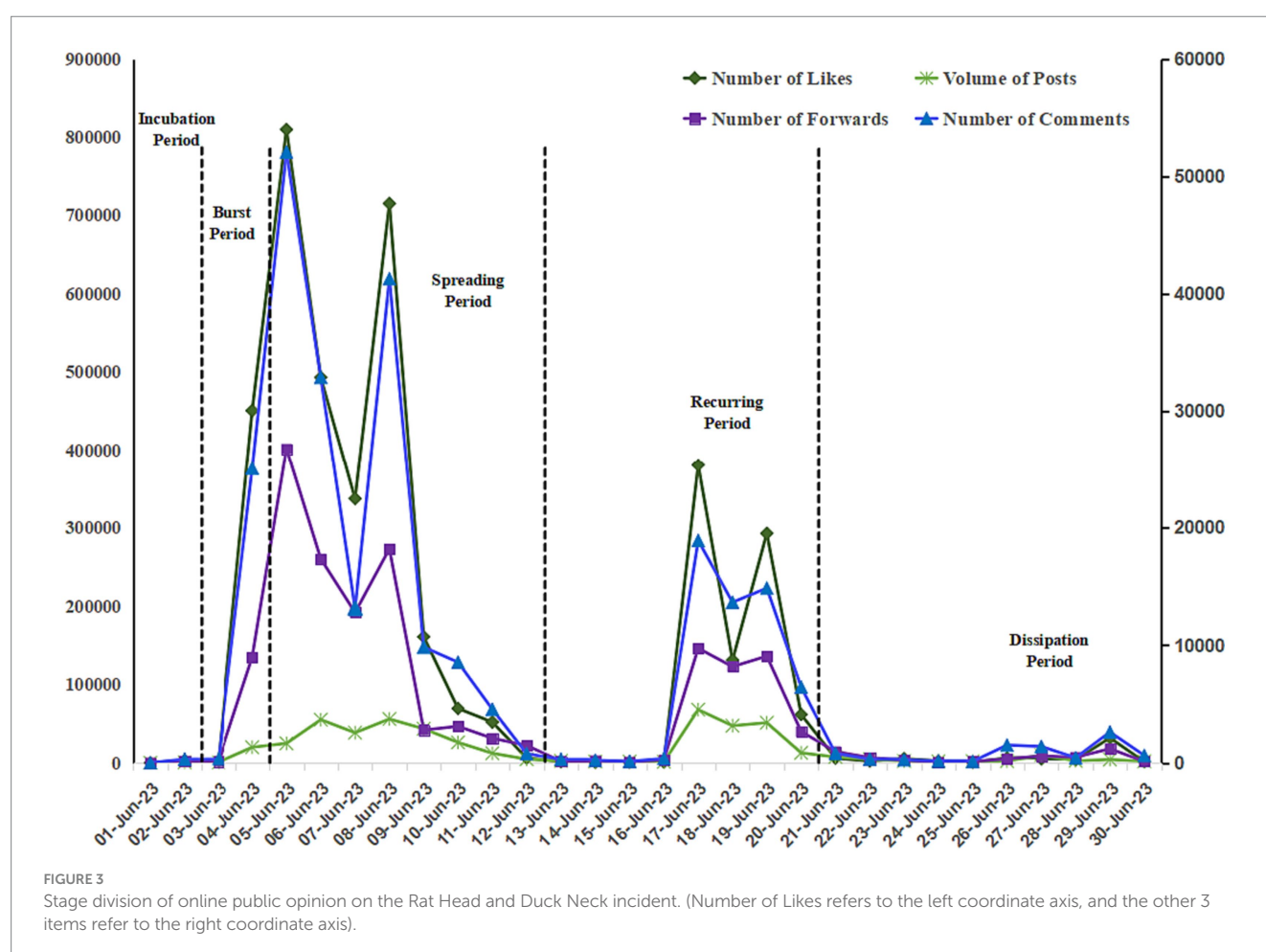
opinion on food safety in universities is sudden, while its demise is often gradual.

4.3 Analysis of online public opinion dissemination of food safety in universities

The main body of online public opinion on food safety in universities is the issue of food safety in universities. At the same time, online public opinion in colleges and universities broke out concentratedly among the student groups. Therefore, the majority of public opinions in colleges and universities are related to online public opinions among students or between students and their schools (18). In the era of all media, the dissemination of online public opinion has broken through the limitations of time and space, and has the characteristics of fast propagation speed and wide diffusion range. The online public opinion triggered by the “Rat Head and Duck Neck” incident follows the information life cycle theory, and each stage presents relatively distinctive characteristics.

4.3.1 Incubation period: public opinion spread in a small area contains risks

The incubation period is the budding period of public opinion information. At this time, public opinion is only spread in a small range, with less media involvement, and has not yet received widespread attention from the public. The incubation period of the



“Rat Head and Duck Neck” incident was short. The incident of a college student eating a rat-headed duck neck occurred on June 1. There was no relevant report on Weibo that day, and only some official media reported the incident the next day. On June 2, the total number of posts on Weibo was small, and the number of retweets, comments, and likes were all at a low level. Through the extraction and analysis of high-frequency words (Figure 4), the public opinion at this stage mainly has three aspects: Theme 1: #yue# disgusting#, the “Rat Head and Duck Neck” incident was initially spread in the form of video. Since the foreign object in the video is highly similar to a rat head, netizens expressed their discomfort with the foreign object after watching the video. This is the most intuitive and real feeling. Theme 2: #University#foodsafety#contractor# expresses netizens’ concerns about food safety in universities, especially their concerns that catering companies such as university contractors cannot guarantee food safety. The occurrence of food hygiene incidents in colleges and universities does not meet people’s expectations for colleges and universities, creating a good deficit before and after. Theme 3: #staff# investigationverification#, netizens hope to investigate and verify as soon as possible and report the truth of the incident. At the current stage, netizens view the incident more rationally and objectively, and the focus of the discussion is their concerns about the current status of food safety in universities. In other words, the practices and responses of universities at this stage have attracted much attention.

The main reason why public opinion is relatively small at this stage is that the dissemination of information follows the life cycle theory, and the fermentation of public opinion requires a certain amount of dissemination time. The spiral of silence plays a significant role in the early stage of public opinion. The expression of personal opinions is a social psychological process. When people find that their opinions are consistent with those of the majority, they will tend to express their opinions. If your views do not conform to the attitudes of the majority, you will choose to remain silent. Especially when the event is not clear enough, even if they see the news about the event, more people tend to remain neutral and have a wait-and-see attitude.

The “Rat Head and Duck Neck” incident has just occurred, and relevant reports are relatively limited. The full picture of the incident is still unclear, and the information is vague and sparse. Coupled with factors such as group pressure and herd mentality, people often choose to remain silent. From the perspective of relevant stakeholders (Figure 5), there are three main categories of stakeholders involved in the incubation period of public opinion. First of all, related information such as the suspected rat-head video will be disseminated by the students involved, students at the scene, and students of the school. Then, the school’s canteen workers, canteen directors, and canteen chefs represent the school and are the main actors directly related to the food safety incident. Finally, there are fewer media outlets with fewer headlines and fewer netizens. From the perspective of the three types of interest entities, it is obvious that the first two are in a state of game and there are conflicts between them. However, the media and netizens are in a wait-and-see attitude, looking at this incident with a casual attitude.

4.3.2 Burst period: improper response triggers crisis of trust

The sudden period is the result of the accumulation of quantitative changes during the incubation period. At a certain point in time, the event reverses or changes, or the event is infinitely amplified by the media, causing the discussion of the topic to rise rapidly. At this time, the number of posts, reposts, comments and likes on the Weibo topic increased dramatically. On June 3, the university officially issued a post clarifying that the “Foreign Object” eaten by the students was a duck neck rather than a rat head. People responded to express doubts about this, which quickly set off a heated discussion among netizens. On June 4, the media conducted interviews and reports on the frontline law enforcement officers of the incident, and the law enforcement officers once again confirmed that the foreign object was a duck neck. This further intensifies the fermentation of public opinion and puts online public opinion at a higher risk. Through text mining at this stage, the representative discussion topics are: #



FIGURE 4
Word frequency chart of public opinion content during the incubation period.

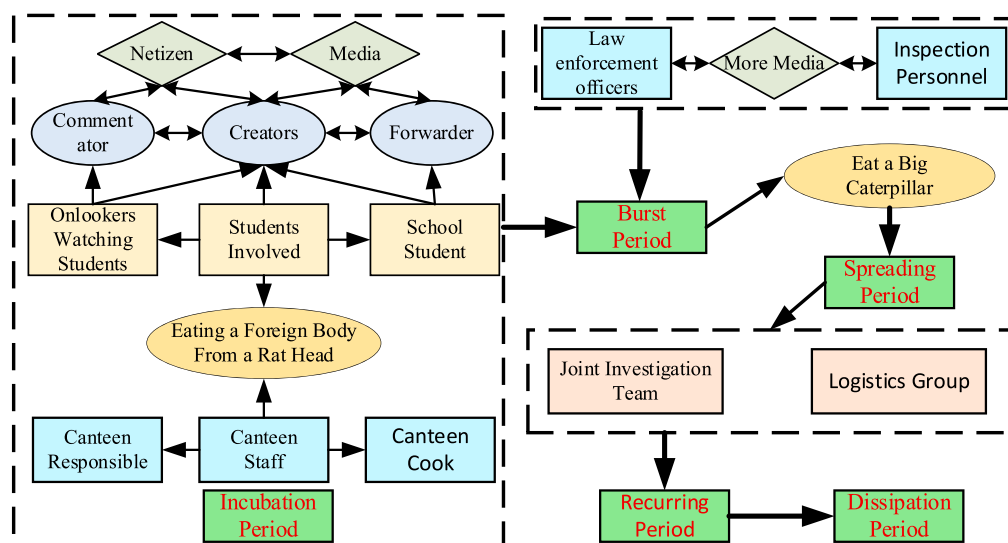


FIGURE 5
Diagram of stakeholder participation at various stages of public opinion.

Municipal Supervision Bureau once again confirmed that foreign matter in college meals is duck neck#, # Municipal Supervision Bureau responded to repeated comparisons and confirmed that it is duck neck#. The specific performance is as follows: the number of posts increased by 3247.5% compared with the previous day, the number of forwards increased by 8923.2%, the number of comments increased by 7140.2%, and the number of likes increased by 16099.9%. Public opinion at this stage was mainly questioning, targeting announcements issued by the school and feedback from frontline law enforcement personnel. The public expressed anger, doubt, and ridicule, conveying their distrust of government agencies, and negative public opinion heated up rapidly. At this stage, new high-frequency words in public opinion such as “Municipal Supervision Bureau,” “Credibility” and “Administration Bureau” appeared. The main focus of conflict has shifted from the food safety crisis to the crisis of trust in universities and the government. The attitude of netizens has shifted from worrying about food safety in universities to questioning the objectivity, fairness, and authority of government law enforcement personnel and law enforcement results.

Cluster analysis of the content posted at this stage (Figure 6) is mainly based on different stakeholders. Rat head, duck neck, rat head, teeth, hair, shape, etc. are general descriptions of the video content. The university, school officials, school cafeteria, Jiangxi, Nanchang, etc. represent the school involved. Market Supervision Bureau, samples, in-depth investigations, etc. represent third-party testing agency departments. Netizens, media, Weibo videos, disgusting, etc. represent a large number of netizens and media participating in the discussion of public opinion. In addition, from the perspective of relevant stakeholders (Figure 5), compared with the public opinion incubation period, two new actors, law enforcement officers and testing agencies, have appeared in this stage, and they together form the fourth category of subjects. According to common sense, this type of subject has no interesting relationship with the first three types of subjects. Therefore, the canteen involved will be tested and investigated, and it should be trustworthy. However, the results announced by the test were surprising, and it was still confirmed that

what was eaten was a duck neck rather than a rat head. This directly aroused public dissatisfaction, which in turn led to a rapid rise in public opinion. Of course, the media plays a role in fueling the situation. The media disseminates and analyzes the inspection results of law enforcement personnel and monitoring agencies, which creates a greater risk of online public opinion.

Analyzing the reasons for the explosive growth of public opinion at this stage. To begin with, the development of the Internet provides objective conditions for the rapid dissemination of public opinion. Compared with traditional media, new media platforms such as Weibo allow information to be disseminated faster and more widely. At the same time, the convenience of commenting and forwarding on Weibo can easily lead to the fission-type diffusion of online public opinion online, which is conducive to breaking the spiral of silence mechanism. Besides, the main body of public opinion dissemination is consistent with the main stakeholders of the incident. The main body of online public opinion dissemination is young students, and this college food safety incident first involves the safety of students. The two are similar in age, cultural level, living environment, interest views, etc., and are prone to emotional resonance. The last but not the least, improper response was the direct cause of the outbreak of online public opinion (45), and was also the direct trigger of the explosive growth of public opinion in the “Rat Head and Duck Neck” incident. In fact, after a university in Jiangxi issued a briefing on the situation on its official Weibo, the incident of “College Food Safety” has evolved into a secondary incident in which “School authorities and law enforcement officials are confusing right and wrong.” In this “Rat Head and Duck Neck” incident, the foreign object in the video is obviously a “Rat Head.” The school and front-line law enforcement officials all concluded that the foreign object was a duck’s neck, which made it difficult for the majority of netizens to believe it, and public opinion surged rapidly. Due to the secondary public opinion caused by improper government response, the public opinion caused by food safety management in universities originally belonged to the online public opinion in the social field. However, due to improper handling of the crisis by government departments, risks derived from public

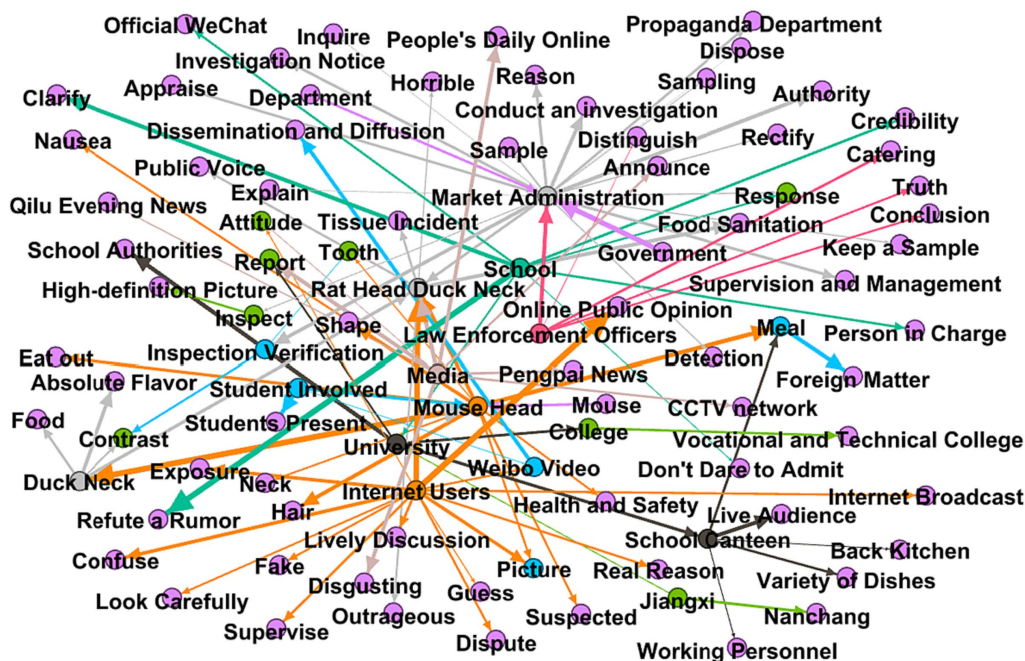


FIGURE 6
Clustering diagram of public opinion content during the burst period.

opinion are transmitted to the political field (46). This in turn causes netizens to question the fairness of law enforcement, and indirectly causes damage to the government's credibility.

4.3.3 Spreading period: the recurrence of similar canteen safety accidents extended the spreading period

The contagion period refers to the in-depth dissemination of information on social platforms (47). Both the subjects participating in public opinion and the number of topics discussed about the incident have reached unprecedented heights. Public opinion reached its peak on June 5, with the number of Weibo retweets, comments, and likes all reaching their highest peaks. In addition, on June 8, large caterpillars appeared in the dishes of the university cafeteria involved, which once again aroused public opinion and resonated with the original public opinion to form a peak of public opinion. The "Big Green Worm" incident broke the pace of public opinion's original dissipation period and extended the duration of the contagion period. Online public opinion resonance refers to the convergence of some events due to their high similarity in the subjects involved, topics, and netizen sentiments. This then forms a cluster of public opinion events on the university food safety online, which are more likely to resonate with each other and produce a greater butterfly effect and resonance effect. There are connections and echoes between food safety incidents of the same type, and the occurrence of new food safety incidents can awaken earlier food safety incidents. The "Big Green Worm" incident resonated with the public opinion of the "Rat Head and Duck Neck" that has not yet ended, triggering a new climax of public opinion. The topic "A college student with a rat head and a duck neck claimed to have eaten a big caterpillar again" quickly set off a climax of public opinion. Compared with the peak of public opinion on June 5, the number of posts increased by 125.8%. In addition, the drop in the

share price of Juewei Yabo has also become a hot topic in public opinion. Judging from the stakeholders participating in this event (Figure 5), compared with the burst period and the spreading period, there are no new increases in stakeholder groups (48). However, the rise in public opinion at this stage is mainly due to the large caterpillar eaten in the same canteen, which echoed the suspected rat heads eaten during the incubation period, so more media participated in related reports.

The attitudes of netizens can be divided into the following three types. The first is the rational group, which uses keywords such as "Investigation" and "Supervision" to express suggestions that the school should replace the canteen contractor as soon as possible. The group called on government departments to fulfill their regulatory obligations and conduct early investigations to give fair results. The second is the mocking group, which imitates the words and deeds of universities and law enforcement officials in the "Rat Head and Duck Neck" incident. Statements such as "After repeated comparisons, it is green peppers" and "Big caterpillars can enhance protein and provide students with extra meals" express their ridicule. The third group is the radical group, saying that the original video footage has left a deep impression on the majority of netizens. The written and oral statements provided by the Municipal Supervision Bureau cannot eliminate the strong impression caused by the original video. Therefore, the majority of netizens angrily questioned why universities and relevant departments regarded rats as ducks, why they did not strictly investigate the hygiene issues in university cafeterias, and how to ensure the food safety of university students. There are two main reasons for the formation of public opinion resonance. On the one hand, colleges and universities did not pay enough attention to this public opinion incident. While the "Rat Head and Duck Neck" public opinion has not dissipated, all food safety incidents in colleges and universities are considered sensitive matters at this time. At this stage,

the colleges and universities involved did not pay enough attention to food safety issues, and failed to immediately investigate their own “Flammable and Explosive” points, which caused the “Big Green Worm” incident in the cafeteria to happen again. On the other hand, the elements of the two food safety accidents are highly similar. The incident in which big caterpillars were eaten again in a university is related to the same subject as the “Rat Head and Duck Neck” incident. They both belong to the field of public health in universities. Netizens’ sentiments are all negative. In other words, before the public opinion of the “Rat Head and Duck Neck” incident has subsided, the relevant subjects and similar incidents are in a highly sensitive period. Any similar emergencies can easily arouse the “Rat Head and Duck Neck” incident and form a resonance of public opinion.

4.3.4 Recurring period: publicity of investigation results and in-depth media digging caused public opinion to fluctuate

The relapse period is the next stage after the spreading period of public opinion, where public opinion gradually declines after a long peak. Because the food safety incident had not been completely resolved, public opinion remained silent for a relatively short period. However, as more new details and content are disclosed, or as the incident progresses, public opinion will reach a climax again. With the follow-up reports of the “Rat Head and Duck Neck” incident, the media dug into the relevant information of the cooperative canteen, which aroused heated discussions among netizens and brought about two sub-peaks of public opinion (Table 1).

On June 17, the joint investigation team reported the investigation status and confirmed that the conclusion that the foreign object was a duck neck was wrong. In other words, this refutes the investigation conclusions previously announced by the university and front-line law enforcement officials. At the same time, a large number of media spread this reversal of the findings. The inconsistencies between the two surveys were highlighted. This aroused public suspicion and dissatisfaction with the preliminary investigation. Public opinion quickly rebounded, forming the first peak in the public opinion cycle. Compared with the peak of public opinion on June 5, the number of posts increased by 172.1%, while the number of forwards, comments, and likes decreased by 63.4, 63.2, and 53%, respectively. The announcement of this investigation means the end of the “Rat Head and Duck Neck” incident, and the outcome of the incident can be reversed. The previous investigations by law enforcement officials and universities were wrong, and the credibility of the Nanchang Municipal Supervision Bureau and the universities involved was once again damaged. At the same time, the joint investigation team was able to respond positively to avoid further deterioration of public opinion and trigger the public to think rationally about the incident. Representative posts: #People’s Daily Online: The more authentic, the more authoritative, the inspiration from the “Rat Head and Duck Neck” incident#. Ange Rui’s comment on the #rat-headed-duck-neck incident forwarded by China Changan Network warned that we must adhere to seek truth from facts#, which accelerated public opinion into a period of dissipation.

Because both universities and grassroots law enforcement officials believe that foreign objects are ducknecks, netizens question the collusion of interests between the school, the government, and the logistics group. As a result, the media have dug out relevant information about the logistics group involved in the university

cooperation and reported on it (Figure 7). It can be seen from this that the media and self-media play a greater role at this stage. Through the continuous disclosure of information related to the rat head and duck neck incident, it has been forwarded by the public, resulting in two sub-peaks of public opinion during the cycle of public opinion. According to relevant media reports, the logistics group operates more than 700 college canteens, which is in sharp contrast to the “Rat Head and Duck Neck” incident that occurred this time. It once again set off waves of public opinion and became the second peak of public opinion in the period of repeated public opinion. Compared with the peak of public opinion on June 5, the number of posts increased by 105.8%, while the number of forwards, comments, and likes decreased by 66.3, 71.6, and 63.9%, respectively. Of course, compared to Peak 1, the number of retweets, comments, and likes have all declined. This shows that the government’s positive response to expose the truth is conducive to controlling public opinion, while the distortion of facts becomes an accelerator for the growth of public opinion. More importantly, public opinion fluctuates repeatedly. Analyzing the reasons, on the one hand, as events develop or change, new information is constantly being disclosed. On the other hand, in the virtual online world, a large amount of false information or rumors will spread (49). Of course, social bots also exist in social platforms. These social robots are used by malicious people to publish misleading and misleading information. These are not information or rumors, but they will be forwarded by a large number of self-media and netizens, thereby expanding the spread of rumors (50). For example, in this incident, many netizens suspected that there was a transaction between the school and the Houqing Group. As it spread, this seemed to directly confirm the news, but there was no actual evidence (10). However, the generation and spread of rumors directly promote the increase in the risk of online public opinion (51).

The main driving force behind this peak of public opinion is the media’s agenda-setting and the complication of stakeholder relations. On the one hand, the media reports by digging into more information about the subjects related to the incident. After the rat-headed duck-neck incident came to a final conclusion, netizens could not help but wonder what force caused many parties to refer to the rat as a duck. China Kuai Group was the canteen involved, and it was one of the subjects that netizens focused on. After the Rat Head and Duck Neck incident came to an end, to continue to obtain corresponding traffic, the media dug out more information about the group in an attempt to attract public attention. The media set a Weibo topic: #founder once said that Zhongfa Catering is a leading brand in the canteen industry#. The companies involved in # “Rat Head and Duck Neck” are exposed! The parent company operates more than 700 college canteens across the country#. Keywords such as “Leading Canteen Brand” are in sharp contrast to the “Rat Head and Duck Neck” incident. Data from more than 700 college canteens once again aroused discussions among netizens. On the other hand, universities play a special and important role in food safety. They are both supervisors of canteen contractors and are also supervised by relevant government departments.

4.3.5 Dissipation period: the declining public opinion leaves more reflections

During the dissipation period, no new tipping point emerged, and public opinion gradually became more rational, mainly focusing on two aspects. Topic 1: #Canteen#Involved#Enterprise#Parent Company#. The company still focuses on catering companies that

TABLE 1 Introduction to the peak information of public opinion recurrence period.

Peak	Time	Key Events	Volume of Post	Difference	Forward volume	Difference	Volume of comments	Difference	Volume of likes	Difference
Crest One	17/6	Joint investigation team announces results	4,530	+172.1%	9,873	-63.4%	19,247	-63.2%	381,711	-53.0%
Crest Two	19/6	Logistics Group operates more than 700 university canteen projects	3,426	+105.8%	9,102	-66.3%	14,872	-71.6%	292,954	-63.9%

cooperate with the universities involved. Because the company cooperates with many universities, and front-line law enforcement officials from the school and the government initially said that the “Foreign Object” in the canteen was a duck neck, this caused netizens to question the collusion between government and business. Topic 2: #University#foodsafety#ring the alarm#. Netizens and related media are worried and thinking about how food safety in universities should be ensured. They call that this rat-head-duck-neck incident should also sound the alarm for other universities.

In the dissipation period, the popularity of online public opinion caused by the rat-headed duck-neck gradually weakened, and its essence was that the public opinion incident was resolved. The dissipation period of public opinion also indicates the end of the recurrence period, and the sub-peaks that appeared in the recurrence period are all declining. This indicates that there will be no new information disclosure, and thus no new peak of public opinion. Public opinion in the dissipation period has always existed but at a relatively low level. At this stage, netizens’ attention to topical events continues to decrease, and public opinion gradually subsides and enters a controllable stage. Analyzed from another perspective, as the joint investigation team released the real announcement, Jiangxi Industrial Vocational and Technical College has terminated its contract with Jiangxi Zhongkuai Logistics Service Co., Ltd. This shows that the public participated in this public opinion victory and public opinion promoted the democratization process. The rat-headed duck-neck incident is not only related to the company that contracted the canteen but also is inseparable from the school’s canteen management model. More importantly, it is even more puzzling that the school and grassroots law enforcement teams did not disclose the truth at first, but instead covered up the facts. However, during the period when public opinion dissipated, the government, schools and other officials did not punish the relevant responsible persons involved, and did not fundamentally change the problems existing in the rat-headed duck-neck incident. Therefore, this highlights the necessity of this study. On the one hand, how should the government and school officials better supervise the hygiene of school cafeterias? On the other hand, in the face of public opinion in colleges and universities, the government and school officials should respond to public opinion as soon as possible. And solve it in time to prevent public opinion from reaching an uncontrollable point.

5 Strategies for managing online public opinion on food safety in universities

Through the analysis of the various stages of public opinion dissemination, it is found that the stakeholders participating in public opinion, topic discussions and public opinion risks are different at different stages, so the governance strategies cannot be generalized. Specifically, the incubation period should identify risks and actively intervene in incident investigations. During emergencies, we should face problems head-on and pursue fairness and objectivity. During the spreading period, we should be highly vigilant and proactively investigate potential risks. During the recurrence period, follow-up should be carried out promptly and positive responses should be given to dismissal. During the dissipation period, the supervision system should be improved to solve the problem from the root cause (52).

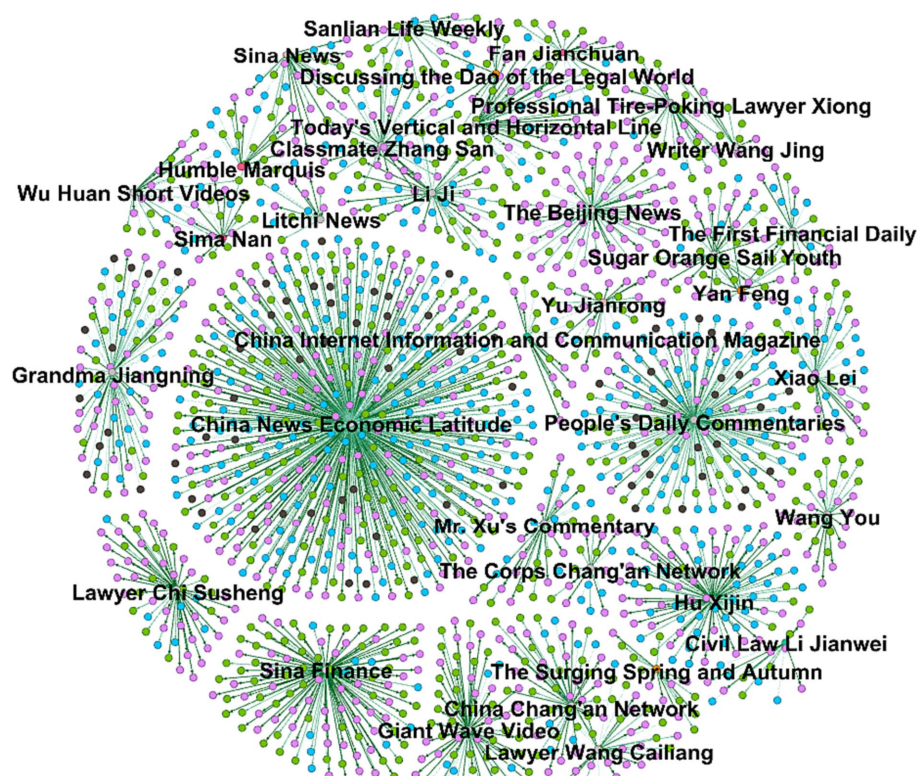


FIGURE 7
Media post forwarding path diagram.

5.1 Incubation period: identify risks and actively intervene in incident investigation

During the incubation period, when public opinion has not spread on a large scale, it is the golden period to control the dissemination of public opinion. The following two points should be achieved at this stage: In the first place, identify risks. Colleges and universities are gathering places for intellectuals, and students have a special identity. They are not only college students with a greater awareness of rights protection, but also Internet users who actively participate in social platforms. Therefore, online public opinion in universities has a wide range of influence and lasts for a long time, and it is easy to trigger large-scale public opinion. Food safety is related to health and is also a topic of great concern to the public. Therefore, colleges and universities should conduct food safety inspections, regularly inspect the operation of canteens, increase penalties for canteens, and provide students with more channels to safeguard their rights (53). Once a food safety incident is discovered, identify risks as early as possible and adopt multiple contingency plans to intervene as soon as possible (54). The second is timely intervention and correct response. The parties involved in food safety incidents in universities include universities, canteens that cooperate with universities, and the government. Universities are the primary supervisory bodies of their cooperative canteens. They should proactively intervene in the incident and investigate the canteens involved, and publish the results of the investigation promptly, and release corresponding details when necessary. As the supervisor of food safety in colleges and universities, the government should also intervene promptly to conduct investigations, handle the incidents fairly and objectively, and fulfill its supervision obligations (55).

5.2 Burst period: face problems head-on and pursue fairness and objectivity

The outbreak period of public opinion is the stage when netizens express their emotions. Facing the emotions and demands of netizens directly is the best way to stabilize public opinion. Firstly, establish a public opinion emergency management system. When public opinion enters an outbreak period, corresponding public opinion data must be collected and sent to the expert group, which analyzes the existing data and past cases in the case library. Analyze the categories and development trends of public opinion, provide public opinion emergency plans and detail work arrangements (56). Secondly, respond positively to the issues that netizens are concerned about. Analyze and clarify the concerns and conflicts of netizens, grasp the key to the problem and respond to it (57). Taking this "Rat Head and Duck Neck" incident as an example, netizens unanimously believed that the foreign object in the video was a rat head, and the school and the government should provide true investigation results. Thirdly, the announcement of investigation results adopts a leader-responsibility system. To avoid further development of the situation or the occurrence of secondary incidents, formal incident investigation results need to be released promptly. And adopt a leader responsibility system, the implementation of which is conducive to improving the fairness of investigations. Finally, attention should be paid to the guidance of public opinion by opinion leaders. Authoritative comments have a guiding role, calling on mainstream media and authoritative self-media to correctly guide online public opinion and guide netizens to be objective and rational.

5.3 Spreading period: be highly vigilant and proactively investigate potential risks

During the spreading stage, netizen attention reaches its peak, hot topics continue to deepen, and more information continues to be disclosed. At this stage, you should be highly vigilant about the situation turning to the worse side (24). Therefore, three things need to be done at this stage. Above all, in the relatively complex period of public opinion spread, we must be able to grasp the focus of the public opinion debate at this stage and be able to prepare solutions to the focus issues. Then, we need to return to the investigation of the rat head and duck neck incident, strive to draw conclusions as soon as possible and publish a response, and take practical actions to answer the public's doubts. At last, we must pay attention to the health and safety of existing canteens to avoid similar incidents from happening again. The university where the incident occurred and the cooperating logistics group should promptly investigate potential food hygiene hazards. Other universities and logistics groups should also sound the alarm and proactively investigate and improve relevant food safety supervision systems (53).

5.4 Recurring period: timely follow-up, positive response to dispel doubts

The tortuous development of the incident and the occurrence of secondary incidents will lead to a period of repeated public opinion. In food safety incidents in universities, inappropriate responses from the government or universities will break the pattern of public opinion entering a subsidence period. The rising voices of doubts from netizens have pushed public opinion into a period of recurrence. The essence of the existence of the period of recurrence is that the problem of the incident has not yet been completely resolved. Although the joint investigation team announced relatively realistic results, the public is still confused about the previous school authorities and grassroots law enforcement officers. Therefore, this stage needs to focus on resolving secondary incidents that cause fluctuations in public opinion, responding to relevant issues in a targeted manner, and taking measures to punish the subjects involved when necessary (25). Of course, the subsequent progress of the incident should be disclosed promptly at this stage. Publicizing the details and progress of the handling of the incident by holding media meetings and other forms, and responding positively to netizens' questions will help public opinion enter the fading period as soon as possible (21).

5.5 Dissipation period: improve the supervision system and solve the problem from the root cause

During the subsidence period of public opinion, the development of things has come to an end, and the situation has been controlled to a certain extent. In the absence of new stimulus points, new public opinion crises will not arise again. At this stage, attention should be paid to the continuous tracking of evaluation feedback of public opinion events and tracing the source (23). The first is to establish an evaluation and feedback mechanism for public opinion, analyze the characteristics of each life cycle stage of public opinion, and sort out the causes of public opinion crises. Analyze the key nodes of public

opinion control, evaluate and reflect on whether the responses of each subject are appropriate, and think about how to respond to similar emergencies in the future (58). The second is to continue to track public opinions and be alert to the occurrence of new public opinions. Continue to track sensitive words that can easily trigger public opinion crises, and be careful not to enter a period of repeated public opinion. The third is to get to the root of the problem. The frequent occurrence of food safety problems in colleges and universities has exposed the current backwardness of food safety supervision, imperfect supervision systems, and even whether the standards and procedures for the introduction of canteens are scientific. Corresponding supervision systems, canteen introduction processes and standards should be improved. Solve the problem fundamentally and avoid the occurrence of public opinion arousal effect and resonance effect (53).

6 Research conclusions and future prospects

6.1 Research conclusions

Through the research of this paper, the following conclusions can be drawn: (1) The Development of Online Public Opinion on Food Safety in Universities is in Line With the Life Cycle Theory. This paper uses the life cycle theory to explain the entire process of the development of Shutou Yabo online public opinion. According to this theory, online public opinion is divided into five stages. The causes and characteristics of online public opinion in different stages are different. At the same time, the use of text mining, especially the use of cluster analysis methods, can effectively analyze the content of public opinion at various stages of public opinion. On this basis, proposing corresponding emergency countermeasures for each stage of online public opinion on food safety in universities can achieve very good results. This provides a new idea for the government or school officials to prevent and control online public opinion in colleges and universities. (2) The Resonance Effect of Online Public Opinion Media on Food Safety in Universities is Significant. The "Resonance Effect" refers to the fact that mainstream media have a large number of users and fans, etc., and act as public opinion leaders when reporting official news, affecting the discourse direction of other media. During the development of this "Rat Head and Duck Neck" incident, the agenda-setting among the media also referred to each other's reporting content. The agenda-setting always flowed from the more authoritative media to other media. Mainstream media such as People's Daily Online and Toutiao News have established a dominant position in information dissemination with their strong influence. After the mainstream media publishes the report, it triggers other media to forward or follow-up reports based on the discourse. Similar information is reposted in large numbers in a short period. In the Weibo reports reported by mainstream media, there is a high degree of consistency in reporting time, labels, genres, forms, attitude tendencies, etc., creating a resonance effect between media. (3) The Development of Online Public Opinion on Food Safety in Universities is Repetitive. There were a total of four public opinion peaks in the "Rat Head and Duck Neck" incident, that is, there were periodic recurrences of public opinion. The first spike in public opinion occurred because universities and the government responded inappropriately. The second peak of public opinion occurred because similar incidents occurred again, and the recurrence of similar incidents can easily awaken earlier food safety incidents and form a

resonance of public opinion. The third peak of public opinion occurred because the joint investigation team announced its investigation results and the incident itself took a turn. The reason for the fourth peak of public opinion was that the media dug into relevant information about the college cafeteria involved. Analysis revealed that there are various reasons for the recurrence of public opinion on Weibo. In addition, the first peak of public opinion is the highest, and the subsequent three peaks of public opinion decrease in sequence. (4) A Fair Response is Conducive to Promoting the Dissipation Period of Negative Public Opinion in Universities. In public opinion on food safety incidents, inappropriate responses from relevant subjects may directly push public opinion to a peak, triggering the rapid growth and spread of negative public opinion. In the “Rat Head and Duck Neck” incident, the school and the government ignored the facts and responded inappropriately, triggering the rapid spread of negative emotions among netizens. Moreover, the original focus of public opinion on food safety has shifted to the collusion of interests between the school and the government, which has reduced the government’s credibility. When the joint investigation team announced the truth of the incident, it pushed public opinion into a dissipation period. Therefore, responding fairly and facing the doubts of netizens directly will help push negative public opinion into a dissipation period as soon as possible.

6.2 Future prospects

This study has certain shortcomings, and the data sources studied in this paper are limited. We selected data from the Weibo platform about the “Rat Head and Duck Neck” incident for research. However, the Weibo platform is only one of many social platforms, and it is difficult to fully reflect all public opinions on the rat head and duck neck incident. There may be certain deviations between the summary of online public opinion patterns regarding this incident and the actual situation. In future research, the discussion on the resonance effect of public opinions on multiple food safety online can be strengthened. This includes the mechanisms and scope of impact between food safety incidents. In addition, after the outbreak of food safety emergencies in universities, public opinion may have experienced multiple cycles due to the complexity of society and the tortuous nature of the incident itself. Therefore, the multi-cycle pattern of online public opinion on food safety is also worthy of further exploration. For example, compare the reasons for the emergence, duration, and scope of influence of multi-cycle public opinions.

Data availability statement

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

data is also available at <https://doi.org/10.6084/m9.figshare.24638799.v2>.

Author contributions

JL and SW: Conceptualization, Methodology and Formal Analysis. JL and ZW: Investigation, Original draft Preparation and Review and Editing. SC: Supervision and Funding acquisition. All authors contributed to this work 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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Rural community perceptions and practices toward the novel coronavirus (COVID-19) prevention in Konso Zone, Southern Ethiopia: a lesson for the next pandemic

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Background: Corona Virus Disease (COVID-19) has provided a lesson on preparedness and coping mechanisms for similar pandemics to different community segments. To control and prevent the spreading of COVID-19, people need to possess the correct attitude and perception to follow the appropriate practices against the causative agent. Therefore, this study aimed to assess the rural community's perceptions and practices toward COVID-19 prevention among southern Ethiopia's Konso zone rural communities.

Methods: A community-based cross-sectional study conducted from April to May 2022 on 605 study participants in the Kena district of the Konso zone of Ethiopia. Participants were recruited using simple random sampling techniques. Face-to-face interviews were conducted to collect data using structured questionnaires developed from the World Health Organization guide and related literature. A logistic regression model was used to identify determinants of perception and practice.

Results: Among the 564 participants, 296 (52.5%) believed they would go to the healthcare facility if they contracted COVID-19. About 276 (48.9%) perceived that COVID-19 is not a stigma and should not be concealed. About 233 (41.3%) perceived COVID-19 would be controlled. However, the majority, 451 (80%), 440 (78%), 384 (68.1%), 381 (67.6%), 337 (59.8%), and 317 (56.2%) perceived that the cause of COVID-19 is sin, eating some food items were effective against the virus, no cases in their locality, living far away from COVID-19 area, the virus does not exist, respectively. Overall, only 22.5% of the study participants have good perceptions. About 58.5% practiced handwashing to prevent COVID-19, and 45.2% covered their mouth and nose while coughing/sneezing. Among the participants, 39.8% were vaccinated, and about a quarter (24.8%) of the respondents had good prevention practices. Participants with better educational status, use of social media as a source of information, and those with better income levels are found to be protective factors while being married is a risk factor.

Conclusion: The status of the participant's perception and preventive practices toward COVID-19 was meager. There was a substantial magnitude of wrong perceptions about controlling such pandemics. High inaccurate perceptions and low preventive practice need an urgent and sustained improvement strategy to tackle similar pandemics or epidemics.

KEYWORDS

COVID-19, Konso, perception, practice, rural community, Ethiopia

1 Introduction

Infectious diseases have become increasingly prevalent and continue to infect and harm people around the world. Disease outbreaks significantly threaten global public health, as evidenced by recent events (1). The COVID-19 pandemic has caused significant loss of life and livelihoods and disrupted economic stability and people's mobility (2, 3). This has resulted in a severe and acute public health crisis that may persist for some time (4).

The coronavirus is highly contagious and has spread globally at an alarming rate (5). As of August 19, 2022, the World Health Organization had reported over 591.68 million confirmed cases and 6.44 million deaths worldwide, with South Africa, Morocco, and Tunisia being the most affected African countries (6). In Ethiopia, as of August 7, 2022, there were 492,491 confirmed COVID-19 cases and 7,569 deaths, with a mortality rate of 1.5% (7). As there is currently no exact treatment for COVID-19, prevention is the most effective strategy to curb the spread of the pandemic (8).

The main measures recommended globally include vaccination, physical distancing, hand washing, staying at home, and wearing face masks (9). The World Health Organization has also developed guidelines and online training sessions to increase community awareness of pandemic prevention (10). However, some residents have not complied with these health and safety measures, as recommended by the WHO and their respective country's health departments (11).

The knowledge, attitudes, and practices (KAP) that people hold toward the disease play a crucial role in determining their readiness to accept behavioral change measures from health authorities (12). The Ethiopian government has implemented several preventive measures, including declaring a state of emergency for nearly 6 months. However, many Ethiopians overlook these measures, exacerbating the spread of the virus (8). To control and prevent COVID-19 infection and transmission, people must have sufficient knowledge of the virus, a positive attitude, and proper viral prevention methods (11). Unfortunately, misinformation has assisted the virus in spreading rapidly across the globe, revealing division, distrust, inequality, and trade tensions (13, 14). During the 2014 Ebola epidemic, a similar picture of misinformation, lack of awareness about the disease outbreak, and negative attitudes was observed, leading to several dangerous practices being carried out by people trying to stay safe (15, 16).

Reports from developed countries indicated significantly better knowledge of symptoms, high-risk groups, transmission routes, and treatment options than those from developing countries (17).

Conversely, reports from India showed that study participants had strong knowledge and appropriate practices about the COVID-19 pandemic, but there was a gap in perception of underlying myths and beliefs (18). Studies conducted in Ethiopia found that cultural and religious dependencies, the belief that the pandemic does not affect the young, misinformation about the disease, and a lack of trust in prevention measures were the major obstacles to practicing COVID-19 prevention measures (19, 20). A study in northwest Ethiopia also showed poor KAP during the pandemic (21). Most studies on the KAP of COVID-19 have focused on urban settings, despite the pandemic's impact on both urban and rural communities. Poor healthcare facilities, limited availability of testing kits, isolation facilities, and low levels of awareness due to a lack of information on preventive measures could make controlling the virus difficult in rural areas (5). For example, the country's capital city, Addis Ababa, reported the highest caseload with 334,202 cases compared to the country's regional states (7). Although much has been done to assess the KAP of COVID-19 worldwide, including in Ethiopia, greater attention has been given to urban communities with internet access through different media platforms than to rural communities, which comprise most of the population.

Understanding local perceptions of COVID-19 among residents and COVID-19 prevention practices in the context of people's socio-cultural and educational backgrounds is crucial in designing educational interventions to promote COVID-19 control measures and strengthen adherence to these measures. Therefore, it is important to assess rural community perceptions and practices of COVID-19 in the Kena district, to fill gaps in perception and practice toward COVID-19 and similar pandemics and to assist the fight against the pandemic in a local context.

2 Methods and materials

2.1 Study setting and period

From April 21 to May 6, 2022, a study was carried out in the Kena district, which is located in the Konso zone of southern Ethiopia. The research collected information about the COVID-19 pandemic in the area. The district is situated about 574 km from Addis Ababa, the capital city of Ethiopia, and 247 km from Hawassa, the capital city of the South Nation Nationalities and Peoples Region. It encompasses 10 kebeles, which are the lowest level of government administration in Ethiopia, and has a total population of 82,019 with 14,217 households. Additionally, there

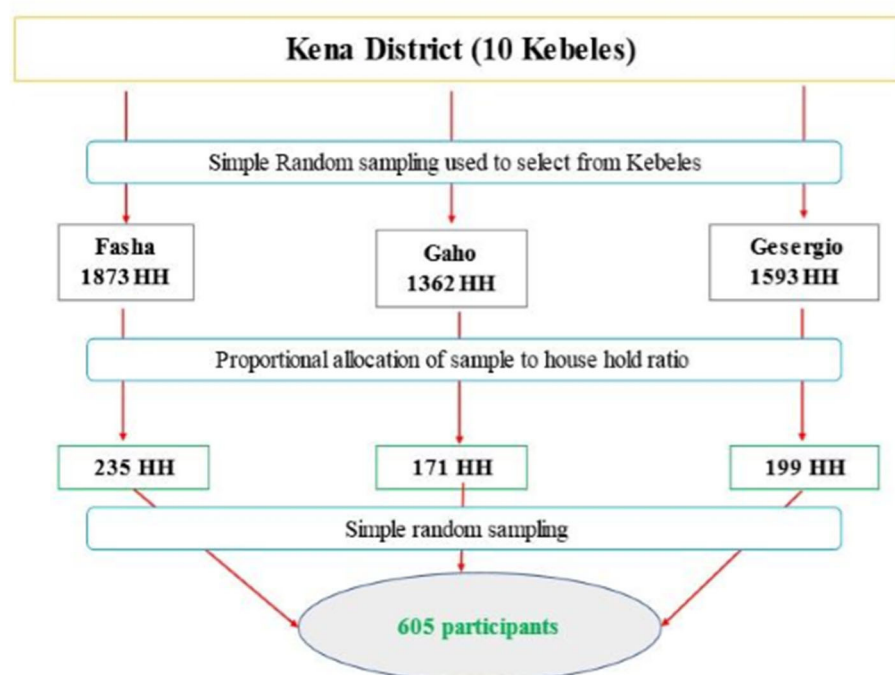


FIGURE 1

Sampling techniques and procedures used to select study participants in Kena district, Konso zone, southern Ethiopia, 2022.

are four health centers and 17 health posts in the district at the time of the study.

2.2 Study design

A community-based cross-sectional study was conducted among rural communities to assess their perceptions and practices toward the pandemic.

2.3 Source and study populations

All the people in the Kena district of southern Ethiopia were the source population. All the eligible individuals aged 18 years and older in selected households that belong to the randomly selected three Kebeles of the district were included in the study. Those who were severely ill at the time of data collection were excluded.

2.4 Sample size determination

The sample size was determined using the single population proportion formula by considering the following assumptions.

$$n = \frac{(Z_{\alpha/2})^2 \cdot P \cdot (1 - P)}{d^2}$$

Where: n : sample size.

Z : the standard normal variance at 95% CI (1.96).

P : the proportion of good perception and practice level in the local community is taken as 50% since no previous study has been done similar to this; $p = 0.5$; $q = (1 - p) = (1 - 0.5) = 0.5$.

d : marginal errors 5% = 0.05.

$$n = \frac{(1.96)^2 \cdot 0.5 \cdot (1 - 0.5)}{(0.05)^2}$$

$$n = 384$$

Since simple random sampling techniques were used at Kebele and at the household level to select an eligible study participant in the study area, a 1.5 design effect was accounted for. Then the final sample size with a 5% non-response rate was 605.

2.5 Sampling technique and procedures

To establish the sample size, three Kebeles were chosen randomly out of ten, as displayed in Figure 1. The number of sample households was then proportionally allocated to the selected Kebeles. A random number generator was employed to choose households from each Kebele, using the family roster previously registered at the respective health posts. Finally, for each chosen household, individuals aged 18 or above were randomly selected through the lottery method in case the household head was not present during data collection.

2.6 Study variables

The perceptions and practices of the respondents toward COVID-19 were the dependent variables. Whereas, sociodemographic characteristics like age, sex, marital status, educational status, occupation, family size, monthly income, and source of information were the independent variables.

2.7 Data collection, management, and quality assurance

We gathered the data through a structured questionnaire, which we adapted in English from the WHO Risk Communication and Community Engagement (RCCE) action plan guidance and various related literature (8, 20, 22, 23). Next, we translated the questionnaire into Amharic to ensure that the data collectors and interviewees could better understand it. The questionnaire included questions about demographics, perceptions, preventative practices, and sources of information. Before beginning the actual data collection, we pretested the questionnaire on 30 households outside the selected kebeles in the Karat Zuria district using the Amharic version to make any necessary amendments. Experienced supervisors provided training and instructions to the data collectors.

2.8 Statistical analysis

First, the data collected was coded and entered into Epi-Data version 3.1. It was then exported to SPSS version 23 for analysis after cleaning it. Before the final analysis, all variables were recoded and transformed as needed. The variables were described using frequency distributions, cross-tabulations, and graphs. After evaluating the normal distribution of the data, bivariate logistic regression was used to analyze the association between the outcome and predictor variables. Each independent variable was analyzed separately, and predictor variables with a *p*-value of <0.25 were selected for the final model. All candidate variables were then analyzed using multivariate logistic regression. The Hosmer-Lemeshow test was used to check the model's fitness. An adjusted odds ratio with a 95% confidence interval was calculated, and *P*-values <0.05 were considered statistically significant. Finally, the results were presented using texts, graphs, figures, and tables.

2.9 Contextual definitions

The perception: Was dichotomized as good if the overall score was $> 50\%$ and poor if $\leq 50\%$ (24). It consisted of 14 questions, and participants who correctly answered more than seven questions were categorized as “good perception,” and those who scored less than or equal to seven were categorized as “poor perception.”

The practice: Was dichotomized as good if the overall score was $\geq 50\%$ and poor if $< 50\%$ (24, 25). The practice

TABLE 1 Sociodemographic characteristics of the respondents in Kena district, southern Ethiopia, April–May 2022.

Variables	Response category	Frequency	Percentage
Sex	Male	260	46.1
	Female	304	53.9
Age in years	18–29	177	31.4
	30–39	227	40.2
	≥ 40	160	28.4
Educational level	Cannot read and write	279	49.5
	No formal education but read and write	73	12.9
	Primary (1–8 grade)	111	19.7
	Secondary (9–12 grade)	46	8.2
	College and above	55	9.8
Marital status	Single	88	15.6
	Married	454	80.5
	Other	22	3.9
Occupational status	Farmer	167	29.6
	Merchant	49	8.7
	Housewife	244	43.3
	Employed	32	5.7
	Student	55	9.8
	Other	17	3.0
Religion	Protestant	403	71.5
	Orthodox	154	27.3
	Other	7	1.2
Family size	≤ 4	160	28.4
	> 4	404	71.6
Monthly Income (ETB)	$< 1,000$	130	23.0
	1,000–1,999	270	47.9
	2,000–4,000	136	24.1
	$> 4,000$	28	5.0

n = 564.

ETB, Ethiopian Birr.

questionnaire consisted of seven questions, and participants who correctly answered four or more questions were categorized as “good practice,” and those who scored < 4 were categorized as “poor practice.”

Inaccurate beliefs: Misperception resulting from incorrect reasoning. The unscientific way the rural community thinks about how to prevent and how they interpret information related to the current global COVID-19 pandemic.

Correct perception: The scientific way the rural community thinks about how to prevent and how they interpret information related to the current global pandemic COVID-19.

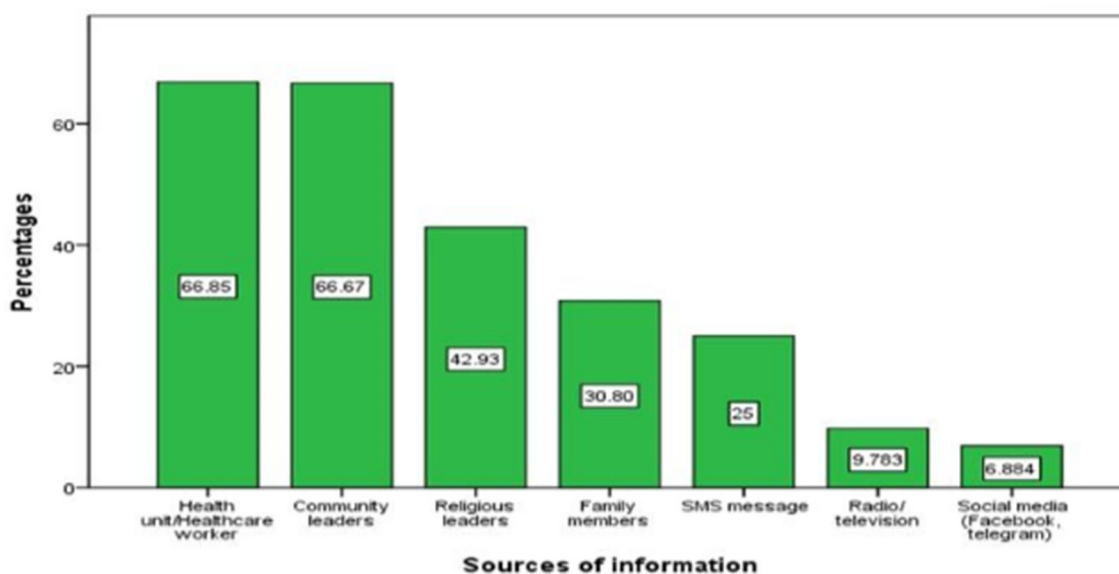


FIGURE 2

Source of information about the global pandemic in Kena district, southern Ethiopia, April–May 2022 (n = 564).

TABLE 2 Perception toward COVID-19 disease in Kena district, southern Ethiopia, April–May 2022 (n = 564).

Perception of respondents toward COVID-19	Freq. (%)	
	Yes	No
Do you think you can contract COVID-19?	199 (35.3)	365 (64.7)
If you were getting infected with COVID-19, would you go to the health facility?	296 (52.5)	268 (47.5)
Do you think you are well-informed about the current pandemic?	228 (40.4)	336 (59.6)
Do you think COVID-19 is not a stigma and you should not hide the infection?	276 (48.9)	288 (51.1)
Would you think COVID-19 will be successfully controlled?	233 (41.3)	331 (58.7)
Do you believe using garlic, ginger, etc. as home remedies are a necessity to confront coronavirus?*	124 (22.0)	440 (78.0)
Do you believe drinking local alcohol is necessary to protect against COVID-19?*	315 (55.9)	249 (44.1)
Do you think you are living far away from COVID-19/s rampant areas?*	183 (32.4)	381 (67.6)
Do you think there are no locally reported COVID-19 cases so far?*	180 (31.9)	384 (68.1)
Do you believe you are religious enough to control COVID-19?*	222 (39.4)	342 (60.6)
Do you believe you have traditional medicine against COVID-19?*	247 (43.8)	317 (56.2)
Do you think that the cause of COVID-19 is happened because of our sins?*	113 (20.0)	451 (80.0)
You don't believe COVID-19 exists?*	227 (40.2)	337 (59.8)
Do you think the disease is being exaggerated?*	303 (53.7)	261 (46.3)

*Correction rate calculated from "No" response for false statements.

2.10 Ethical considerations

The Ethical Committee of Jimma University has approved the study protocol for collecting the data from the respondents. IRB letter reference number is IHRPG1/442/22. The respondent's right to refuse or withdraw from participating was fully maintained, and the information provided by each respondent was kept strictly confidential. Written consent was obtained from each of the study participants.

3 Results

3.1 Sociodemographic characteristics of the respondents

This study had 583 participants, with a response rate of 96.4%. Of the total participants, 304 (53.9%) were female. The majority, 453 (80.5%) were married and 244 (43.3%) were housewives (Table 1). Refer to Figure 2 for the source of information the respondents had heard about the pandemic. Out of the 583 respondents, 564 (96.74%) claimed that they had heard about COVID-19.

3.2 Perception and practice of respondents toward the COVID-19 disease

In Table 2, the study participants' perceptions of the pandemic are presented. More than half of the participants (52.5%) indicated that they would seek medical attention if they were infected. However, the majority of respondents (80%) mistakenly

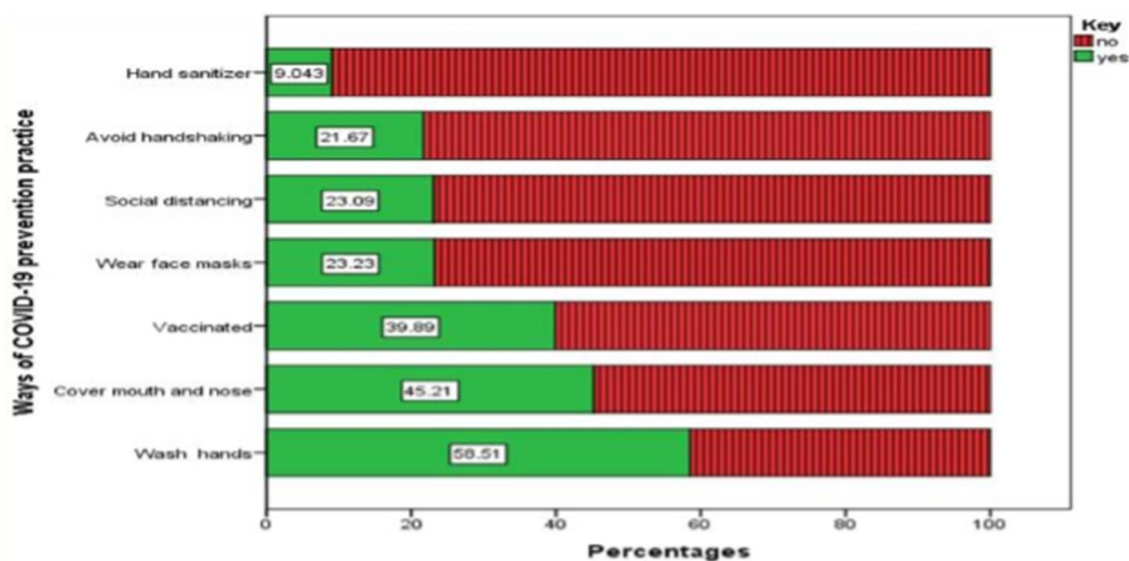


FIGURE 3

The status of the prevention practice of the participants toward COVID-19 among the residents of Kena district, southern Ethiopia, April–May 2022 (n = 564).

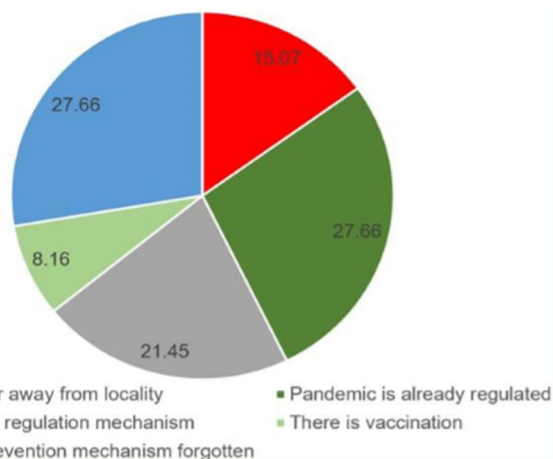


FIGURE 4

Responses of the participants for not practicing COVID-19 prevention practices in Kena district, southern Ethiopia, April–May 2022 (n = 564).

believed that COVID-19 was caused by sin, and a significant portion (78%) believed that using certain food items and spices like garlic, ginger, honey, and lemon as home remedies could effectively combat the virus. Figure 3, a graph below, displays the prevention practices of the rural community participants. Shockingly, a vast majority of them (91%) did not use hand sanitizer when soap and water were not available, while 78.3% did not avoid handshakes when greeting others. In contrast, Figure 4 illustrates the reasons why some participants were not practicing prevention methods.

3.3 Factors associated with the status of perception on COVID-19

Our analysis used binary logistic regression to identify factors associated with respondents' perceived status of the pandemic. The model showed that sex, age, educational level, marital status, occupational status, income level, and various sources of information such as healthcare workers, radio/television, religious leaders, SMS messages, and social media were significant. Additionally, practice level was also found to be significant. All of these variables were included in the multivariable analysis model, as shown in Table 3.

After analyzing multiple factors using a multivariate analysis, it was found that a person's level of education and their use of social media as a source of information has a significant impact on their perception. Individuals with secondary education were found to be four times more likely to have a good perception compared to those who cannot read or write. Similarly, college students and those with higher education were 4.71 times more likely to have a good perception than their counterparts. Additionally, those who use social media as a source of information were found to be three times more likely to have a good perception compared to those who don't use social media.

3.4 Factors associated with the practice of COVID-19 prevention

To know the associated factors with the status of the prevention practice, all the variables were entered into the binary logistic regression model (Table 4). Accordingly, sex, age, educational level, marital status, occupational status, income level, SMS message as a source of information, social media as a source of information,

TABLE 3 Factors determining the level of perception toward COVID-19 among Kena district residents, southern Ethiopia, April–May 2022 (n = 564).

Variables	Response category	Perception level		COR (75% CI)	p-value	AOR (95% CI)	p-value
		Poor (%)	Good (%)				
Educational level	Cannot read and write	246 (88.2)	33 (11.8)	1		1	
	No formal education but read and write	60 (82.2)	13 (17.8)	1.61 (1.07–2.43)	0.180*	1.26 (0.56–2.82)	0.566
	Primary (1–8 grade)	92 (82.9)	19 (17.1)	1.54 (1.07–2.20)	0.168*	0.95 (0.43–2.12)	0.913
	Secondary (9–12 grade)	24 (52.2)	22 (47.8)	6.83 (4.57–10.20)	0.0001*	4.05 (1.32–12.36)	0.014**
	College and above	15 (27.3)	40 (72.7)	19.87 (13.21–29.90)	0.0001*	4.71 (1.19–18.63)	0.027**
Source of information using social media (FB, telegram)	Yes	9 (23.7)	29 (76.3)	14.07 (8.9–22.23)	0.0001*	3.69 (1.31–10.39)	0.013**
	No	428 (81.4)	98 (18.6)	1		1	

COR, Crude Odd Ratio; AOR, Adjusted Odd Ratio; ETB, Ethiopian Birr.

*p-value < 0.25 statistically significant, **p-value < 0.05 statistically significant. Bold values indicate that their p-values are < 0.05.

and perception level had a *p*-value of <0.25 and fitted into the multivariable analysis model.

In multivariable logistic regression analysis, educational level, marital status, and income level affected the prevention practice. It was revealed that those who attended primary education were two times (AOR = 2.19, 95% CI 1.38–4.88) more likely to use good practices to prevent COVID-19 than those who cannot read and write. The odds of having good preventive practice were four times (AOR: 3.89; 95% CI: 1.03–14.77) among the monthly income level category >4,000 than those who had <1,000 income level. Moreover, being married was 59% times (AOR: 0.41; 95% CI: 0.18–0.94) less likely to have good COVID-19 prevention practices than being single.

4 Discussion

This research examined how rural communities perceive and respond to the global pandemic 2 years after its emergence. The study identified factors that influence their perception and practices in preventing the spread of the virus. The results can provide valuable insights for health offices, health extension workers, and other stakeholders in rural areas. It is essential to use these findings to promote behavioral change and maintain preventive measures, as well as address any gaps in current literature.

According to our finding, rural communities primarily relied on healthcare workers (66.8%) and community leaders (66.6%) for information. These communities trusted health workers and community leaders, including health extension workers, the health development army, and health professionals. However, studies conducted in Tigray, Gedeo zone, and Southern Ethiopia (24–26) found that most residents obtained COVID-19 information from TV/radio and social media. This difference may be due to the location and population of the study area. The study participants were from remote areas without telecommunications and electrical

services. This highlights the need for tailored interventions to increase awareness about COVID-19 and mitigation measures, utilizing professionals and community leaders.

The study found that a significant number of respondents (ranging from 44.1 to 80%) held inaccurate beliefs about COVID-19. Specifically, they believed that consuming local alcohol, certain food items (such as garlic, ginger, and honey), and traditional medicines could protect them from the virus. Some respondents also subscribed to religious myths, such as the belief that the pandemic was caused by an increase in human sin, and that being religious enough could control the spread of the virus. Additionally, false assurances from local people that they were safe from the virus, as well as the belief that COVID-19 did not exist, contributed to the prevalence of inaccurate beliefs. The study found that this level of inaccurate belief was higher than in a previous study conducted in Ethiopia (20). The study suggests that such inaccurate beliefs are damaging and could hinder efforts to prevent and reduce the spread of COVID-19. It is therefore important for concerned bodies to make more effort to reduce these beliefs and improve education around COVID-19.

On the other hand, in this study, there were lower reports on the correct perception statements, ranging from 35.3 to 52.5% which was found inconsistent with the study done in Northwest Ethiopia and Northern Ethiopia (8, 24). These differences might be related to educational status, cultural beliefs, and study periods. Thus, adequate and sustained health information should be provided to the community. Generally, the current study revealed that the overall perception of the rural community was very poor (22.5%). This finding is lower compared to studies conducted in northeast Ethiopia (57.9%) (27), northwest Ethiopia (62.6%) (8), and southern Ethiopia (90.3%) (28) where their perception level toward COVID-19 is higher. This variation might be due to the study area, period, and population. The current study was done after 2 years of the emergence of the pandemic, unlike previous studies.

TABLE 4 Factors determining COVID-19 prevention practice among Kena district residents, southern Ethiopia, April–May 2022 (*n* = 564).

Variables	Response category	Practice level		COR (75% CI)	<i>p</i> -value	AOR (95%CI)	<i>p</i> -value
		Poor (%)	Good (%)				
Educational level	Cannot read and write	237 (84.9)	42 (15.1)	1		1	
	No formal education but read and write	54 (70.0)	19 (26.0)	1.98 (1.38–2.85)	0.029*	1.31 (0.65–2.63)	0.436
	Primary (1–8 grade)	72 (64.9)	39 (35.1)	3.05 (2.26–4.12)	0.0001*	2.19 (1.14–4.21)	0.018**
	Secondary (9–12 grade)	30 (65.2)	16 (34.8)	3.01 (2.00–4.51)	0.002*	2.77 (0.96–7.95)	0.059
	College and above	31 (56.4)	24 (43.6)	4.36 (3.02–6.30)	0.0001*	2.56 (0.67–9.82)	0.169
Marital status	Single	51 (58.0)	37 (42)	1		1	
	Married	353 (77.8)	101 (22.2)	0.39 (0.29–0.52)	0.0001*	0.41 (0.18–0.94)	0.035**
	Widowed	20 (90.9)	2 (9.1)	0.13 (0.05–0.33)	0.010*	0.23 (0.04–1.32)	0.100
Monthly income (ETB)	<1,000	109 (83.8)	21 (16.2)	1		1	
	1,000–1,999	212 (78.5)	58 (21.5)	1.42 (1.03–1.96)	0.211*	1.47 (0.78–2.77)	0.226
	2,000–4,000	91 (66.9)	45 (33.1)	2.57 (1.82–3.63)	0.002*	1.95 (0.90–4.22)	0.088
	>4,000	12 (42.9)	16 (57.1)	6.92 (4.12–11.61)	0.0001*	3.89 (1.03–14.77)	0.042**

COR, Crude Odd Ratio; AOR, Adjusted Odd Ratio; ETB, Ethiopian Birr.

p*-value < 0.25, *p*-value < 0.05 statistically significant. Bold values indicate that their *p*-values are < 0.05.

Furthermore, this finding was lower than perception studies on COVID-19 from Egypt (29), and Saudi Arabia (30). These discrepancies might be due to the study period, geographical areas, and the number and type of questions used. The previous studies were done at the beginning, but the current one was conducted after 2 years. The former abroad studies' participants have better access to healthcare information compared to this rural community study.

The current study depicted that the status of perception regarding COVID-19 was affected by educational status, and social media as a source of information. Those who had secondary education and above college were four times more likely to have good perception than those who could not read and write. This study was consistent with studies from Northeast Ethiopia (23) and Southern Ethiopia (28) where higher educational level was positively associated with good perception than their reference group. This might be a result of educated individuals being more informed (getting more information through various communication platforms) about the illness and suggested preventative measures.

Furthermore, the current study demonstrated that participants who had exposure to social media as a source of information had a good perception of COVID-19. This is consistent with the previous study (24) which looked if social media could be wisely used might bring behavioral change.

Due to the absence of an exact treatment, prevention is a highly recommended strategy to control the spread of the COVID-19 pandemic (8). As a result, the main measures

recommended globally to prevent the pandemic were vaccination, physical distance, hand washing, staying at home, and wearing face masks (9). However, in this study, only a quarter (24.8%) of the respondents practiced the recommended prevention measures. This finding is higher compared to findings from Dirashe district (31) and Gedeo zone (28), Ethiopia, where the preventive practices were 12.3 and 20%, respectively. This variation might be related to changes in the study setting, study period, socio-economic factors, and awareness of the communities.

On the other hand, the practice level of the current study was found to be lower than previous studies done in Ethiopia. It was lower than Addis Ababa (59.8%) (32), and Sidama region (65%) (33) studies conducted on preventive measures. This discrepancy might be explained because of the difference in the study period, the number of study participants, and the cut-off point used to categorize the preventive measures into poor or good status. When the study period would be seen, the previous studies were conducted a few months after the occurrence of the pandemic while the current study was done after 2 years of the emergence of the disease. This indicates prevention measures should be practiced sustainably.

Moreover, the preventive practices in the current study were found lower than the studies done in India (88.1%) (18), and Malaysia (95.9%) (12). This variation might be related to socio-economic status, study period & population, and methods of data collection. In this study, data was collected face-to-face among the

most illiterate category of respondents, while the former studies were collected online.

Respondents of this study were also asked about the reason why they didn't practice the recommended preventive measures for the virus. As a result, the study participants' main reason was they perceived that the disease was controlled/regulated and reduced 27.6%, similarly, they considered the issue of the diseases was forgotten even by asking the data collectors back by saying "*Is there incidence/case of COVID-19 present?*" The current reasoning was not in agreement with the study conducted in Dessie town, Northeast Ethiopia which reasoned that it "takes too much effort" (27). This difference may be related to the variation in the study setting, period, participants, and type of questions. Because the current study was conducted after 2 years after the occurrence of the pandemic compared to its counterpart. It might be suggested that the residents were performing the prevention method because of the enforcement of the regulatory bodies but not understanding the risk of the virus. From these responses, the low role-playing of concerned bodies could be understood which might awaken the bodies to sustain the recommended preventive measures and behaviors.

Based on the multivariable model, those who attended primary education were twice more likely to have good practices to prevent COVID-19 than those who cannot read and write. The study conducted in southern Ethiopia (28) supported this association. This shows the higher the educational level, the higher the practice of preventive measures against the disease. Additionally, the odds of having good preventive practice were four times higher among the income level category >4,000 than those who had <1,000 income level. This is consistent with the study conducted in the Sidama region in Ethiopia (33). This shows that those who have higher incomes can afford the recommended preventive personal protective equipment, like face masks, hand sanitizers, and soap. Furthermore, marital status was found to be statistically associated with the prevention practices of the participants. Participants who had married were 59% times less likely to practice the prevention measures for COVID-19 than those who didn't (single ones). The current study differs from the study done in the Sidama region, Ethiopia (33), where those married were twice as practicing the prevention measures than their reference group. This variation might be because of sociocultural disparities, levels of knowledge, access to information sources, etc.

In Ethiopia, around 80% of the citizens live in rural areas. The majority of the population residing in these rural areas face a variety of health-related problems due to poor access to transportation, poor healthcare facilities, lack of awareness, and a shortage of well-equipped facilities in the local area. Similarly, COVID-19 awareness creation activities and preventive practices did not reach these remote areas. In addition, studies conducted in Ethiopia on COVID-19 had given greater attention to urban communities with internet access through different media platforms like social media, mass media, and telecom. However, all these channels are not accessible and suitable for rural communities. Previous studies are also focused on educated population (internet users). Hence, strengthening existing local health systems like health extension packages, and health development armies and continuously improving the perception of the local communities is imperative.

Therefore, scholars must reach this remote unprivileged population to develop appropriate intervention measures based on the local context.

Having strengths, this study may face limitations like assessment of the cause–effect relationship was not possible due to the cross-sectional nature of the study, there could be social desirability, and the knowledge of community members on the illness was not addressed.

5 Conclusion

Finally, the study revealed that a high number of the study participants had poor perceptions and prevention practices toward the control of the pandemic in the community. There was a substantial magnitude of wrong perceptions and very low. Educational level, income level, knowledge status, and social media as a source of information acted as protective factors at a p -value of 0.05 against the prevention of the pandemic. While marital status was a risk factor for COVID-19 prevention. Therefore, the risk communication and community engagement efforts in collaboration with concerned bodies should investigate the beliefs that could exacerbate/inhibit the spread of the disease, provide the communities with real information about the virus, and work on prevention measures sustainably. Behavioral change communications are also imperative to strengthen COVID-19 prevention practices. It needs an urgent and sustained improvement strategy to tackle similar pandemics or epidemics.

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 Ethical Committee of Jimma University has approved the study protocol for collecting the data from the respondents. IRB letter reference number is IHRPG1/442/22. The respondent's right to refuse or withdraw from participating was fully maintained, and the information provided by each respondent was kept strictly confidential. Written consent was obtained from each of the study participants.

Author contributions

GK: Conceptualization, Formal analysis, Methodology, Writing—original draft. AA: Supervision, Writing—review & editing. WB: Supervision, Writing—review & editing. LA: Writing—review & editing. HL: Writing—review & editing. MB: 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.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

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Supplementary material

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Risk perceptions of COVID-19 in Beijing: a cross-sectional study

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Background: The Chinese government has ended the “dynamic zero-COVID” policy, and residents are now living together with the SARS-CoV-2 virus. Only a limited number of studies have investigated the specific content and structure of COVID-19-related risk perceptions, as well as their underlying determinants. This study measured the residents’ risk perception of COVID-19 and analyzed the predictors of RP.

Methods: We conducted a comprehensive questionnaire-based survey among residents mostly in Beijing, using a specially designed scale consisting of 11 items to accurately measure COVID-19 risk perceptions. We then utilized multiple linear regression analysis to investigate the factors associated with risk perceptions.

Results: A total of 60,039 residents participated in the survey. Our study reveals that COVID-19-related worries are significantly influenced by other dimensions of RP ($p < 0.001$), except for perceived society’s control of the epidemic. Several experiential and socio-demographic factors, including gender, educational level, and infectious experience, are notably correlated with all dimensions of risk perceptions of COVID-19.

Conclusion: This study evaluates the specific content and structure of COVID-19-related risk perceptions, as well as their determinants. It is essential to understand the risk perceptions and health-protective behaviors of residents with diverse educational levels, incomes, and medical histories.

KEYWORDS

COVID-19, risk perception, determinants, cross-sectional study, pandemic

1 Introduction

1.1 Background

COVID-19, also known as the coronavirus disease 2019, is a highly contagious respiratory illness caused by the SARS-CoV-2 virus. It was first identified in December 2019 and has since spread rapidly, becoming a global pandemic that affects billions of people worldwide. As of May 21st, 2023, over 766 million confirmed cases and over 6.9 million deaths have been reported globally, which is revealed by WHO in the latest edition of *COVID-19 Weekly Epidemiological Update*. The disease is primarily spread through respiratory droplets when an infected person talks, coughs, or sneezes, and also by exposure to surfaces contaminated with the virus. COVID-19 can cause a range of symptoms, from mild to severe and even fatal,

including fever, cough, shortness of breath, fatigue, and loss of taste or smell. Older adults are at higher risk of severe disease and death than younger ones (Chen et al., 2021) and evidence suggests that there are remarkable racial and ethnic disparities in SARS-CoV-2 infections and COVID-19 hospitalizations (Mackey et al., 2020). In response to the pandemic, the World Health Organization declared the outbreak of COVID-19 a “public health emergency of international concern” (PHEIC), on the historical date of January 30th, 2020.

To prevent the spread of COVID-19, health-protective behaviors, such as social distancing, wearing masks, and frequent hand washing are highly recommended. Besides providing healthcare information, many countries also adopt governmental measures which can be commonly divided into elimination (known as “zero-COVID”) and mitigation (known as “flattening the curve”) (Thunström et al., 2020; Al-Mustapha et al., 2021). During the COVID-19 pandemic, the Chinese government is specifically committed to the national “dynamic zero-COVID” strategy and it has turned out to be an enormous success (Burki, 2022). Yet, the Chinese authorities cannot help but think about the adjustment of the zero-COVID policy, considering the mighty power of the Omicron variant and unignorable socioeconomic issues (Chen and Chen, 2022). On December 7th, 2022, China officially announced the “new 10 prevention and control measures” after enforcing the elimination policy for more than two years. Since then, the Omicron pandemic has spread swiftly in major cities in China, including Beijing, the capital where the predominant Omicron BF.7 has put significant pressure on the healthcare system. By December 22nd, it is estimated that the Omicron outbreak had peaked in Beijing, with 76% of the Beijing residents infected (Leung et al., 2023). On 5 May 2023, Tedros Adhanom Ghebreyesus, the World Health Organization (WHO) Director-General, eventually declared that COVID-19 “is now an established and ongoing health issue which no longer constitutes a PHEIC.”

1.2 Contagion: risk perception during and after pandemics

Research on risk perception began in the 1940s when Gilbert White published his pioneering paper, *Human Adjustment to Floods*. White redefined how human responses to hazards should be studied (White, 1942) and found that personal experience with floods directly affected people's behavior when they were under a similar threat again (Macdonald et al., 2012). In other words, a brand new way to research risk and multihazard environments has been brought out. In 1969, Chauncey Starr discovered systematic relationship between the acceptance of technology risks and perceptions of costs and benefits, based on a revealed preference approach (Starr, 1969). Over the following decades, risk perception research evolved into psychological experiments and public surveys in which individual perceptions could be assessed with the help of several theories and approaches (Kellens et al., 2013). As such, studies have shown that risk perception is a subjective mental construction that is influenced by cognitive, experiential, and socio-cultural factors (De Dominicis et al., 2015; van der Linden, 2015). Even though higher levels of risk perception may have a positive impact on improving individuals' behaviors when faced with environmental risks, it is suggested that

RPs need to be accompanied by coping appraisal for a positive response (Bubeck et al., 2012). Among victims of natural disasters, concern about risk is notably associated with psychological stress, with possible feedback from pre-adopted mitigation measures on RPs (Suzuki et al., 2015).

Since the COVID-19 pandemic outburst in 2019, research has demonstrated that perceived risk and knowledge are influential factors which would shape individuals' engagement in health-protective behaviors and affect their intentions toward vaccination, as well as their mental status (Faasse and Newby, 2020; Motta Zanin et al., 2020). Approximately 43.6% of the participants perceived themselves at a high risk of exposure to COVID-19, while 50% considered the disease to be serious (Honarvar et al., 2020). Additionally, older adults are more likely to associate a higher risk of death with COVID-19 infection (Bruine De Bruin, 2021). Experts in work and organizational psychology have been focusing on the perception of COVID-related risks and mental well-being as well. The perception of worker safety can be articulated through four distinct dimensions that reflect the organization's capability amidst the COVID-19 pandemic, namely “situational awareness, capacity to communicate and make decisions effectively and efficiently, and the capacity to recognize additional mental and physical fatigue (Flin et al., 2013).”

Nowadays, the COVID-19 pandemic has entered a new phase characterized by fluctuations in transmission rates but with lower mortality rates. This study utilized a standardized scale to measure COVID-19 risk perception, while also collecting personal information and COVID-19 infection status through a questionnaire. The risk perception of residents was analyzed after adjusting the zero COVID policy, and the factors influencing COVID-19 risk perception were explored. Our research findings can contribute to the development of a solid research foundation for the prevention and management of COVID-19 outbreaks among Beijing residents and in other regions. In this paper, we ask two crucial questions about COVID-19; (a) how concerned are people? and (b) what social-psychological factors determine their level of concern?

2 Materials and methods

2.1 Procedure

This study was a cross-sectional study aiming to investigate the health situation of community residents during the COVID-19 pandemic and the impact of the coronavirus disease, conducted by a research team from Peking University Third Hospital and School of Public Health, Peking University. The sample of our study is community residents who have experienced the Omicron outbreak from late 2022 to early 2023, since the Chinese government declared the “new 10 prevention and control measures” and ended the zero-COVID strategy in December 2022. Data collection took place between January 13th and February 13th, 2023.

2.2 Participants

To ensure the representativeness of the survey sample, this study used the 16 administrative districts of Beijing as the basic sampling

TABLE 1 Basic information about the citizens in the study.

Characteristic	N = 54,415
<i>Gender</i>	
Male	19,646 (36%)
Female	34,769 (64%)
<i>Age</i>	
18 ~ 30	8,122 (15%)
31 ~ 45	20,362 (37%)
46 ~ 60	16,384 (30%)
>60	9,547 (18%)
<i>Marriage</i>	
Married	46,328 (85%)
Others	8,087 (15%)
<i>Education level</i>	
Middle school and below	10,720 (20%)
High school/Technical school	25,005 (46%)
College degree and above	18,690 (34%)
<i>Region</i>	
Central city	14,548 (27%)
Suburb	39,867 (73%)
<i>Income</i>	
Rich	11,768 (22%)
Ordinary	41,446 (76%)
Poor	1,201 (2%)
<i>Healthcare worker</i>	
Y	7,129 (13%)
N	47,286 (87%)
<i>Payment type</i>	
Urban employee medical insurance	40,007 (74%)
Urban and rural resident medical insurance	8,293 (15%)
Free medical insurance	2,505 (5%)
Uninsured	2,762 (5%)
Other	848 (2%)
<i>Live alone</i>	
Y	2,611 (5%)
N	51,804 (95%)
<i>Chronic disease</i>	
Y	35,455 (65%)
N	18,960 (35%)
<i>Infected with Covid-19</i>	
Y	45,451 (84%)
N	8,964 (16%)

n (%).

frame and randomly selected 8 to 42 Community Healthcare Centers in each district based on population proportion, totaling 293 Community Healthcare Centers. Within each center, 3 to 5 family-contracted doctors were selected, and each doctor selected 40 to 50

contracted residents as the survey subjects. The study conducted a questionnaire survey on a total of 60,039 residents. 5,624 responses were excluded because they were not filled out properly (missing essential information). This resulted in a final sample of 54,415 participants.

2.3 Measures

Following Xie et al. (2005), van der Linden (2015), and Dryhurst et al. (2020), our dependent variable “COVID-19 Risk Perception” was measured as a set of indexes, involved with several dimensions to provide a comprehensive measure of RP.

2.4 Predictors

Our social-psychological predictor variables were based on the “climate change risk perception model” (CCRPM) by van der Linden (2015), which included measurements of personal experience and socio-demographics (Table 2). Specifically, we included items on direct contagious experience with the SARS-CoV-2 virus, as well as income, career, payment type, and chronic medical history.

3 Results

We collected basic information about the citizens, most of whom live in Beijing (Table 1). With 5,624 responses eliminated due to absent information, 54,415 samples were included in our analysis. About 64% of them were female and 84% had got infected with COVID-19 at least once.

3.1 Exploratory factor analysis

After that, we conducted the exploratory factor analysis (EFA) for the dimensionality reduction analysis of the scale. First, the Kaiser–Meyer–Olkin (KMO) test and Bartlett test of sphericity were implemented to test the suitability of the data. KMO was calculated as 0.9 (≥ 0.9); besides, EFA was validated to be suitable by the Bartlett test of sphericity (χ^2 : 430.3598, $p < 0.001$). Then, we successfully performed EFA on the data, as such, factors were extracted through varimax rotation. According to Table 2, all 11 items were divided into three dimensions, accounting for 53% variance. Drawing on insights from psychological theory and literature (Qin et al., 2021), dimensions 1 to 3 were distinctly classified as “Perceived health threat,” “Perceived severity & controllability,” and “Perceived infection possibility.”

3.2 Relations between dimensions of risk perception

By analyzing the relations between the dimensions of risk perception, we would have a better understanding of the influencing factors of COVID-19-related worries. As such, we ran a simultaneous regression analysis, using the degree of COVID-19-related worries as dependent variables, and other dimensions of RP as predictors

TABLE 2 Exploratory factor analysis of the risk perception scale.

Risk perception scale	Component		
	Factor 1	Factor 2	Factor 3
1. The degree of worry about COVID-19 (not worried at all-very worried)	−0.08	−0.06	0.90
2. The impact of COVID-19 on individuals (small-large)			
3. The impact of COVID-19 on society (small-large)	0.00	0.00	0.79
4. The consequences of COVID-19 (delayed-immediate)			
5. The characteristics of COVID-19 (natural-artificial)	0.15	0.10	0.56
6. The impact of infection with SARS-CoV-2 (short term-long term)			
7. Perceived society's control of COVID-19 (controllable-uncontrollable)	0.43	0.06	0.12
8. Perceived individuals' control of COVID-19 (evitable-inevitable)			
9. The knowledge about COVID-19 (familiar-unfamiliar)	0.62	−0.05	0.06
10. Perceived probability of infection with COVID-19 among the general population (small-large)			
11. Perceived probability that I get infected with COVID-19 (small-large)	0.61	0.11	0.10
	0.66	0.18	−0.10
	0.16	0.65	−0.01
	0.54	−0.09	−0.05
	−0.04	0.83	0.03
	−0.11	0.93	−0.04

(Table 3). Our indicators of all dimensions, in fact, were significantly associated with COVID-19-related worries, except for perceived society's control of the epidemic. People who perceived more probability of infection tend to have less worry about COVID-19 ($\beta = -0.05$, [95% CI: -0.06 , -0.04]), suggesting that individuals who are more exposed to information about the virus or have experienced COVID-19 firsthand could develop a sense of familiarity or desensitization to the risks, leading to decreased anxiety levels.

Research suggests that the dimension of whether a risk event is “not at all worried” or “very worried” has been considered a significant contributor to the degree of risks. The results of our study reconfirmed this assumption, in part, it is obvious that the “very worried” experience is directly related to psychological panic.

3.3 Determinants of COVID-19 risk perception

Next, we ran a multiple linear regression model to illustrate a detailed overview of the predictors that make a difference in COVID-19 risk perception (Table 4). Based on the results of EFA, our indicators, within the predictor model, of experience with the virus, history of chronic diseases, payment types, as well as socio-demographics, were all significantly related to three dimensions of risk perception.

TABLE 3 Analysis of the relations in risk characteristics of COVID-19.

Characteristic	β	95% CI1	p -value
The impact of COVID-19 on individuals	0.47	0.46, 0.48	<0.001
The impact of COVID-19 on society	0.28	0.27, 0.29	<0.001
The consequences of COVID-19	0.02	0.01, 0.03	<0.001
The characteristics of COVID-19	0.04	0.03, 0.05	<0.001
The impact of infection with SARS-CoV-2	0.05	0.04, 0.06	<0.001
Perceived society's control of COVID-19	0.00	−0.01, 0.01	0.55
Perceived individuals' control of COVID-19	0.05	0.04, 0.06	<0.001
The knowledge about COVID-19	0.02	0.01, 0.03	<0.001
Perceived probability of infection with COVID-19 among the general population	−0.05	−0.06, −0.04	<0.001
Perceived probability that I get infected with COVID-19			

TABLE 4 Regression outputs of the risk perception of COVID-19 among citizens.

Experiential and socio-demographic factors	Perceived health threat		Perceived severity and controllability		Perceived infection possibility	
	β^a	95% CI	β^a	95% CI	β^a	95% CI
<i>Gender</i>						
Male	—	—	—	—	—	—
Female	1.8***	1.7, 1.9	1.1***	1.0, 1.2	0.92***	0.84, 1.0
<i>Age</i>						
18 ~ 30	—	—	—	—	—	—
31 ~ 45	1.1***	0.90, 1.2	0.81***	0.63, 1.0	1.1***	1.0, 1.3
46 ~ 60	1.4***	1.2, 1.6	0.67***	0.47, 0.86	1.3***	1.1, 1.4
>60	1.5***	1.3, 1.7	1.4***	1.1, 1.6	1.3***	1.1, 1.5
<i>Marriage</i>						
Married	—	—	—	—	—	—
Others	−0.41***	−0.58, −0.25	−0.07	−0.24, 0.09	−0.23**	−0.36, −0.09
<i>Education level</i>						
Middle school and below	—	—	—	—	—	—
High school/Technical school	0.18*	0.04, 0.32	0.30***	0.16, 0.45	0.46***	0.34, 0.57
College degree and above	0.19*	0.02, 0.36	0.92***	0.75, 1.1	1.3***	1.1, 1.4
<i>Region</i>						
Central city	—	—	—	—	—	—
Suburb	0.07	−0.05, 0.18	−0.56***	−0.68, −0.45	−0.16***	−0.26, −0.07
<i>Income</i>						
Rich	—	—	—	—	—	—
Ordinary	−1.7***	−1.8, −1.6	−1.5***	−1.6, −1.4	−1.0***	−1.1, −0.86
Poor	−3.0***	−3.4, −2.7	−2.6***	−3.0, −2.3	−1.9***	−2.2, −1.6
<i>Healthcare worker</i>						
Y	—	—	—	—	—	—
N	0.77***	0.62, 0.92	1.1***	0.91, 1.2	−0.16*	−0.28, −0.03
<i>Payment type</i>						
Urban employee medical insurance	—	—	—	—	—	—
Urban and rural resident	−0.37***	−0.52, −0.22	−0.59***	−0.74, −0.44	−0.60***	−0.72, −0.47
Medical insurance						
Free medical insurance	−0.12	−0.36, 0.11	−0.39**	−0.63, −0.16	−0.28**	−0.47, −0.09
Uninsured	−0.41***	−0.64, −0.18	−0.47***	−0.70, −0.24	−0.64***	−0.83, −0.46
Other	−0.11	−0.51, 0.28	0.07	−0.33, 0.46	0.00	−0.32, 0.32
<i>Live alone</i>						
Y	—	—	—	—	—	—
N	0.62***	0.38, 0.86	0.37**	0.13, 0.61	0.40***	0.21, 0.59
<i>Chronic disease</i>						
Y	—	—	—	—	—	—
N	1.4***	1.2, 1.5	1.1***	0.94, 1.2	0.83***	0.74, 0.92
<i>Infected with Covid-19</i>						
Y	—	—	—	—	—	—
N	0.60***	0.46, 0.73	0.07	−0.07, 0.20	−1.6***	−1.7, −1.5

*Multiple linear regression.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Specifically, there is a gender effect, such that females perceive more risk compared to males (e.g., $\beta = 1.8$, [95% CI; 1.7, 1.9]). Aging plays a considerable role in contributing to increased concerns about COVID-19, in part, individuals over 60 perceive more risk versus youngsters aged 18 to 30 (e.g., $\beta = 1.5$, [95% CI; 1.3, 1.7]). The less money people think they earn compared to others around, the less risk they perceive (e.g., $\beta = -3.0$, [95% CI; -3.4, -2.7]), in other words, the relative level of income is negatively associated with RP. Results show that the currently married (e.g., $\beta = 0.41$, [95% CI; 0.25, 0.58]) and residents of the central city (e.g., $\beta = 0.56$, [95% CI; 0.45, 0.68]) perceive more risk, while healthcare workers (e.g., $\beta = -1.1$, [95% CI; -1.2, -0.91]) and people who live alone (e.g., $\beta = -0.62$, [95% CI; -0.86, -0.38]) appear fewer concerns about COVID-19. Educational level is positively correlated with risk perception, in addition to a payment effect, such that residents without medical insurance perceive less risk than those covered by Urban Employee Medical Insurance (e.g., $\beta = -0.64$, [95% CI; -0.83, -0.46]). People who have had contagious experience with the virus perceive less threat ($\beta = -0.60$, [95% CI; -0.73, -0.46]), but more infection possibilities ($\beta = 1.6$, [95% CI; 1.5, 1.7]) in comparison with those who have never been infected yet. Besides, there is a negative correlation observed between the history of chronic diseases and the factors of RP (e.g., $\beta = -1.4$, [95% CI; -1.5, -1.2]).

4 Discussion

In this paper, we set out to analyze and model the risk perception of COVID-19 mostly in Beijing. Across the study, we find that worries about COVID-19 are significantly influenced by other dimensions of RP. We divided 11 items of RP into three general dimensions, based on the exploratory factor analysis which we have conducted. Several socio-psychological factors emerged as critical predictors. Consistent with the achievements in the domain of contagious risk, experiential, and socio-demographic factors show important correlations in our RP regression model.

The results provide a comprehensive understanding of the sources of psychological anxiety in the population, which involves the structure of risk perceptions. Even though this may not reflect the overall pattern of people's perceptions of risk events and hazards, for the specific risk of COVID-19 pandemics, however, the perceived society's control of the epidemic has not played a major role in RP. Concerns and panics hardly originate from the social response system and policy of COVID-19, instead, it is probably the pandemic itself that matters to the residents. Our study also reveals that individuals with higher levels of education and income tended to have higher risk perceptions of COVID-19. This could be attributed to their greater access to information and resources, allowing them to better understand the potential risks and consequences of the SARS-CoV-2 virus (Honarvar et al., 2020). In addition, we find that overall risk perceptions of COVID-19 in Beijing have maintained a relatively moderate level (44 out of 77 on average).

A possible explanation is that the capital city of China has experienced an unstoppable outbreak of the Omicron variant (Dyer, 2022), after which 84 percent of the residents have got infected by the virus at least once. While COVID-19 can hit twice and even more, it is not likely to experience reinfections within 3 months after the first diagnosis of infection (Pilz et al., 2022), and this knowledge may have reduced the public's awareness and concern. Interestingly, results show

that risk perceptions varied across different age groups, with older individuals perceiving a higher risk than younger individuals. This may be due to the fact that older individuals are more vulnerable to severe complications and even death from COVID-19. On the other hand, retired seniors may struggle to perceive support from organizations in the same way younger workers do, which is negatively correlated with the social dimension of well-being (Capone et al., 2022).

In short, our findings considerably suggest that risk perceptions of COVID-19 in Beijing are influenced by a variety of socio-experiential factors, including age, gender, education, and income. These findings can contribute to public health efforts and strategies aimed at promoting greater awareness and governance of infectious diseases. We provide valuable insights into the determinants of COVID-19-related worries and risk perception among the residents in Beijing, most notably the "big picture" overview of communication between human and natural hazards. By analyzing these factors, we can pave the way for rewarding health campaigns and patient education, ultimately building trust and encouraging health-protective behaviors. The importance of mental well-being cannot be overstated, as it is significantly linked to our overall health and resilience, affecting our capacity to cope with challenges across the lifespan.

And of course, our research is not without limitations. The sample size and demographics of the participants may have influenced the results, and further research is needed to confirm the validity of these findings in other settings. It is important to notice that although our samples were abundant in number, they were residents who have been to the medical institutions and therefore are not completely representative of the population in Beijing. In addition, we conducted a massive cross-sectional study that covered different aspects of COVID-19, in other words, it is not specific research only focused on risk perception. As such, our study was not exhaustive, and other significant factors ought to be considered, including Non-Technical Skills (Converso et al., 2021).

5 Conclusions and implications

This study evaluates the specific content and structure of COVID-19-related risk perceptions, as well as their determinants. It is essential to understand the risk perceptions and health-protective behaviors of residents with diverse educational levels, incomes, and medical histories. By doing so, we would develop targeted interventions to address the specific concerns and needs of different population groups and ultimately contribute to the effective prevention and control of infectious diseases.

Data availability statement

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

Author contributions

QL: Conceptualization, Data curation, Investigation, Writing – review & editing. YT: Methodology, Visualization, Writing – original draft. ZZ: Formal analysis, Methodology, Software, Writing – review & editing. JZ: Conceptualization, Investigation, Resources, Writing

– review & editing. YF: Writing – review & editing. QW: Writing – review & editing. ZN: Writing – review & editing. LY: Funding acquisition, Supervision, Writing – review & editing, Investigation. XL: Supervision, Project administration, Resources.

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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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Evaluation of community knowledge and attitude toward COVID-19: the case of Hawassa city, Sidama, Ethiopia

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Background: Scientific information on the knowledge and attitude of the community toward the COVID-19 pandemic is a vital step for effective control measures. This study aimed to investigate the level of knowledge and attitude of Hawassa city residents toward COVID-19 and the interaction among knowledge and attitude toward COVID-19.

Methods: A community-based cross-sectional study with stratified random sampling was used from June 2020 to August 2020. Five hundred and eighty-seven residents were selected for the study, which aimed to evaluate their knowledge and attitude toward COVID-19 using a standardized structured questionnaire. Data were collected using face-to-face interviews that strictly follow the WHO and the Ministry of Health Ethiopia guidelines for COVID-19 prevention. Attitude and knowledge were categorized based on the mean score value. Descriptive statistics and two independent multiple logistic regressions were applied to identify the possible determinants of knowledge and attitude using SPSS version 20 set at 95% CIs with a value of p of <0.05 considered statistically significant.

Results: In total, 61.7% of the participants were knowledgeable about the virus and 65.9% had a positive attitude toward COVID-19. Educational level with the categories of second degree and above (AOR = 29.709, 95% CI = 1.239–712.55), first degree (AOR = 3.476, 95% CI = 3.278–22.02), certificate/diploma (AOR = 1.062–18.24, 95% CI = 1.062–18.24), and grade 12 completed (AOR = 1.903, 95% CI = 2.12–6.809); employment status of respondents who were self-employed (AOR = 9.545, 95% CI = 1.165–78.173) and employed respondents (AOR = 10.053, 95% CI = 1.783–56.673); reading interest with categories always (AOR = 34.45, 95% CI = 26.608–4462.226) and sometimes (AOR = 17.24, 95% CI = 17.213–1661.966); and habit of using social media with categories always (AOR = 38.708, 95% CI = 5.086–294.610) and sometimes (AOR = 3.432, 95% CI = 3.504–23.378) were the significant explanatory variables that were correlated with knowledge of the respondents.

Conclusion: Although the knowledge and attitude of respondents toward COVID-19 were positive, there is a need to use more effective strategies to improve their knowledge and attitude toward COVID-19, and increasing knowledge on preventive behaviors among the community was mandatory to attain better results. The educational level, use of social media, and reading habits of the respondents appear to play significant roles in determining their level of knowledge and attitude toward COVID-19.

KEYWORDS

knowledge, attitude, COVID-19, community, Hawassa city, Ethiopia

Introduction

SARS-CoV-2 is a family of viruses that can cause illnesses such as common cold, camel flu, and SARS. In 2019, a new coronavirus (SARS-CoV-2) was identified as the cause of the COVID-19 disease outbreak that originated in Wuhan, China and expanded across China and other countries. Most people contaminated by the COVID-19 virus experience light-to-mild respiratory sickness and get better without needing special treatment. Adults and those with underlying medical problems such as chest pains, diabetes, long-term respiratory disease, and cancer are more likely to experience severe sickness (1).

The virus that causes COVID-19 is part of a huge family of single-stranded ribonucleic acid viruses that cause sickness, starting as a viral rhinitis to SARS (2). Signs and indicators of COVID-19 may come into view 2–14 days after infection. General signs and symptoms can include fever, cough, tiredness, shortness of breath or difficulty breathing, muscle aches, headache, chest pain, loose stools, pink eye (conjunctivitis), runny nose, and sore throat (3). The aged population and patients with coexisting or co-occurring conditions are more susceptible to being infected and are, in addition, more prone to severe problems, which may be related to adult respiratory distress syndrome and hypercytokinemia (4).

Till the time of this study being conducted, from June 2020 to August 2020, there was no confirmed cure or vaccine obtained for COVID-19. Infection control measures such as washing hands with soap, keeping distance, and wearing a mask were the main interventions to reduce the spread of the virus in the community (5). Public knowledge of the virus plays an excellent role in limiting its spread. Vaccine or medicine development is expected to take a number of days or years, and thus, administration of the pandemic depends first and foremost on communities' adherence to the optional measures in use (6).

Experts believe that the virus that causes COVID-19 spreads mainly from individual to individual via droplets and from an infected person (7). Adults and sick persons with pre-existing diseases (such as congenital heart disease, respiratory tract anomaly, abnormal hemoglobin level, high blood pressure, obesity, heart disease, and lung disease) are identified as possibly having a risk of harsh malady and death (8, 9). Till the time of this study, scientists have not obtained an antitoxin healing drug or immunization for COVID-19 (2). The World Health Organization (WHO) suggests the elimination of person-to-person transference by avoiding close contact with others, wearing a mask, allowing rooms to circulate air, keeping away from traffic, washing hands, and coughing into a bent elbow or tissue (1).

Knowledge about the infection plays a fundamental role in limiting the expansion of disease to the community. Organization of the disaster depends mainly on people's adherence to the optional measures taken. These measures are largely affected by the knowledge, attitude, and practice (KAP) of the public (6). Measuring communities' knowledge and attitudes is vital in recognizing gaps and supporting ongoing prevention efforts. To the best of the author's knowledge, covariates significantly determining the level of knowledge and attitude of the general population of Hawassa city and the interaction among knowledge and attitude toward COVID-19 have not been assessed. Specifically, no study has been conducted on the level of knowledge and attitude toward COVID-19 among the general population of Hawassa city, Sidama, Ethiopia. Thus, this study aimed to investigate the level of knowledge and attitude of the general

population of Hawassa city on COVID-19 and the interaction among knowledge and attitude toward COVID-19.

Methods and materials

Study design

A community-based cross-sectional study was conducted.

Data gathering and quality control

The information was gathered using a pretested standardized questionnaire from 3 June 2020 to 30 August 2020. Data were collected using face-to-face interviews that strictly follow the WHO and the Ministry of Health Ethiopia guidelines for COVID-19 prevention. After checking the validity of the questionnaire using 10% of the sample size, which was not included in the analysis later, the survey was settled. The questionnaire was translated into local languages (Sidamic and Amharic), and during data collection, information was checked for completeness each day by supervisors and investigators. Data were used to assess internal consistency and reliability using Cronbach's alpha.

Sampling design

The sampling technique used for this study was the stratified sampling method. The strata used were sub-cities of Hawassa city, Sidama region administrations.

Target population

The target populations were residents of Hawassa city, Sidama, Ethiopia aged 18 years or older who understood the content of the questionnaire and agreed to participate in the study. Participation in the study was on a voluntary basis, and informed written consent was given to the participants.

Sample size determination

A simple random sampling method was used using the formula (10)

$$n = \frac{\sum_{i=1}^k \frac{N_i^2 p(1-p)}{W_i}}{\frac{N^2 d^2}{Z_{\alpha/2}^2} + Np(1-p)},$$

where n refers to the required total sample size, N refers to the total number of households (targeted residents) in Hawassa city, Z refers to the inverse of the standard normal cumulative distribution that corresponds to the 5% level of confidence ($Z = 1.96$), k refers to the total number of sub-cities (strata) in Hawassa city administration

($k=7$), N_i refers to the number of households in each sub-city (for $i=1, 2, 3, 4, 5, 6, 7$), W_i refers to the estimated proportion of N_i to N (sub-city households to the total number of households in Hawassa city), p refers to the probability of knowledge and attitude on COVID-19, and d refers to the level of precision (sampling error). Using proportional allocation, the subsample size from each sub-city is given below (Table 1).

The probability of success was 0.5, which was determined via a pilot study. The level of precision preferred for this study was 4%. The desired sample size from the target population was 587.

Data processing and analysis

Data were entered as input to SPSS version 20 for cleaning and analysis. Data were presented using both descriptive and inferential statistics. Variables with a p -value less than 0.05 in the bivariate analysis were included in the multivariate analysis. Multivariate logistic regression analyses were employed at a 95% confidence interval to determine the presence of an association between independent variables with knowledge and attitude. A p -value of <0.05 at a 95% CI was taken as statistically significant. The Kaiser–Meyer–Oklin (KMO) measure was issued to check the validity of the items and should be more than 0.6. Cronbach's α was determined to check internal consistency.

Operational definitions

Good knowledge: Participants who scored the mean value or above for the given knowledge-based questions.

Poor knowledge: Participants who scored below the mean value for the given knowledge-based questions.

Positive attitude: Participants who scored above the mean value for the given attitude-related question.

Negative attitude: Participants who scored below the mean value for the given attitude-related questions.

Ethics approval and consent to participants

Ethical clearance (DRBH/125/2020) was obtained from the Department Review Board of Hawassa University. The reason and

significance of the study were explained, and informed written consent was obtained from the respondents before conducting the study. All of the data collectors strictly followed the WHO and the Ministry of Health Ethiopia guidelines for COVID-19 prevention.

Results

Sociodemographic characteristics of the study participants

A total of 587 study participants with a 100% response rate completed the questionnaire. There were 315 (53.7%) male participants. In terms of the education, 12.1% of the study participants were illiterate, and in terms of education level, 11.6% of them had a second degree and above (Table 2).

Respondents' knowledge regarding COVID-19

The average COVID-19 knowledge score was 15.425 (S.D. = 3.12, min = 0, max = 25). Cronbach's α for the knowledge scale was 0.770, indicating that the questionnaires were reliable. Furthermore, the KMO values were 0.759, which shows that the criteria of validity are met. All the items in knowledge satisfied the standard loading value of >0.40 . The average COVID-19 knowledge score was 15.425 (SD = 3.12, min = 0, max = 25). Although all participants in the city, 100%, heard about COVID-19, only approximately 61.7% of the respondents were aware of the disease, and the remaining 38.3% were not aware. Approximately 56.4% of the respondents were aware that the disease is viral, and 59.6% were informed with the intention that children and youngsters should take action to prevent infection by COVID-19. In total, 20.3% of the study participants believe that children are not at greater risk for COVID-19 than adults (Table 3).

Respondents' attitude toward COVID-19

The average attitude score for COVID-19 was 63.2 (S.D. = 4.6, min = 19, max = 76). Cronbach's α for the attitude scale was 0.802, indicating that the questionnaires were reliable. Furthermore, the KMO values were 0.753, which shows that the criteria of validity are met. All the items in attitude satisfied the standard loading value of >0.40 . Overall, 65.9% of the study participants had scored an attitude score greater than the mean attitude score (63.2) and had a positive attitude toward COVID-19. In total, 77% of the study participants agreed to take a vaccine for COVID-19 when available, 79 (13.5%) respondents agreed to welcome friends and family with a handshake; 312 (53.2%) agreed that washing hands was the necessary action to prevent the infection, 340 (57.9%) agreed that sidestepping from the individuals was the best way to prevent the disease, 396 (67.5%) agreed to clear their hands frequently and for a sufficient period of time to prevent the infection, and 368 (62.7%) agreed to wear a facemask to prevent the infection (Table 4).

Variables that were identified as significant in the univariate analysis were included in the multivariate analysis and shown in

TABLE 1 Sample size by sub-cities.

i	Sub-cities	Total number of households in each sub-city (N_i)	W_i	n_i
1	Addis Ketema	2,321	0.092	54
2	BahilAdarash	1,387	0.055	32
3	Hayik Dar	1,924	0.076	45
4	MehaKetema	1,726	0.069	40
5	Menaheriya	4,235	0.169	99
6	Misrak	1,492	0.059	34
7	Tabour	12,099	0.480	283
Total		25,184	1	587

TABLE 2 Sociodemographic characteristics of the study participants in Hawassa city, Sidama region, Ethiopia, 2021 ($n = 587$).

Variables	Frequency ($N = 587$)	Percentage (%)
Age in years		
18–28	75	12.8
28–38	285	48.6
38–48	123	21
Above 48	104	17.7
Gender		
Man	315	53.7
Woman	272	46.3
Marital status		
Single	213	36.3
Married	258	44
Divorced	116	19.8
Educational level		
No formal education	71	12.1
Up to and 12 completed	99	16.9
Certificate/diploma	158	26.9
Degree	191	32.5
M.Sc. and above	68	11.6
Employment status		
Unemployed	154	26.2
Employed	292	49.7
Self-employed	141	24.0
Monthly income in birr		
Under 1,000	116	19.8
1,000–3,000	131	22.3
3,001–6,000	207	35.3
Above 6,000	133	22.7
Accommodation		
Living alone	181	30.8
Not living alone	406	69.2
Total family size		
1–4	268	45.7
5–8	137	23.3
Above 8		
Reading habit		
Rarely	183	31.2
Sometimes	167	28.4
Always	237	40.4
Use of media		
Rarely	103	17.5
Sometimes	183	31.2
Always	301	51.3

Table 5. Educational level with categories second degree and above (AOR = 29.709, 95% CI = 1.239–12.55), first degree (AOR = 3.476, 95% CI = 3.278–22.02), certificate/diploma (AOR = 3.37, 95% CI = 1.062–18.24), and grade 12 completed (AOR = 1.903, 95% CI = 2.12–6.809) were the significant variables that were correlated with the knowledge of the respondents. Age of the respondents with categories above 50 (AOR = 1.545, 95% CI = 2.513–4.658), 40–50 (AOR = 1.542, 95% CI = 1.847–2.809), 29–39 (AOR = 0.849, 95% CI = 2.518–1.394) were the significant variables that correlated with attitude.

Discussion

This research attempted to evaluate the level of knowledge and attitude of the general population of Hawassa city toward COVID-19 and the interaction among knowledge and attitude toward COVID-19 from 3 June 2020 to 30 August 2020.

The majority of the participants (61.7%) were knowledgeable about COVID-19. This result is much lower compared to other studies that have been done on Saudi Arabian residents (97%)

TABLE 3 Participants' knowledge about COVID-19 in Hawassa city, Sidama, Ethiopia, 2020 ($n = 587$).

Items related to knowledge (Cronbach's $\alpha = 0.770$; KMO = 0.759***)			Standard loading
Statement	Frequency	Percentage (%)	
COVID-19 is a viral disease.			0.938
No	113	19.3	
Yes	331	56.4	
Not sure	143	24.4	
Children and youngsters should not take actions to prevent the infection by the COVID-19.			0.891
No	350	59.6	
Yes	168	28.6	
Not sure	69	11.8	
To prevent COVID-19, everyone should avoid densely packed places, for example train stations and public transportation.			0.962
No	0	0	
Yes	551	93.9	
Not sure	36	6.1	
Successful measures of decreasing the spread of COVID-19 are via isolation and care of individuals who are contaminated by COVID-19.			0.861
No	124	21.1	
Yes	337	64.2	
Not sure	86	14.7	
Individuals who contact persons infected with COVID-19 should isolate separately. Generally, the isolation time is 14 days.			0.900
No	24	4.1	
Yes	460	78.4	
Not sure	103	17.5	
Common cold, stuffy nose, runny nose, and sneezing are uncommon in individuals infected by COVID-19.			0.845
No	220	37.5	
Yes	22	3.7	
Not sure	345	58.8	
Currently there is no successful cure for COVID-19, but timely advice and helpful action can assist most victims to get better from the disease.			0.927
No	87	14.8	
Yes	466	79.4	
Not sure	34	5.8	
The older adult and persons with underlying chronic diseases are at risk of rigorous infection and death.			0.803
No	146	24.9	
Yes	306	52.1	
Not sure	35	23	
COVID-19 can be transferred by eating or touching wild animals.			0.748
No	121	20.6	
Yes	268	45.7	
Not sure	198	33.7	
Individuals who are infected by COVID-19 cannot contaminate others while fever is not there.			0.874
No	467	79.6	
Yes	79	13.5	
Not sure	41	7	
Hygienic standard hand wash and using facemasks are primary prevention methods of COVID-19 spread.			0.977
No	36	6.1	
Yes	526	89.6	
Not sure	25	4.3	
COVID-19 can be transferred to individuals who touch other individuals infected by the virus and then touch their own face.			0.928
No	0	0	
Yes	562	95.7	
Not sure	25	4.3	
An individual can be infected by COVID-19 via insect bite.			0.777
No	74	12.6	
Yes	211	35.9	
Not sure	302	51.4	

(Continued)

TABLE 3 (Continued)

Items related to knowledge (Cronbach's $\alpha = 0.770$; KMO = 0.759***)			Standard loading
Statement	Frequency	Percentage (%)	
An individual can be infected by COVID-19 via water and meals.			0.666
No	294	50.1	
Yes	163	27.8	
Not sure	130	22.1	
An individual can be infected by COVID-19 though matters infected by coronavirus.			0.745
No	185	31.5	
Yes	312	53.2	
Not sure	90	15.3	
Hand cleaning, covering the nose and mouth while coughing, and keeping away from ill contacts can help with the avoidance of COVID-19 spread.			0.800
No	108	18.4	
Yes	479	81.6	
Not sure	0	0	
COVID-19 can be transferred from creature to individual.			0.891
No	134	22.8	
Yes	314	53.5	
Not sure	139	23.7	
COVID-19 cause pneumonia and respiratory difficulty and leads to death.			0.959
No	95	16.2	
Yes	378	64.4	
Not sure	114	19.4	
COVID-19 is spread via air and making contact with fecal-oral routes.			0.754
No	75	12.8	
Yes	285	48.6	
Not sure	227	38.7	
COVID-19 can be transferred from individual to individual via a short distance.			0.878
No	92	15.7	
Yes	462	78.7	
Not sure	33	5.6	
COVID-19 can be spread by contact with a surface contaminated by the virus and touching the mouth, nose, and eyes.			0.835
No	0	0	
Yes	511	87.1	
Not sure	76	12.9	
All individuals with COVID-19 do not have dangerous cases. Only elderly adults with lifelong sickness tend to have harsh cases.			0.834
No	271	46.2	
Yes	112	19.1	
Not sure	204	34.8	
Pregnant women are more at risk of contamination than non-pregnant women.			0.965
No	314	53.5	
Yes	126	21.5	
Not sure	147	25	
Children are not at greater risk for COVID-19 than adults.			0.898
No	302	51.4	
Yes	119	20.3	
Not sure	166	28.3	

***Significant at $p < 0.001$.

who were knowledgeable regarding COVID-19 (11, 12). Another research that has been done in Iran indicated that 56.5% of the study participants were knowledgeable regarding COVID-19 (13). Our study result was much lower compared to other studies conducted in the Chinese general population (90%) and the United States (80%) (6, 14). This difference might be due to the difference in the study period or the difference in questions that measure the knowledge and attitude of the respondents.

Knowledge about the symptoms of COVID-19 was 62.5%. This result was much lower compared to other studies conducted in Iran's general population (80%) (15). In this study, some misconceptions about the disease persisted. For example, 35.9% of the participants believe that the virus can be spread by insect bite and 53.5% believe that the virus is transmitted via animals. This study result was almost similar to the study done in Henan, China (16). In our setting, education and more detailed comprehensive training were vital in improving the knowledge of participants about COVID-19.

TABLE 4 Participants' attitude on COVID-19 in Hawassa city, Sidama, Ethiopia, 2020 ($n = 587$).

Items related to attitude (Cronbach's $\alpha = 0.802$; KMO = 0.753***)			Standard loading
Statement	Frequency	Percentage (%)	
When I get together with friends and family, I will always welcome them with a handshake.			0.568
Strongly disagree	251	42.8	
Disagree	256	43.6	
Agree	79	13.5	
Strongly agree	1	0.2	
When I get together with friends and family, I will always welcome them with a hug.			0.569
Strongly disagree	138	23.5	
Disagree	230	39.2	
Agree	217	37	
Strongly agree	2	0.3	
I clean my hands frequently and for a sufficient period of time.			0.617
Strongly disagree	5	0.9	
Disagree	50	8.5	
Agree	396	67.5	
Strongly agree	136	23.2	
I regularly wear a facemask to defend myself from the danger of virus.			0.796
Strongly disagree	0	0	
Disagree	19	3.2	
Agree	368	62.7	
Strongly agree	200	34.1	
If I see an individual contaminated with the infection, I will tell the public health service.			0.722
Strongly disagree	0	0	
Disagree	97	16.5	
Agree	230	39.2	
Strongly agree	260	44.3	
If I feel any of the indications linked with the infection, I will tell the public health service.			0.803
Strongly disagree	1	0.2	
Disagree	118	20.1	
Agree	230	39.2	
Strongly agree	238	40.5	
If I touch an individual contaminated with the disease, I consent to be isolated at home for a definite period of time until it is confirmed that I am free from the sickness.			0.853
Strongly disagree	0	0	
Disagree	136	23.2	
Agree	209	35.6	
Strongly agree	242	41.2	
If I touch an individual contaminated with the disease, I consent to be isolated at quarantine facility for a certain period of time until it is confirmed that I am completely free from the sickness.			0.829
Strongly disagree	0	0	
Disagree	107	18.2	
Agree	274	46.7	
Strongly agree	206	35.1	
If I am requested to be isolated for some period of time, I believe that my wage should be carried on in this period.			0.677
Strongly disagree	8	1.4	
Disagree	152	25.9	
Agree	171	29.1	
Strongly agree	256	43.6	

(Continued)

TABLE 4 (Continued)

Items related to attitude (Cronbach's $\alpha = 0.802$; KMO = 0.753 ^{***})			Standard loading
Statement	Frequency	Percentage (%)	
If an immunization is obtainable for the infection, I am ready to get it.			0.752
Strongly disagree	17	2.9	
Disagree	118	20.1	
Agree	205	34.9	
Strongly agree	247	42.1	
I regularly track updates about the spread of the infection in my country.			0.64
Strongly disagree	0	0	
Disagree	21	3.6	
Agree	213	36.3	
Strongly agree	353	60.1	
I regularly track updates about the spread of the infection globally.			0.782
Strongly disagree	0	0	
Disagree	29	4.9	
Agree	306	52.1	
Strongly agree	252	42.9	
If a talk about the infection is prepared around me, I will be there.			0.720
Strongly disagree	2	0.3	
Disagree	90	15.3	
Agree	242	41.2	
Strongly agree	253	43.1	
If brochures are distributed that contains facts about COVID-19, I am ready to read them and follow the teachings introduced in them.			0.751
Strongly disagree	0	0	
Disagree	63	10.7	
Agree	327	55.7	
Strongly agree	197	33.6	
If defensive measures and tools are obtainable at a reasonable cost, I will purchase them.			0.739
Strongly disagree	1	0.2	
Disagree	17	2.9	
Agree	313	53.3	
Strongly agree	256	43.6	
It is necessary to sidestep from others to evade the spread of COVID-19.			0.710
Strongly disagree	0	0	
Disagree	29	4.9	
Agree	340	57.9	
Strongly agree	218	37.1	
Hand washing is necessary to defend myself from COVID-19.			0.894
Strongly disagree	0	0	
Disagree	21	3.6	
Agree	312	53.2	
Strongly agree	254	43.3	
To defend myself from COVID-19 contact, I should stay at home.			0.666
Strongly disagree	0	0	
Disagree	98	16.7	
Agree	316	53.8	
Strongly agree	173	29.5	
COVID-19 will finally be effectively managed.			0.635
Strongly disagree	55	9.4	
Disagree	166	28.3	
Agree	233	39.7	
Strongly agree	133	22.7	

***Significant at $p < 0.001$.

TABLE 5 Association of explanatory variables with knowledge and attitude of residents at Hawassa city at Sidama region, Ethiopia, 2020 ($n = 587$).

Variable	Categories	Knowledge AOR (CI: 95%)	Attitude AOR (CI: 95%)
Age in years	18–28	1	1
	28–38	0.993 (0.271–3.630)	0.849 (2.518–1.394)*
	38–48	1.035 (0.125–8.548)	1.542 (1.847–2.809)*
	Above 48	1.331 (0.038–2.895)	1.545 (2.513–4.658)*
Gender	Man	1	1
	Woman	0.927 (0.330–2.61)	0.774 (0.506–1.185)
Marital status	Single	1	1
	Married	2.501 (0.714–8.754)	2.690 (1.127–6.234)*
	Divorced		3.700 (0.844–2.745)*
Educational level	No formal education	1	1
	Up to and 12 com	1.903 (2.12–6.809)*	1.188 (0.707–1.997)
	Certificate/diploma	3.37 (1.062–18.24)*	2.769 (1.448–5.155)*
	Degree	3.476 (3.278–22.02)*	3.875 (0.232–6.275)*
	M.Sc. and above	29.709 (1.239–12.55)*	3.997 (1.008–5.274)
Employment status	Unemployed	1	1
	Employed	10.053 (1.783–56.673)*	0.607 (0.232–1.591)
	Self-employed	9.545 (1.165–78.173)*	0.981 (0.368–2.619)
Monthly income in birr	Under 1,000	1	1
	1,000–3,000	0.109 (0.225–5.460)	2.282 (1.009–5.163)*
	3,001–6,000	0.466 (0.142–4.134)	2.690 (1.127–6.423)*
	Above 6,000	1.763 (0.183–11.662)	3.811 (1.452–9.943)*
Accommodation	Living alone	1	1
	Not living alone	0.847 (0.128–5.602)	1.472 (0.822–2.635)
Total family size	1–4	1	1
	5–8	0.666 (0.081–5.498)	1.622 (1.879–2.993)*
	Above8	0.988 (0.139–7.009)	2.158 (1.128–4.129)*
Reading habit	Rarely	1	1
	Sometimes	17.24 (17.213–1661.966)*	2.512 (0.319–0.822)*
	Always	34.45 (26.608–4462.226)*	5.625 (0.057–0.833)*
Use of social media	Rarely	1	1
	Sometimes	3.432 (3.504–23.378)*	2.367 (0.235–0.573)*
	Always	38.708 (5.086–294.610)*	3.891 (0.144–5.681)

*Significant.

The majority of the study participants (65.9%) showed a positive attitude toward COVID-19. A probable reason is that good knowledge about COVID-19 among participants may be a guide to a positive attitude. This positive attitude was improved by a high association between the knowledge and attitude of the respondents ($\chi^2 = 22.644$, $p = 0.00$), which was statistically significant. This result is in line with the study (17) that found that more than 60% of respondents have a positive attitude toward COVID-19. In our study, gender, marital status, employment status, and accommodation had no significant association with the attitude of participants toward COVID-19. These results are in line with a study done in the United States (14), which indicated that the attitude regarding COVID-19

was not associated with marital status, gender, and employment status.

Based on logistic regression analysis, female respondents were more likely to be knowledgeable about COVID-19 than male respondents, but the difference was not significant. Pearson's correlation coefficient revealed significant positive linear correlations between knowledge and attitude, which was significant. This correlation may be explained by reasoned action theory. The theory states that a person's intention to undertake a specific behavior is a function of their attitude toward that behavior (18). In total, 79.4% of the participants knew that there was no successful cure for COVID-19 as of the date of this study. Viral contaminations have been recognized to be highly infectious among people in close contact (19). However, approximately 21.3% of

the respondents were unaware that COVID-19 could transfer from individual to individual via a short distance. It was also evident that, of the current general population, 48.6% were unaware that children are not at less risk for COVID-19 than adults. According to the WHO, all persons are susceptible to COVID-19 (13). These findings highlight the need to continue to encourage and emphasize maintaining social distancing and creating knowledge. The study recommends that health ministries should provide an ample training program, targeting younger age groups, women, and lower income groups to promote all precautionary and defensive measures of COVID-19 to achieve balance in terms of knowledge about COVID-19.

Some of the significant factors that are associated with the knowledge of the participants were educational level, employment status, reading habits, and uses of social media. This finding is supported by other studies that identified employed persons, those with higher income levels, and more educated respondents who are more knowledgeable about emerging communicable diseases (11, 20). Approximately 62.4% of the study participants agreed that the virus can be successfully controlled. This finding is consistent with a recent study conducted in China, where the majority of participants were convinced that the disease is curable and that their country will combat the disease (6).

Women were more likely to have knowledge and optimistic attitudes toward COVID-19. These findings are consistent with other studies showing that, in response to SARS and MERS, men were significantly less likely to take preventive and protective measures than women (15). Almost 90.7, 96.8, and 86.4% of the participants believe that cleaning hands, regularly wearing a facemask, and avoiding shaking hands, respectively, are methods to control the spread of the infection. Respondents had good knowledge and a positive attitude as a result of Ethiopian health authorities providing education and outreach materials to boost public understanding of the infection. Finally, the study findings may be useful to inform policymakers and healthcare professionals on further public health interventions, knowledge raising, policies, and health education programs.

Limitations

The data existing in this study are self-reported and somewhat dependent on the respondents' honesty and recall ability; thus, they may be subject to recall unfairness. Future research might employ administrative data to address this issue. Regardless of these limitations, the study findings provide valuable information about the knowledge and attitudes of residents.

Conclusion

Our results indicate that Hawassa city residents, especially men, older persons, the educated ones, readers of newspapers, and followers of mass media such as television and radio, have good knowledge and positive attitudes toward COVID-19. Although the general knowledge and attitude of respondents toward COVID-19 was positive, there is a need to use more effective strategies to improve knowledge and attitude toward COVID-19, and knowledge creation on preventive behaviors

among the community is highly recommended to attain better results. The educational level, use of social media, and reading habits of the respondents appear to play significant roles in determining their level of knowledge and attitude toward COVID-19. The results of this study suggest that more emphasis should be placed on less educated persons, lower income persons, women, and younger persons. The results may assist policymakers in recognizing the target populations for COVID-19 prevention.

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

Ethical clearance (DRBH/125/2020) was obtained from the Department Review Board of Hawassa University. The reason and significance of the study were explained, and informed written consent was obtained from the respondents before conducting the study.

Author contributions

BW: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Supervision, Validation, Visualization, 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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The impact of social distancing measures (quarantine) policy on tertiary education and medical consultations in China during the COVID-19 pandemic

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KEYWORDS

COVID-19, pandemic, immunity, lockdown, long COVID-19

Introduction

The 2019 novel coronavirus (COVID-19) pandemic prompted the implementation of rigorous social distancing measures, including quarantine protocols, to curb the virus's spread. This opinion focuses on the consequences of such measures on two critical aspects of society in China: tertiary education and healthcare. By examining the shifts in educational practices and healthcare delivery, the current opinion aims to understand the implications for students and educators in adapting to remote learning modalities, the efficacy of online education platforms, and their academic performance. The current opinion also focused on the management of patients during these unprecedented times. Additionally, the research explores innovative approaches adopted by educational institutions to maintain academic continuity and support the patient's wellbeing from their communities.

Education sector impact: adapting education during the COVID-19 pandemic

This opinion aims to analyse the challenges faced by students in adapting to remote learning modalities, the efficacy of online education platforms, and the psychological effects on both students and educators. Additionally, the research explores innovative approaches adopted by educational institutions to maintain academic continuity and support the wellbeing of their communities.

The imposition of COVID-19 restrictions, including social distancing and limited mobility, prompted a nationwide lockdown (1, 2), leading to the sudden closure of schools and universities. In response, the Ministry of Education, China, decided to suspend in-person classes but not cancel them entirely, necessitating a shift from traditional teaching to online instruction (3).

Amid the initial and subsequent waves of the COVID-19 outbreak, educational institutions across China transitioned to online teaching, with Tencent Meeting serving as a crucial delivery platform. Chengdu University, for example, successfully adapted its curriculum for 1st-year Medical (4) and Nursing students (5) during the initial extensive 6-month lockdown in 2020 (involving rigorous maintenance of social distancing). Course coordinators seamlessly shifted lectures online, offering live-streamed sessions and recorded content for later review.

Surprisingly, there was a discernible improvement in academic scores across various subjects, including Science, Literature, Biochemistry, Anatomy, and Histology. Even courses heavily reliant on hands-on practice, such as Anatomy and Histology, witnessed higher performance achievements among students (4). The curriculum evolved with the integration of digitized whole slide images, effectively transforming in-person instruction into online tutorials (4, 5). The success of this unintentional shift to online teaching, driven by factors that included focused learning time and convenient class review, is likely to influence future educational practices beyond the pandemic.

Supporting the effectiveness of online modules, a tertiary hospital in Shanghai developed modules for Intern/Registrar training in the clinical management of COVID-19 patients (6). This demonstrates the potential for effective online training even in complex clinical scenarios. Overall, these data suggest that the imposition of social distancing had minimal impact on academic performance amongst college students, while strongly minimizing the risk of viral transmission during the pandemic.

However, it is crucial to acknowledge the adverse psychological consequences of the prolonged 3-year of intermittent lockdown, particularly on individuals with pre-existing mental health issues. Approximately 35% of participants reported distress, including feelings of anxiety and depression, with the closure of schools having unfavorable effects, especially on children and adolescents (7). This underscores the importance of addressing mental health concerns alongside the adaptation of novel educational strategies.

Impact of stringent measures on healthcare access during the COVID-19 pandemic

Social distancing measures, while essential for public health, posed challenges to routine healthcare services. The opinion examines the impact on patient consultations, focusing on changes in medical infrastructure, telemedicine adoption, and the overall patient experience. By assessing the effectiveness of these adaptations, the opinion aims to provide insights into the evolving dynamics of healthcare delivery during the pandemic.

The aftermath of the stringent national lockdown in the initial months of 2020 led to significant restrictions on patients' visits to hospitals and clinics, directing those with fever symptoms to designated Fever clinics (8). Access to medical care required Quick Response code (QR code) scanning and a recent, within 72 h, negative polymerase chain reaction (PCR) test. The most significant concern in relation to this screening system was medical access failure that may occur in the case of an emergency, e.g., asthmatic attack (9) or dialysis patients (10). Additionally, some patients who had attended Emergency were required to wait desperately for medications, but were unable to access the medication until their QR code turned into the green color (11).

Primary care access underwent substantial changes due to pandemic-related administrative processes, resulting in over a 25% reduction in patient visits in the first 6 months of 2020. To curb viral transmission, general practitioner (GP) consultations were moved outdoors, utilizing tents to facilitate fresh air circulation (8).

Notably, visits for respiratory issues decreased, likely influenced by measures such as social distancing, mask-wearing, and avoiding gatherings. Patients visiting clinics sought larger prescriptions to minimize frequent visits, while anxiety and depression-related visits increased, possibly linked to the fear of infection and long-term lockdown (8). These data suggest that keep social distancing and/or lockdown provided a useful approach for reducing/minimizing viral transmission among patients and/or the general population.

Subsequently, during the Omicron variant outbreak of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (12), the Shanghai authorities implemented the strictest lockdown measures ever, i.e., nobody was allowed to leave their homes under any circumstances for an entire 2 months (13). As a direct consequence of this lockdown, face-to-face medical consultations were immediately suspended (13). In response to this formidable challenge, GPs were determined to provide seamless care for patients with chronic diseases. For those individuals with comprehensive medical records stored in the hospital's electronic file system (8), GPs initiated telephone consultations to assess their current health status. Urgent cases were directed to designated COVID-19 Hospitals for emergency care. Surprisingly, there was no significant correlation between patient visits and COVID-19 infection rates, indicating the effectiveness of stringent control measures, i.e., maintaining social distance. However, these rigorous measures overlooked the adverse mental health impacts.

The debate over the necessity of extensive restrictions and prolonged lockdowns continues, with a need to weigh the benefits against potential adverse impacts on the wellbeing of Shanghai residents.

Abolition of zero tolerance policy

In the light of the rapid and unstoppable spread of the Omicron variant throughout China, a significant shift in the preventative landscape occurred on December 7, 2022, when Chinese authorities made a noteworthy overnight decision to abolish abruptly the dynamic-zero policy that had been in place for 3 years. This pivotal decision was accompanied by the re-classification of the COVID-19 virus as a category-B infectious pathogen (14), which corresponds to a classification as moderately easy to disseminate; resulting in moderate morbidity and low mortality rates. Furthermore, individuals were actively encouraged to resume normal social activities with the goal of reaching a turning point in the overall level of infections within the community, with the ultimate aim of rapidly reducing the number of acute infectious cases circulating in the community. However, to achieve this objective, essentially the authorities aimed to introduce herd immunity *via* by initially causing rapid and widespread acute infections throughout the community (15).

However, there is a potential issue raised from such an abrupt action. Specifically, what are the consequences of the lack of development of host immunity against SARS-CoV₂ variants during the 3 years of lockdown? Despite the claim that the vaccination rate had reached >90%, in Shanghai patients' visits to hospital

were noted to surge dramatically at the time of the abolition of the COVID-19 zero-tolerance policy, raising lessons for any future response (15). Such findings suggest that people may be better off if they had been offered more effective targeted vaccination, in addition to progressive exposure over time to small amounts SARS-CoV₂ virus, to progressively build some host immunity within the community, *via* the gradual easing of restrictions, e.g. by allowing community activity (shopping, working etc.) while maintaining a suitable level of social distancing and mask use. The dramatic cessation of zero tolerance, incorporating the complete abolition of social distancing policy is arguably not the best approach in dealing with such a challenge.

Ongoing viral mutation and long COVID-19—Maintaining social distancing and mask usage

While WHO has declared an end to the COVID-19 pandemic, the repercussions of COVID-19 persist due to new mutation(s). Subsequently, the mutated virus has been reintroduced into the community. Even though there is no longer a pandemic, it raises the question of whether continued monitoring of this relatively minor virus is necessary for the wellbeing of the older adult and immunocompromised population in China, as has been suggested in Australia (16).

Furthermore, cases of long COVID-19 persist both in China (17) and internationally (18, 19). In addition to immediate symptoms, a significant number of patients experience post-COVID-19 syndrome, commonly known as long COVID (20). Long COVID-19 affects the respiratory (21), neurological (22), cardiovascular (23), muscular (24), and digestive systems, with many documented cases within China. This necessitates substantial and costly therapeutic interventions. Approximately 10% of patients are estimated to experience persistent organ damage following infection with the SARS-CoV-2 virus. The precise underlying mechanism of long COVID-19 is still under investigation, as are the diagnostic and treatment options for this condition. The linkage between social distancing and long-COVID-19 remains to be explored.

Although the use of social distancing and facial masks is no longer a mandatory requirement for Chinese residents, there are still quite a number of people voluntarily wearing facial masks and minimizing their exposure to large gatherings, considering recent cluster outbreaks of respiratory issues over the last few months (25).

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Conclusion

The findings of this study contribute to a comprehensive understanding of how social distancing measures, particularly quarantine, have influenced education outcomes and medical consultations in China during the COVID-19 pandemic. By highlighting challenges and innovative solutions, the research provides future preparedness strategies for similar global health crises, emphasizing the importance of flexibility and technology integration in sustaining essential societal functions. Finally, this opinion prompts consideration of the challenges and strategies in education and healthcare against similar global health crises. Additionally, the psychological effects of prolonged and restricted quarantine on students, educators, and patients should be taken into account in preparation for unforeseen future circumstances.

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COVID-19, new challenges to human safety: a global review

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In the context of sustainable human development, human safety has gradually shifted from traditional state and political conflict to social conflict and horizontal inequality, and the pandemic has exacerbated this variation risk. This narrative review includes literature from 40 countries on five continents since 2020, explored and tidy up the impacts of pandemics on human safety based on three perspectives: personal safety, family safety and social safety, refined the macroscopic concept of human safety. The comprehensibility of the global review conclusions is enhanced by combining it with Maslow's hierarchy of needs. Finally, some novel and comparative results are included to broaden the understanding of the impact of the pandemic, and help policymaker better understand human safety changes from a new perspective.

KEYWORDS

sustainable human safety, safety crack, DV, IPV, crime, COVID-19

1 Introduction

The 1994 Human Development Report state (1): the human safety approach refocused the safety debate from territorial safety to the safety of people. Human safety is about living free from want, free from fear and free from humiliation. It is about protecting what we humans value most in our lives. The United Nations General Assembly (UNGA) reflected a consensus that human safety is “the right of people to live in freedom and dignity, free from poverty and despair. All people, especially the most vulnerable, are entitled to freedom from fear and freedom from want, with equal opportunities to enjoy all their rights and fully develop their human potential.” Recently, the United Nations Development Program, in its Special Report (2022) has shown that humanity is facing increasingly serious multiple and overlapping threats, and exacerbated by pandemic (2).

According to the Special Report (2), the disconnect between human development and safety may be a by-product of pursuing a developmental approach, coupled with the legacy of historical injustices such as colonization, development has not benefited all, and even in some cases has left some groups behind. An approach to development that focuses most of its attention on economic growth, and much less on equitable human development, leads to serious and growing inequalities and puts increasing pressure on the planet. The pandemic exacerbated this incomplete impact. The pandemic has now affected everyone, threatening every dimension of our well-being and creating an acute sense of fear across the globe, combined with rising geopolitical tensions, widening inequalities, democratic backsliding and destructive weather events (linked to climate change), threatens to reverse decades of development gains and further derail progress toward the sustainable development goals. The pandemic has affected almost everyone and has become a full-blown crisis of human safety and development. The most tragic impact has been a global death toll of more than 10 million (excess mortality in 2020–2021). But the impact goes far beyond this harrowing record. Most

countries have experienced acute recessions. And with the outbreak, a growing sense of insafety has taken hold. It is estimated that six out of seven people around the world feel insecure in the years leading up to a pandemic. Not only is this sense of insafety high, but it has also increased in most countries for which data are available, including spikes in some of the countries with the highest human development indexes.

The pandemic highlights the interconnectedness of factors affecting human safety and reveals new cumulative threats to human safety—violent conflict and rising horizontal inequalities (2). At present, the concept of violent conflict is gradually shifting from the traditional political confrontation between states to a people-centered conflict between individuals and societies, encompassing the stabilization of social order and the safety of individuals. For these two main points, this review synthesizes the impact of pandemic on personal health in terms of personal spirituality and life safety. An overview of the impact of pandemic on social order in terms of changes in social crime. In response to the horizontal inequality to human safety, this review focuses on changes in gender inequality during the pandemic. It is noteworthy that the ongoing pandemic seems to have triggered an increase in domestic and social violence (with women and children being the main victims). Conflict and violence may force people to leave their homes, exposing them to further threats.

Based on the above background, this study concludes that human safety requires consideration of overlapping threats and systemic response that adapts to changing circumstances (Figure 1). According to the Maslow's hierarchy of needs, only when the life existence been protected, then will move on to higher safety needs. Thus, in addition to studying the impact that the pandemic have had on human survival (processes A to B in Figure 1), it is important to understand that the human being is a complex synthesis, the pandemic also have far-reaching effects on human safety beyond the need for survival, researchers not only should focus on the most basic human needs, but also on spiritual and a range of other human safety needs that overlap in complexity. Unfortunately, it is clear from the literature cited in this review that while most studies have analyzed the impact of pandemics on suicides, domestic violence, robberies, shootings, and so on, these have been exploratory studies of a single target or a specific group of people; what is lacking is a review that combines these studies with human security research. Therefore, this narrative review aims to provide an overview of the impact of pandemics on human safety in the form of a synthesis and to summarize these non-linearly overlapping safety factors into three main dimensions: personal,

family and social safety (Processes C, D and E in Figure 1) to help us better understand the far-reaching impact of the pandemic and to provide policy makers with a kind of early warning to formulate better adapted policies to address some under-appreciated but highly deserved societal problems.

2 Methods and data synthesis

Given the early stage in the evolving literature on this topic, this review performed a literature search in Pubmed and Web of Science electronic databases up to 31 May 2023 using “COVID-19” as the primary keyword, “violence,” “crime,” “depression,” “anxiety” and “suicide” as secondary keywords, and the reference lists of the selected literature were reviewed. Then 308 publications were identified by deleting the same. Based on this, the author performed a comprehensive reading to these literature, and screened them according to the following inclusion criteria: (1) the study need to include explicit positive or negative perspectives; (2) the literature need to include a variety of country and research target; (3) the focus of the studies should be on COVID-19-related impacts; (4) the research target need to be representative a group, community, or country. A study was excluded if it (1) used mainly qualitative methods and had neutral conclusions, (2) mainly modeling or methodological innovations without focusing on practical impacts. Ultimately, based on the above criteria, the author assessed all 308 publications, and evaluated the authority of these publishers empirically, a total of 94 full publications were selected to include in this narrative review.

3 Results

Based on the literature, it is known that the human safety challenges resulting from COVID-19 were found to be intricate, and it's involved almost every continent (Table 1). In order to provide the reader with a better understanding of such intricate issues, this study categorizes such issues into three categories: personal security, family security and social security, a categorization that has the advantage of making the macro-concept of human security more nuanced and easier to understand. Personal safety focuses primarily on individuals, outlining changes in both psychiatric and life during the pandemic, identifies trends in the fluctuation of these changes over time, highlights which populations are most affected, and reveals gender

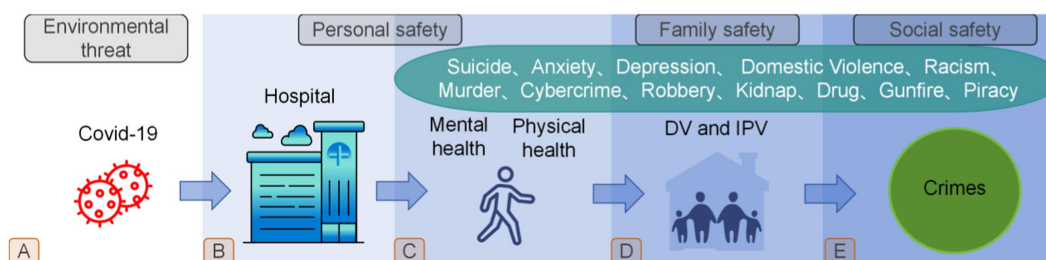


FIGURE 1
New human safety challenges due to COVID-19.

TABLE 1 Human safety issues arising from the pandemic.

Continent	Nation	COVID-19 caused safety issue	References
America	Canada, United States, Trinidad and Tobago, Colombia, Peru, Mexico, Brazil	Depression and anxiety, Youth suicide, IPV, Societal crime, Gun violence, Robberies, Kidnappings, Homicides, Organized crime, Shootings, Racial discrimination	(3–17)
Europe	Germany, Hungary, Poland, Croatia, Austria, Sweden, Lithuania, Spain, France, Denmark, United Kingdom, Belgium, Turkey, Norway, England, Wales	Anxiety and depression, Suicide, Young female suicide, IPV, DV, Homicide, Drugs, Cybercrime, Hacking	(18–40)
Asia	South Korea, Bangladesh, Japan, Nepal, Russia, Palestine, Iraq, Jordan, Israel	Depression and anxiety, Suicidal ideation, Youth suicide, Domestic violence, Sexual assault, Violence against women, Violent crime, Property crime, Drug trafficking	(41–62)
Africa	Nigeria, Tunisia, Uganda, Kenya, Malawi, Zimbabwe	Mental health, Youth vulnerability, Women's aggression, IPV, Night-time crime, Illicit drugs, piracy incidents, Racial discrimination	(63–71)
Oceania	Australia, New Zealand	Suicide, Domestic violence	(72–74)

differences. Family safety is formed on the basis of personal safety, mainly to show what happens when two different safety factors are combined, and whether personal safety is strengthened or challenged? Social safety, is an interconnected system of individual and family, although family safety constitutes the vast majority of social safety. However, the possibility that individuals may be separated from their families and pose a threat to social safety cannot be ignored. Therefore, the social safety are synthesized into a combination of individual and family safety, which points to a larger human safety structure.

3.1 Personal safety

The most direct damage to mankind from the pandemic is the biological attack on each individual (devastation the human immune system), which is a physical damage. However, man is an emotional being with an independent consciousness, and the need for mental safety cannot be ignored. In addition to the severe physical damage that the pandemic has inflicted on the human body, it has also had an even more severe long-term negative impact on the human spiritual world. The pandemic erosion to the human spirituality has increased the mental health crisis globally, and this erosion has seriously affected human behavior and increased suicidal ideation among individuals, especially among vulnerable groups: young people and women.

3.1.1 Mental safety

Evidence suggests that personal safety concerns due to mental disorders will be the leading cause of global health-related burden by 2020, with depression and anxiety disorders being the primary manifestations (75). The emergence of the pandemic has created an environment that exacerbates many of the determinants of poor mental health. In a study examining the impact of the pandemic on the prevalence and burden of major depression and anxiety disorders worldwide in 2020, researchers found that the greatest increase in the prevalence of major depression and anxiety disorders in 2020 would occur in the regions most affected by the pandemic. The study estimated a 27.6% increase in cases of major depression, and a 25.6% increase in cases of anxiety disorders worldwide as a result of the

pandemic. Of these, women were more likely to be affected by the pandemic than men, and younger people were more likely to be affected than older people (76). These trends have similarities in the Americas, Europe and Asia. For example, In Canada, researchers assessed depression and anxiety in 1,412 non-clinical adults from October 2018 to April 2022 (three pre-epidemic and seven post-epidemic) and found that depression and anxiety showed significant changes during the epidemic, with significant increases in depression and anxiety early in the epidemic (3). An assessment of levels and longitudinal changes in fear, anxiety, and depressive symptoms among 6,551 adults in Germany during the epidemic found that fear, anxiety, and depressive symptoms were significantly higher during the epidemic and that people with pre-existing anxiety, depression, and other psychiatric disorders were more vulnerable to exacerbated effects (18). A large online survey ($n = 1,000$) was conducted from 4 to 11 June in South Korea 2020. A series of regression analyses showed that depression was negatively associated with support for 'everyday distance policies and stronger social distance policies' (41). The prevalence of depression and anxiety after the pandemic is significantly higher than the 2.6 and 2.8% rates of depression reported in the Korean Community Health Survey in 2020 and 2018, respectively, and the 5.7% rate of anxiety reported in the Korean Mental Illness Survey in 2016 (42).

3.1.2 Life safety

The impact of the COVID-19 pandemic on psychological and mental health could be far-reaching, and there also has some evidences that it is likely to lead to an increase in suicide rates, although this is not inevitable. As the epidemic spreads, suicide may become a more pressing issue. The rate of suicidal ideation during the pandemic is higher than that reported in studies of the general population before the pandemic, and may lead to higher suicide rates in the future (77). Suicide rates among survivors may increase during and after the pandemic, including mental health crises, which may last longer and peak later than the actual pandemic (78). In Bangladesh and Nepal, prevalence of suicidal ideation increases with the pandemic, with the effects lasting longer for women (43, 44). The economic environment of a country can play a determining role in medical assistance and social welfare, the better the social

environment, the lower of exposure to life-safety threats. However, this is not absolute, suicide trends similar to those in underdeveloped countries have been observed in some developed countries during pandemics. From 2010 to 2019, the suicide mortality rate in Hungary decreased steadily, but this trend changed after the epidemic, with a significant increase in the suicide mortality rate in the post-epidemic period compared to the pre-epidemic trend: an overall increase of 16.7% (19). Compared to the average number of deaths in 2017–2019, the number of deaths in Poland in 2021 increased by 26.86%, with a higher increase in attempted suicides (20). In Croatia, the number of suicides increased significantly at the beginning of the epidemic in February 2020, with significantly more suicides recorded among married and unemployed people compared to the same period in 2019 (21). The Austrian government issued a blockade order from 16 March to 15 May 2020, and its strict measures may have had a serious impact on people's mental health, leading to an increase in suicide attempts during the blockade period (22). In Japan, the suicide rate is highest in October 2020 (45). In the first 5 months of the epidemic (February to June 2020), the monthly suicide rate fell by 14%, which may be due to a number of complex reasons, including generous government subsidies, reduced working hours and school closures. In contrast, during the second wave (July to October 2020), the monthly suicide rate increased by 16%, with larger increases among women (37%) and adolescents (49%) (46).

Studies have shown that unemployment is one of the main reasons for the increase in suicide rates during the epidemic. In an experiment, the researchers predicted that a loss of 24.7 million jobs in the high scenario and 5.3 million jobs in the low scenario. In the high scenario, the global unemployment rate would increase from 4.936% to 5.644%, which would be associated with an increase in suicides of about 9,570 per year. In the low scenario, unemployment would rise to 5.088%, associated with an increase of about 2,135 suicides (79). In Sweden, researchers conducted a health survey of 1,558 people between February 2021 and February 2022 and found that unemployment and layoffs during the pandemic led to varying degrees of depression and anxiety, which are important mental safety factors that contribute to individual suicides (23). Factors that undoubtedly contributed to the increase in suicides during the epidemic also include a wide range of possibilities, and according to the study, in Lithuania and Poland (2,459 participants, 57.2% of respondents were female), the main factors for female suicides during the pandemic included a high level of environmental adaptation and loneliness, these factors are significantly correlated with suicidal tendencies (24).

3.1.3 Teenagers show more vulnerability

The pandemic has had a significant impact on the mental health of teenagers, who are likely to be the group that suffers more during the epidemic. Suicidal behavior among adolescents increased by 35% during the pandemic, and suicide rates rose after an initial stabilization (80). Overall, the pandemic had a limited short-term effect on suicidal intention, but young people were more likely to report more severe suicidal ideation during the epidemic (81). Spanish researchers find significant increase in hospital admissions for suicidal behavior in adolescents during epidemic (25). Suicide is the leading cause of death among adolescents in the United States, and a proportion of young people have been significantly affected by the pandemic, leading to evidence of an increased risk of adolescent suicide (4). In Canada, students most at risk of suicide are those who are emotionally overwhelmed by the pandemic and unable to seek help (5). An online

survey (including 509 Israeli citizens) shows that pandemic-related heart health complications are more common among the older adult, but that COVID-19 is also having a profound impact on the younger population (47). Using data from 1,109,776 Korean adolescents aged 13 to 18 years from the Korean Youth Risk Behavior Network Survey from 2005 to 2021 (for a nationwide series of cross-sectional surveys), found that during the pandemic period: sadness increased from 25.0% in 2020 to 26.6% in 2021, and the suicide rate: increased from 10.7% to 12.5% in 2021 (48). The study found that pandemics exacerbate the risk of suicide among adolescents through an online survey of 536 male and female students (age 21.46 ± 2.95 years) at Russian universities (49).

3.1.4 Gender difference

During the pandemic, women suicide rates were higher than men, and were associated with depression, schizophrenia, alcoholism and other mental disorders. In Israel, the pandemic caused high levels of psychological distress in the general population. Observations of 587 participants showed that the mental health status of men and women in the general population in Israel was very different during the first blockade, with men and women likely to have different vulnerabilities to disaster-related stressors (such as those experienced during the pandemic), with younger women reporting more mental health problems (50). In assessing the range of psychopathological symptoms (anxiety, stress, depression, burnout) and their risk factors among frontline healthcare workers during the pandemic in the Russian Federation, the researchers found that the main factors contributing to the risk of psychopathology included: female and youth (51). A study of depression and anxiety symptoms during the pandemic in Australia found that younger age and being female were significantly associated with higher depression and anxiety scores (72). In France, there has been a significant increase in female suicide attempts since January 2021. Adolescent girls seem to be the most affected (26). In Korea, the total number of suicides during the pandemic did not differ from projections based on the pre-pandemic period. However, the number of suicides among women and women under 34 years of age was much higher than expected. The pandemic significantly increased suicides among women and young people (52). In Japan, compared to the average suicide rate from 2018 to 2019, the increase in women's suicide rates increased more than men's, with women experiencing the largest increase in October 2020, and people under 30 doing worse during the epidemic (53). It is worth noting that while women are more at risk of suicide overall, in some countries men may be more vulnerable. The suicide rates among Japanese men in 2020 increased in October and November compared to previous years (54). Suicide rates increased in India in the first year of the pandemic, with male suicides increasing most in 2020 compared to previous years (55). However, in Denmark, contrary to the rise in suicides is the proportion of self-inflicted injuries decreased for both women and men after the pandemic, but the decrease for men was smaller than that for women: 5.7% for women and 3.2% for men (27).

3.2 Family safety

While pandemic are a major global health threat, another global public health emergency—Domestic Violence (DV)—is becoming a growing challenge. Since the implementation of pandemic-related

lockdown and physical distance, there has been a significant increase in cases of domestic violence globally. The pandemic poses a threat to the mental and life safety of individuals, who in turn transfer this threat to human safety, of which family safety is one. Policies such as curfews, lockdowns and restrictions during pandemics have resulted in people staying at home for longer periods of time than in the past, which, coupled with pandemic-induced job loss, perceived stress, and alcohol abuse, ultimately lead to the amplification of unstable relationships among family members and an increase in family safety issues.

3.2.1 Domestic violence

An editorial published in *BMJ* in May 2020 discusses how the pandemic has amplified the rising incidence of domestic violence globally in two ways, and how the failure of health systems to respond adequately to domestic violence and abuse is a violation of human rights, compromising the health and well-being of survivors and their families. And it notes that while both men and women are affected, the incidence and severity is much higher in women (82). In Australia, a team of researchers from the Justice Centre at Queensland University of Technology (QUT) conducted a national survey which confirmed that the embargo is increasing the prevalence of domestic violence in Australia and around the world, based on survey data from 362 participants from the DFV sector (73). A survey of 602 married or cohabiting adult citizens of Trinidad and Tobago found an increase in perpetration of domestic violence (13%) and an increase in victimization of domestic violence (16%). The findings also indicated that males (17%) and females (13%) in the sample were more likely to be perpetrators of domestic violence, while males (25%) and females (12%) were more likely to be victims of domestic violence (6).

3.2.2 Intimate partner violence

Domestic violence is a global public health problem that negatively affects physical and mental health, and intimate partner violence (IPV) is one of the most common forms. The pandemic contributed to an increase in the incidence and severity of IPV worldwide. Public health restrictions during the pandemic led to an increase in time spent at home with partners and a related increase in incidents of IPV, as evidenced by an increase in calls to hotlines and contact with other support services (83). European member states of the World Health Organization reported a 60% increase in emergency calls from women whose intimate partners had been violent during the pandemic. There was also a fivefold increase in the number of people accessing online violence prevention support lines, compared to the same period last year (84). A 23.38% increase in the incidence of IPV during the 3-month period of the Spanish blockade as a result of the pandemic (28). Palestinian men tend to show their vulnerability during pandemic outbreaks, leading to serious changes in the situation of domestic violence (56). India, significant increase in cases of domestic violence during the pandemic compared to previous years, higher morbidity in the early stages of the epidemic, pandemic affects women more severely than before (57). The number of victims of intimate partner violence in the US is on the rise from December 2019 to March 2022 (7). The types of intimate partner violence (IPV) victimization in the early stages of the US pandemic were primarily physical and sexual violence (8). During the pandemic, the level of violence against women in Spain has increased. In situations of incarceration, it is necessary to develop measures to protect women

who lack social support and who live with the perpetrators of violence (29). During the UK COVID-19 blockade, the number of people seeking help for domestic violence (DV) and homicide increased. In addition, the blockade reduced opportunities for DV detection and disclosure through the suspension and remote provision of clinical services, continuing healthcare and other support services (30).

3.2.3 Why family safety is exacerbated?

The strongest risk marker for IPV perpetration was loneliness, followed by anxiety symptoms, perceived stress, fear, boredom, substance use and lifestyle changes (85). Studies in Belgium have shown that victims of violence are more likely to be dissatisfied with their social interactions, and their weak social support and low trust in health services may lead to more incidents of violence during the pandemic (31). In the United States, a social survey of 13,597 female participants found that IPV experience was associated with poorer sleep quality, shorter sleep duration, and increased alcohol consumption, and that IPV experience at the onset of the pandemic was associated with more severe mental health symptoms and modifiable health factors in female participants under the age of 60 (9). IPV is significantly associated with unemployment, women who do not work and whose partners do not work have higher levels of emotional violence during the pandemic in Turkey (32, 33). In India, unemployment motivates domestic violence perpetrators during restrictions (58). And there are studies showing that the end of the embargo does not necessarily mean a rapid decline in IPV. The incidence of IPV may have increased as a result of the economic fallout. This is particularly worrying as economic stress increases most types of IPV. Particular attention should be paid to couples who have not been exposed to violence before, who have children and who are of lower socio-economic status, as these couples are most affected (86).

3.2.4 Women and children suffer more

During the pandemic, stay-at-home policies were implemented worldwide. However, there is growing concern that such policies may increase violence against women. Domestic violence, including intimate partner violence, is a pandemic that occurred in conjunction with COVID-19. During the pandemic, a large percentage of women who experienced partner violence had to live with their abusers. The incidence of domestic violence is rising rapidly, particularly affecting women and children.

In Nigeria, the conditions of the pandemic blockade not only create opportunities for motivated perpetrators, but also increase women's vulnerability to sexual victimization (63). And the prevalence of IPV was 57.5% in women compared to 42.5% in men, and IPV was significantly associated with younger age (64). In Colombia, recent statistics on domestic violence highlight the need to reorganize the national public health system and adopt effective strategies and emergency plans to mitigate the impact of COVID-19 on the mental health of women and children throughout the country (10). In Peru, where a strict nationwide blockade has been in place since mid-March, nearly 60% of women had experienced violence prior to COVID-19. Using telephone administrative data, researchers found that the incidence of calls to a domestic violence helpline increased by 48% between April and July 2020, with the impact increasing over time (11). A Belgian study on domestic violence found a significant increase in the incidence of psychological aggression among women during the epidemic (34). In Tunisia, violence against women increased

significantly during the blockade (from 4.4% to 14.8%), with psychological abuse being the most common form of violence (96%). The vast majority of those who experienced violence during the blockade did not seek help, and women who were abused before the blockade were at increased risk of violence (65). In Turkey, the pandemic process increases women's vulnerability to intimate partner violence (IPV), and as the frequency of IPV increases, women's perceptions of stress also increase (35). In Iraq, there has been a significant increase in the humiliation, forced sexual intercourse and intimidation of women during the blockade (59). Violence against women in Jordan during COVID-19 was as high as 40%, with unemployment as the main predictor (60). According to data, the risk of and vulnerability to violence against women and girls in Uganda has increased significantly since the outbreak of the pandemic (66). Pandemic mitigation measures such as curfews, lockdowns and movement restrictions can be effective in reducing the spread of epidemics. However, they can also lead to sexual violence. Using data from the Kenya Health Information System and various time-series methods to model the unintended consequences of pandemic mitigation measures on trends in sexual violence in Kenya, researchers found that model-dependent increases in reported sexual violence ranged from 73% to 122%, mainly among 10 to 17-year-olds (67).

Fortunately, some countries have begun to pay attention to this problem and have taken effective measures. For example, in Japan, four phone lines across the country will be open 24h a day, and the Cabinet Office will continue to allocate \$3.6 million for domestic violence counseling during the pandemic (87). As pandemic preparedness activities increased the incidence of intimate partner violence (IPV) and negatively affected access to health and legal systems, this indirectly contributed to the establishment of IPV services in Kenya and Malawi, enabling a significant proportion of the population to access IPV services during the pandemic (68). During the pandemic, the New Zealand government provided housing for women experiencing domestic violence in New South Wales to help them escape domestic violence (74).

3.3 Social safety

Pandemics pose a threat to the mental and life safety of individuals, who in turn transfer this threat to human safety, with family safety being one scenario and social safety another. In this review, the impact of pandemic on social safety mainly includes assaults, thefts, burglaries, robberies, car thefts, homicides, gun violence, drug trafficking, racism, cybercrime, piracy incidents and so on. In social safety, pandemic-induced victimization extends from individuals and families to social members, with a wider range of impacts and diverse manifestations.

3.3.1 Conflicting crime trends

Governments adopt strict social bans during the pandemic, which hindered the spread of the virus while also restricting people's freedom of movement, and indirectly, had an impact on human crimes. Common sense would suggest that the pandemic's contribution to the decline in crimes is inevitable (the macro data also proves it), for example, social bans impose strict street control and require people to stay at home, which prevents criminal behavior and thus reduces social crimes. However, as mentioned above, human safety is multiple, overlapping and interconnected, the review found

that in terms of micro-evidence, the trend of pandemics leading to a decrease in crime rates did not apply in all cases, but rather that specific types of crime increased during pandemics.

3.3.2 Decreased crime

Fear of the dangers posed by the virus has made people more cautious about going out, and this, combined with a home policy that reduces the environmental opportunities for crime, has contributed to a downward trend in the general crime rate and a significant increase in people's sense of social safety. Using police data on daily crime counts, Nivette and colleagues (88) examined the impact of stay-at-home restrictions on assaults, thefts, burglaries, robberies, car thefts and homicides in 27 cities in 23 countries in the Americas, Europe, the Middle East and Asia. The main conclusion was that global crime rates fell by 37% after governments introduced curfew restrictions. An estimate of the impact of pandemic outbreaks on crime, based on data from 25 major US cities, found that Pittsburgh, New York, San Francisco, Philadelphia, Washington, D.C. and Chicago saw crime rates fall by at least 35% (12). In Japan, the 2020 pandemic resulted in a 12.7 and 20.9% reduction in the victimization rates per 100,000 population for violent and property crime, respectively. The researchers also found that intentional crimes, such as burglary and sexual assault, declined more than non-intentional crimes, such as homicide (61). A study examining the impact of curfews on female homicides in Turkey found that the probability of a woman being killed by an intimate partner fell by around 57% during strict social distance, and by 83.8% during curfews, compared to the same period in 2014–2019 (36).

3.3.3 Increased crime

Stay-at-home restrictions are associated with significant reductions in crime rates, but there is wide variation across cities and types of crime. Gun violence in the United States increased by 30% from pre-pandemic levels in 2020–2021 (13). The recent surge in gun sales during the pandemic has been accompanied by a sustained increase in shootings, injuries, fatalities in the period after the pandemic reopened compared to historical years. Gun violence, injuries and deaths increased after the pandemic reopened. In addition, mass shootings increased despite the relative calm initially brought about by the pandemic. This suggests that the "re-opening" exacerbated an already serious national gun epidemic (89). Although crimes related to domestic violence, burglary and car theft fell dramatically in Mexico during the pandemic, crimes related to robbery, kidnapping and homicide were unaffected and organized crime remained stable (14). In Brazil, extortion, theft and robbery fell by at least 41.6% after the pandemic. However, the researchers found no change in organized crime (15). Where there is evidence that nighttime crime rises, and strict measures in the wake of the pandemic may also have led to an increase in piracy incidents in Nigeria (69, 90). In Norway, restrictions and bans on alcohol consumption reduced crime during the pandemic, but when bars were told not to sell alcohol after midnight, there appeared to be an unexpected increase in crime (37). The frequency of total arrests for illicit drug trafficking in Bangladesh showed a sharp upward trend and was 75% higher than expected during the pandemic (62). Sweden, significant falls in total, assault, pickpocketing and burglary, but no change in drug offenses (91). In Canada, all types of crime changed significantly during the pandemic compared to metropolitan areas, with increased crime rates varying across neighborhoods (92). In England and Wales, researchers found that crime in most small areas remained stable throughout the epidemic (38).

The young generation appears to have been involved in more crime during the pandemic. Evidence suggests that pandemic leads to a significant increase in the number of shootings involving young people in the United States 2020 (16). Shootings vary by population. Preschool exposure was lowest for white children and highest for black children (who were 4.44 times more exposed to neighborhood gun violence than white children). The pandemic increased exposure by 27% among the lowest risk population (i.e., white children), but the impact of the pandemic was greater for almost all non-white children. Baseline levels of violence and racial disparities varied widely by region, with the highest levels in the South. There were large racial disparities in children's exposure to neighborhood gun violence, and these disparities widened during the pandemic (93). Zimbabwe has experienced a dramatic increase in the use of illicit drugs during the pandemic, and of particular concern is the upward trend in the use of drug substances among young people (94). Evidence points to a significant increase in the rate of juvenile property-related crime in Israel during the blockade period, compared to other periods (70).

Racism has always plagued human solidarity, and the pandemic has worsened this division. In the United States, the conditions created by the pandemic have exacerbated existing inequalities in communities of color, putting them at risk of violence. Racism against people of Asian descent increased by more than 300% after the pandemic, with one in five Asian Americans reporting a direct experience of overt discrimination, and it has been an important factor in the psychological distress and suicidal tendencies of Asian and Asian American students (17, 95). A large proportion of the Ugandan population were victims of discrimination during the pandemic, most at the hands of law enforcement officials (71).

Stay-at-home policy have prompted people to rely on the Internet more than ever before, which indirectly facilitates cybercrimes. Disruptions to people's real-life patterns can affect cybercrime levels, with blocking measures helping to reduce opportunities for predatory crime in physical spaces, while at the same time people are spending more time connected to the internet, which can lead to increased opportunities for cybercrime. For example, in the UK, growth in both total cybercrime and total fraud has exceeded predicted levels. Particularly online shopping and auction fraud, and social media and email hacking (the two most common types of UK cybercrime) (39, 40).

4 Future trends

With the development of human society, human safety is becoming increasingly interconnected, and the impact of pandemic deepens the multidimensional uncertainty of human safety. As an obstacle to social development, the pandemic not only poses an immediate threat to individual safety, but also deals a severe blow to the safety of families and society. The pandemic has deepened the fissures of existing human safety and opened up new abysses. In order to address these threats, humanity needs to be more united. In particular, it is necessary to strengthen the extension research in the following aspects.

4.1 Human needs

When the concept of human safety is combined with Maslow's hierarchy of needs, it may be possible to better explain the changes in

human safety that occurred during the pandemic. In Maslow's hierarchy of needs, human needs are divided into physiological (basic survival needs), safety (social and occupational safety), social, esteem and self-actualization needs (96). Maslow's model suggests that in order to achieve higher-level goals (e.g., love and belonging, respect, and self-actualization needs), individuals must first address life-safety needs and then higher-level needs. This review believes that the pandemic embargo policy is undermining human safety needs, such as personal safety, which is suffering both mentally and physically, the disruption of family cohesion, and the increase in certain types of societal crime, which are included in Maslow's hierarchy of human needs, such as safety, love, respect, and self-actualization, by incorporating Maslow's model, it can help reveal the deeper phenomena in global human safety crises such as COVID-19. It's important to understand that Maslow's model is not linear and monolithic, policy makers need to consider not only the impact of the pandemic on human physiological needs (human survival during a public health event), but also incorporate safety, love, respect and self-actualization into the policy model to address the COVID-19-related crisis, or else unnecessary and long-term social harm and instability will result.

4.2 Women's insafety

Gender differences show that women suffered more during pandemic. The pandemic increased women's vulnerability. The human needs, such as safety, respect, love and self-fulfillment were reduced during the pandemic. It is worth noting that apart from the fact that there are few gender differences in the impact of pandemic on human survival (virus infection), women are likely to have suffered more after the pandemic globally. First, the pandemic exacerbated women's exposure to family and society injustice, however, women were already more vulnerable before the pandemic. Second, men in most countries showed greater vulnerability during the pandemic (that is strangely similar in developed, developing and underdeveloped countries), and men are transferred this vulnerability to women, deepened the scars in the household. Finally, if women do not receive targeted care from society, their vulnerability may be passed on to the next generation, as they have greater social, legal and moral responsibility as the main actors in the education of the next generation.

4.3 Human resilience

The direct impact of pandemics on human safety has been dramatically reduced as global health cooperation, and public health researchers have made significant advances in this area, providing a foundation for future human safety. However, the impact of a pandemic on people's mental, family and social health is likely to be a far-reaching and long-lasting process that will require interdisciplinary research and deeper pioneering by researchers to build human resilience. In particular, by using interdisciplinary approaches to understand the complex mechanisms underlying human resilience, by using advanced technologies to develop scalable and effective interventions. For example, developing resilience interventions for target populations, environments and socio-cultural contexts. To achieve this, we need to take an interdisciplinary view of human

resilience development and take initiatives to increase resilience recovery across multiple dimensions of human safety. Concerted efforts are needed not only in the short term to respond to emerging challenges (e.g., COVID-19 pandemic), but also in the long term to strengthen pandemic preparedness, improve mental health and promote social cohesion (96).

5 Discussion

This review found the increase in suicide during pandemic is a global trend. Whether in developed countries such as Hungary or in developing countries such as Bangladesh, there is a clear upward trend in suicide rates (19, 43). While better social policies in developed countries may slow the rise in suicide rates in the short term, but in the long term, the upward trend is irreversible. The evidence from Japan and Nepal (44, 46) shows that the significant increase in suicide rates following the pandemic occurred at roughly the same time in both developed and underdeveloped countries (July, August, September 2020). In terms of gender differences, there is evidence of an upward trend in male suicide rates in India in 2020 (55), and a downward trend in male self-inflicted injuries in Denmark (27). While overall global crime declined during the pandemic (12), there is additional evidence that this finding is not universal. For example, there was a significant increase in gun crime in the United States (13), signs of an increase in piracy in Nigeria (90), and a sharp upward trend in the overall frequency of arrests for illicit drug trafficking in Bangladesh (62). It is also important to note that inequality and discrimination are pervasive social problems around the world. A study in Uganda found that a large proportion of the Ugandan population experienced discrimination during the pandemic (71), which may be due to the low level of education *per capita* in underdeveloped countries. But the truth is that the pandemic is also exacerbating inequalities between people of color in developed countries such as the United States (17, 95).

Human safety was hard hit during the epidemic. This impact is not only seen in the safety of human life (life-threatening), but also in the greater negative impact on human psychology. During the pandemic, individuals are not only exposed to viral aggression in their biological systems (which in most cases is innate), but also face significant challenges to their mental endurance and psychological resilience (which in most cases is nurtured). During the pandemic, household safety vulnerabilities may be an indirect consequence of personal safety challenges. According to the World Health Organization that household safety risk was destabilized before the pandemic, and as the pandemic spread, the fissures in safety caused by this risk widened (75). The concept of societal safety is shaped by the combination of human actions and linkages, and when individual actions and linkages are threatened, the societal safety architecture is destabilized (2). Furthermore, as the operational structure of a society changes, new safety threats may emerge.

Some interesting contrasts were found in the study, while journal such as *Nature Human Behaviour* (NHB) has published findings on the decline in global crimes during COVID-19 (88), there are also findings in journal such as *The BMJ* that suggest that pandemics instead promote certain types of crime (13). In addition, both authoritative and individual studies have highlighted the contribution of pandemics to human depression and anxiety, and that impacts on the mental level can lead to life-threatening behaviors. Most studies

have highlighted that more victims of pandemic spin-offs are likely to be adolescents and women, and have analyzed the causes of such effects, but there has been a lack of in-depth research on mitigation and prevention, which could be a focus for future research in this area.

6 Limitations

This narrative review has several limitations. First, generalized descriptions of the impact of the pandemic on the areas of personal safety, family safety, and social safety were limited to the literature cited in the articles (only 40 countries were included). Second, although the review included mainstream literature in relevant areas after the pandemic, the cited literature was not screened according to the quality of the studies and reporting mechanisms, and the screening process incorporated the subjective judgment of the author, which can be biased, that is also unavoidable in review studies (97). Then, after the pandemic, the author did not compare this review with similar reviews to highlight the strengths and weaknesses due to the lack of relevant literature in this area. In addition, when combined with Maslow's hierarchy of needs, the focus of this review is on higher human safety needs other than survival, so the literature related to the survival safety is not included in the topic of new challenges to human security.

7 Conclusion

Based on this review, it may be concluded that COVID-19 exacerbated human safety threats and rift, individual insafety ultimately leads to more serious social insafety. While societal crime rates show a downward trend during the pandemic, however, specific types of crime, such as drugs, firearms and organized crimes, increased. Pandemics provide a fertile breeding ground for domestic violence, which indirectly contributes to the attention given to the family safety. Women and children show more vulnerability to global disasters. In addition, COVID-19 exacerbates discrimination and suicidal behaviors globally. The aim of this review is to understand the changes in human safety during the pandemic through a global review, to increase the comprehensibility of the concept of human safety, to draw attention to the invisible impacts of the pandemic, and to increase the focus of future research on higher-level safety needs beyond the need for survival.

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Behavioral decision-making of government, agricultural product producers, and consumers on agricultural product quality and safety regulation in a digital environment

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The quality and safety of agricultural products are related to people's lives and health, economic development, and social stability, and have always been a hot issue of concern to the government and society. The rapid development of digital traceability technology in the digital environment has brought new opportunities for the supervision of agricultural product quality and safety, but the frequent occurrence of agricultural product safety incidents in recent years has exposed many problems such as the lack of governmental supervision, unstandardized production process of enterprises, and weak consumer awareness. To improve the cooperation efficiency of stakeholders and ensure the quality and safety of agricultural products, this paper proposes a dynamic model based on evolutionary game theory. The model incorporates the government, agricultural product producers, and farmers, and evaluates the stability and effectiveness of the system under different circumstances. The results of the study show that there are multiple evolutionary stabilization strategies in the tripartite evolutionary game model of agricultural product quality and safety supervision, and there are corresponding evolutionary stabilization conditions. There are several factors affecting the stability of the system, the most important of which are government regulation, severe penalties for agricultural product producers, and incentives. When these factors reach a certain threshold, the stakeholder cooperation mechanism can establish an evolutionarily stable strategy. This study contributes to the understanding of the operational mechanism of stakeholder cooperation in agricultural product quality and safety regulation in the digital environment and provides decision support and policy recommendations for stakeholders to promote the sustainable development and optimization of agricultural product quality and safety regulation.

KEYWORDS

agricultural product quality and safety, digital traceability system, quality and safety supervision, game evolution, public health

1 Introduction

The quality and safety of agricultural products are the foundation of food quality and safety, which is related to people's health and life safety, and has a bearing on farmers' income increase and the high-quality development of agriculture and rural areas (1, 2). Ensuring the quality and safety of agricultural products has become an important challenge as the demand

for agricultural products increases year after year with the growing population and accelerated urbanization (3, 4). With the continuous progress of science and technology and the popularization of information technology, digital technology has brought new opportunities for supervising agricultural quality and safety (5), such as real-time monitoring and collection of agricultural product quality data, and agricultural product quality traceability based on blockchain. However, there have been frequent incidents of quality and safety of all kinds of agricultural products (6, 7), such as the “stale grain” incident, the “Sudan red incident” (8), the “malachite green incident,” the “artificial honey” incident in Wuhan, Hubei, and other places, and so on. These events have exposed that digital traceability technology has not been effectively used in the supervision of agricultural product quality and safety, and how to apply digital technology to the supervision of agricultural product quality and safety has become an urgent problem to be solved (9).

The process of monitoring the quality and safety of agricultural products involves the government, agricultural production enterprises, consumers, and other multi-interested parties (10, 11). Scholars at China and abroad have conducted some studies on the roles played by various subjects in the supervision of agricultural product quality and safety. The government plays a leading role in the process of regulating the quality and safety of agricultural products and is involved in the complete industrial chain of agricultural products from field to table (12, 13). Teng et al. (14) argue that effective government regulation can promote farmers’ green production behavior. According to Bhatt, the regulation of agricultural product trading has gradually tended to be government-led (15), with coordinated social supervision covering the media, consumers, the general public, and even farmers and enterprises. Agricultural production enterprises, as important providers of agricultural products, also play an important role in the management of agricultural product quality and safety (16, 17). Enterprises, as a fit between business and information flows, have different advantages in food safety and quality control practices (18). Lezoche et al. (19) believe that the core enterprises of the agricultural supply chain have an important position in the agricultural supply chain, can influence other members of the supply chain to maintain a dynamic cooperation mechanism, and play an important role in quality and safety management (20). Consumers, as direct stakeholders (21), have become important participants in the supervision of agricultural product quality and safety (22). Introducing consumer participation in governance and giving full play to the power of consumer groups can effectively alleviate the problem of insufficient regulatory resources and help eliminate regulatory blind spots, which is an inevitable choice for social co-governance of food safety (23).

Traceability is vital in food quality and safety management (24). With the deep integration of digital technologies such as the Internet of Things, big data, cloud computing, blockchain, and other digital technologies with intelligent agriculture (2, 25), the digital agricultural product traceability system provides a new way of thinking for the supervision of agricultural product quality and safety (26). Consumers are also more inclined to buy traceable produce (21). Establishing the digital agricultural product traceability system requires the joint participation of the government, agricultural product producers, processors, inspection and certification organizations, consumers and other main bodies, which is indispensable.

An evolutionary game model is a mathematical model that uses the principles of evolution and the framework of game theory to study the interactions between individuals in a biological population (27). The model aims to explore how the frequency of different types of individuals in a population changes over time and how this change is affected by interactions between individuals and environmental influences (28, 29). Evolutionary game models are often used by scholars to discuss the interrelationships between the three parties in an interaction. For example, in environmental monitoring, Encarnação et al. (30) develop a new framework based on evolutionary game theory, envisioning that the state, business and civil sectors are faced with the dilemma of deciding between maintaining the status quo or shifting to a new paradigm, and the results show that public intervention is essential for shifting to a new paradigm, and that synergies between the private and civil sector are an important step in supporting the paradigm shift. In Healthcare Investing, Alalawi et al. (31) provide a theoretical and simulation analysis of healthcare business models involving Public Healthcare Providers, Private Healthcare Providers and Patients, contributing to the modeling of the healthcare economy by analyzing the dynamics of agents and the emergence of collaborative behaviors in the three populations. Bova et al. (32) use evolutionary game models to explore the role governments can play in building regulatory markets for AI systems to prevent reckless behavior. So it can be concluded from previous studies that the evolutionary game model can help us analyze the conflict of interest and cooperation between different stakeholders (33). In our research, the field of agricultural product quality and safety supervision involves multiple stakeholders (34), and the evolutionary game model helps to reveal the complex game relationship among them. Simulating the strategy selection and decision-making process of each participant helps to optimize the regulatory system and improve the quality and safety of agricultural products (35). In the regulation of agricultural product quality and safety, information asymmetry often leads to increased difficulty in regulation, and the dynamic process of information transfer and gaming can be better understood using evolutionary game models (36). The evolutionary game model can predict the behavioral evolution paths of different players in different contexts (37), which helps to formulate more effective regulatory strategies and countermeasures and improve regulatory effectiveness quality and safety levels.

Therefore, scholars have widely used game theory in the study of quality and safety control of agricultural products (38, 39). Chen et al. (40) analyzed input capacity constraints’ impact on food quality and quality regulation through game theory. Based on the evolutionary game theory, a game model between the government, farmers, and consumers was established, and the results showed that the government subsidy strength, to farmers, consumer trust coefficient, and willingness to pay the premium for carbon-labeled agricultural products were positively correlated with the adoption of low-carbon production behavior by farmers. Chen et al. (41) introduced the social preference theory to construct an evolutionary game model among multiple subjects and studied how to guide the behavioral decisions of multiple subjects to be standardized and rationalized (42). Teng et al. (14) studied the evolutionary decision-making behavior of government, farmers, and consumers based on the perspective of agricultural product

quality and safety. Ma et al. (43) constructed a three-party evolutionary game model of consumers, government, and farmers in the context of COVID-19 prevention and control normalization. The results showed that the cost of government regulation, the evaluation of the government by consumers and pig farmers, the government's subsidies to pig farmers and consumers, and the proportion of stakeholder behaviors affect the formation of the three-party relationship.

Some scholars have used evolutionary game theory to model incentives and agreement compliance. For example, Li et al. (44) established an evolutionary game model of the governance mechanism of the recycling industry and analyzed the impact of government punishment on the behavioral strategies of recycling firms. Sasaki et al. (45) combine key aspects of characterizing different punishment mechanisms in an evolutionary game-theoretic perspective and introduce a strategy of simultaneous commitment to cooperation and peer punishment to investigate a new mechanism for maintaining social order. Starting from a game-theoretic model that captures hegemonic competition in the field using artificial intelligence techniques, Han et al. (46) show how sanctions, when applied unconditionally to potentially unsafe behaviors, may produce socially undesired outcomes. With the help of evolutionary game theory, Ogbo et al. (47) analyze how ex-ante commitment can enhance the coordination of parties in two-by-two and multi-party interactions when the outcome presents an asymmetric payoff structure. Barrett uses a simple game model to illustrate whether and how treaties and related institutions can change incentives to align national self-interests with collective interests (48). Han, on the other hand, shows that evolutionary game theory provides a suitable tool for studying the evolution of cooperative behaviors in social dilemmas as they are governed by institutional incentives and prior commitments (49). Therefore, this paper also adopts evolutionary game theory to discuss the dynamic reward and dynamic punishment mechanism under the participation of multiple actors in the supervision of agricultural product quality and safety.

Some scholars have also taken digitization into account. Wan (50) applies big data technology to the governance of agricultural product quality and safety and utilizes extensive data methods to study the critical control points in the traceability process of agricultural products. Considering the altruistic reciprocity of supermarkets and the fairness concern of processors, respectively, Qin et al. (51) placed the Stackelberg game model under the Corporate social responsibility of processors and investigated the effects of Corporate social responsibility, altruistic reciprocity, and fairness concern on the quality improvement of agricultural supply chains.

In summary, most of the existing studies are on traditional agricultural product quality and safety supervision, and some scholars have studied agricultural product quality and safety traceability and governance from the perspective of big data technology. Few scholars have applied evolutionary game models to agricultural quality and safety regulation in digital environments. Therefore, this paper adopts the evolutionary game method to study the behavioral strategies of the government, agricultural product producers, and consumers in the process of agricultural product quality and safety supervision under the digital environment, analyze the mutual influence of strategic choices between different subjects, and provide theoretical references for the construction of the digital agricultural product traceability system, to further improve the quality and safety of agricultural

products, safeguard the rights and interests of consumers, and continuously maintain the stability of the social order.

2 Model assumptions and construction

2.1 Model assumptions

In this paper, we choose three subjects: government, agricultural producers, and consumers, and put forward the following hypotheses:

1. The government is Participant 1, the agricultural producer is Participant 2, and the consumer is Participant 3. All three participants are assumed to be finite-rational and aim to maximize profit.
2. The government's strategic choice is to "Regulate" or "Not regulate." Assume that the probability that the government chooses to "regulate" is x ($0 < x < 1$), and the probability that it chooses "Not regulate" is $1-x$. When the government chooses to "Regulate," it will incur the cost of regulation, but it will also enhance the government's image and trust, and gain certain benefits; when the government chooses "Not regulate," it will not incur the cost of regulation, but it will lower the government's image and trust, and incur the certain loss of trust.
3. The strategic choice of the agricultural producer is "Build" or "Not build." Assume that the probability that an agricultural enterprise chooses to "build" is y ($0 < y < 1$), and the probability that it chooses to "not build" is $1-y$. When an agricultural producer chooses to "building," i.e., construct a digital traceability system for agricultural products, it will incur the cost of construction, but the government will provide incentives, and at the same time improve the reputation and trust of the enterprise; When an agricultural product manufacturer chooses "not build," i.e., chooses not to build a digital traceability system for agricultural products, it will save the technical, human and financial costs of building a traceability system, but it will be penalized by the government accordingly, and at the same time, it will also reduce the reputation and trust of the enterprise.
4. The consumer's strategic choice is "satisfied" or "dissatisfied." Assume that the probability that the consumer chooses "satisfied" is z ($0 < z < 1$), then the probability that the consumer chooses "dissatisfied" is $1-z$. When consumers are "satisfied" with the products produced by agricultural product manufacturers and the operation of the digital agricultural product traceability system, they will receive corresponding economic, health and environmental benefits. When consumers are "dissatisfied" with the products produced by agricultural product manufacturers and the operation of the digital agricultural products traceability system, they will incur corresponding rights defense costs. In contrast, agricultural product manufacturers will incur corresponding losses.

Based on the above, the game process between the government, agricultural producers, and consumers is visualized by building a game tree, as shown in Figure 1.

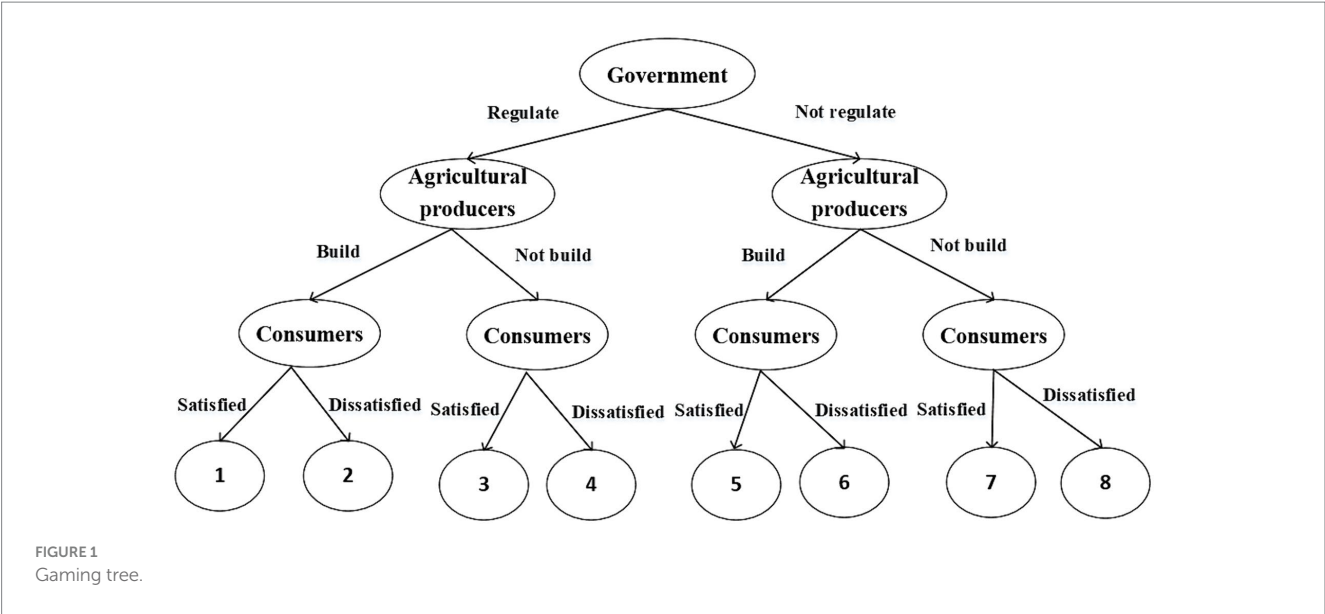


TABLE 1 Related parameter settings.

Parameter name	Parameter description
C_1	Costs incurred by Governments choosing to “Regulate”.
R_1	Gains from the Government’s choice to “Regulate”.
L_1	Loss of trust resulting from the Government’s choice to “Not regulate”.
C_2	Costs incurred by agro-producing firms choosing to “Build”.
A	Government incentives for agricultural producers to choose “Build”.
P	Penalties for agricultural producers choosing not to construct.
R_2	Benefits to consumers when they are “Satisfied” with the produce they purchase.
C_3	Costs incurred by consumers in purchasing agricultural products.
C_4	Costs of advocacy when consumers are “Dissatisfied”.
L	Losses incurred by agricultural producers when consumers opt for “Dissatisfied”.

TABLE 2 Payment matrix for the three parties of the game.

Strategic choice			Government	
			Regulate x	Not regulate $1-x$
Agricultural producers	Build y	Satisfied z	$R_1 - C_1 - A, A - C_2, R_2$	$-L_1, -C_2, R_2$
		Dissatisfied $1-z$	$R_1 - C_1, A - C_2, -C_4$	$-L_1, -C_2, -T_1 - C_4$
	Not build $1-y$	Satisfied z	$R_1 - C_1 + P, -P, R_2$	$-L_1, 0, R_2$
		Dissatisfied $1-z$	$R_1 - C_1 + P, -P - L - C_4, -C_3 - C_4$	$-L_1, 0, -L - L_1 - C_3$

2.2 Model construction

2.2.1 Parameter setting

2.2.2 Payment matrix

According to the parameter settings in Table 1, the payment matrix of the three parties of the game is constructed, as shown in Table 2.

3 Model analysis

An evolutionarily stable strategy is a strategy in a population that maintains a high degree of adaptability in the face of different strategies and cannot be replaced by other strategies (52). This strategy maintains its dominant position in the group through stability and non-invasiveness, and remains relatively stable during the evolutionary process. We search for more stable

strategies by building game models and analyzing the evolution of strategies.

3.1 Government's evolutionarily stable strategy

The expected returns to government regulation and non-regulation E_{11} , E_{12} , and the average expected return \bar{E}_1 are:

$$\begin{aligned} E_{11} &= yz(R_1 - C_1 - A) + y(1-z)(R_1 - C_1) + z(1-y)(R_1 - C_1 + P) \\ &\quad + (1-y)(1-z)(R_1 - C_1 + P) \\ &= R_1 - C_1 - yzA + (1-y)P \end{aligned}$$

$$\begin{aligned} E_{12} &= yz(-L_1) + y(1-z)(-L_1) + z(1-y)(-L_1) \\ &\quad + (1-y)(1-z)(-L_1) = -L_1 \end{aligned}$$

$$\bar{E}_1 = xE_{11} + (1-x)E_{12} = x[R_1 - C_1 - yzA + (1-y)P] + (1-x)(-L_1)$$

The replication dynamic equation for government strategy choice is:

$$F(x) = dx/dt = x(E_{11} - \bar{E}_1) = x(x-1)[C_1 - R_1 + yzA - (1-y)P - L_1]$$

When $y = \frac{P + L_1 - C_1 + R_1}{ZA + P}$, $\frac{dF(x)}{dx} \equiv 0$, It is in a steady state regardless of the value of x . If $y \neq \frac{P + L_1 - C_1 + R_1}{ZA + P}$, it is in a steady state at $x = 0$ and $x = 1$.

Perform a derivation of

$$F(x): \frac{dF(x)}{dx} = (2x-1)[C_1 - R_1 + yzA - (1-y)P - L_1].$$

When $y > \frac{P + L_1 - C_1 + R_1}{ZA + P}$, $\left. \frac{dF(x)}{dx} \right|_{x=1} > 0$, $\left. \frac{dF(x)}{dx} \right|_{x=0} < 0$, $x^* = 0$ is an evolutionarily stable strategy. When $y < \frac{P + L_1 - C_1 + R_1}{ZA + P}$, $\left. \frac{dF(x)}{dx} \right|_{x=1} < 0$, $\left. \frac{dF(x)}{dx} \right|_{x=0} > 0$, $x^* = 1$ is an evolutionarily stable strategy.

3.2 Evolutionary stabilization strategies for agricultural producers

The expected returns of agricultural producers E_{21} , E_{22} , and the average expected returns \bar{E}_2 are:

$$\begin{aligned} E_{21} &= xz(A - C_2) + z(1-x)(-C_2) + x(1-z)(A - C_2) \\ &\quad + (1-z)(1-x)(-C_2) = xA - C_2 \end{aligned}$$

$$\begin{aligned} E_{22} &= xz(-P) + x(1-z)(-P - L - C_4) \\ &= x(-P) + x(1-z)(-L - C_4) \end{aligned}$$

$$\begin{aligned} \bar{E}_2 &= yE_{21} + (1-y)E_{22} = y(xA - C_2) + \\ &\quad (1-y)[x(-P) + x(1-z)(-L - C_4)] \end{aligned}$$

The replication dynamic equation for the strategy choice of agricultural producers is:

$$F(y) = dy/dt = y(E_{11} - \bar{E}_1) = y(y-1)[x(1-z)(-L - C_4) - xA + C_2 - xP]$$

If $z = \frac{xA - C_2 + xP + xL + xC_4}{xL + xC_4}$, $\frac{dF(y)}{dy} \equiv 0$, it is stable regardless of the value of y . If $z \neq \frac{xA - C_2 + xP + xL + xC_4}{xL + xC_4}$, then it is in a steady state at $y = 0$ and $y = 1$.

Perform the derivation on $F(y)$:

$$\frac{dF(y)}{dy} = (2y-1)[x(1-z)(-L - C_4) - xA + C_2 - xP]$$

When $z > \frac{xA - C_2 + xP + xL + xC_4}{xL + xC_4}$, $\left. \frac{dF(y)}{dy} \right|_{y=1} > 0$, $\left. \frac{dF(y)}{dy} \right|_{y=0} < 0$, $y^* = 0$ is an evolutionarily stable strategy. When $z < \frac{xA - C_2 + xP + xL + xC_4}{xL + xC_4}$, $\left. \frac{dF(y)}{dy} \right|_{y=1} < 0$, $\left. \frac{dF(y)}{dy} \right|_{y=0} > 0$, $y^* = 1$ is an evolutionarily stable strategy.

3.3 Evolutionary stabilization strategies for consumers

Consumer satisfaction and dissatisfaction expected returns E_{31} and E_{32} , and average expected return \bar{E}_3 are:

$$E_{31} = xyR_2 + y(1-x)R_2 + (1-y)xR_2 + (1-y)(1-x)R_2 = R_2$$

$$\begin{aligned} E_{32} &= xy(-C_4) + y(1-x)(-T_1 - C_4) + x(1-y) \\ &\quad (-C_3 - C_4) + (1-x)(1-y)(-L - L_1 - C_3) \end{aligned}$$

$$\bar{E}_3 = zE_{31} + (1-z)E_{32}$$

The replication dynamic equation for consumer strategy choice is:

$$\begin{aligned} F(z) &= dz/dt = z(E_{31} - \bar{E}_3) = z(z-1) \\ &\quad (-C_3 - L - L_1 - R_2 - C_4x + C_3y \\ &\quad - C_4y + Lx + L_1x + Ly + L_1y \\ &\quad - T_1y + C_4xy - Lxy - L_1xy + T_1xy) \end{aligned}$$

If $y = \frac{C_3 + L_1 + L - R_1 + xC_4 - xL - xL_1}{C_3 - C_4 + L + L_1 - T_1 + xC_4 - xL - xL_1 + xT_1}$, $\frac{dF(z)}{dz} \equiv 0$, it is stable regardless of the value of z . If $y \neq \frac{C_3 + L_1 + L - R_1 + xC_4 - xL - xL_1}{C_3 - C_4 + L + L_1 - T_1 + xC_4 - xL - xL_1 + xT_1}$, then it is in a steady state at $z = 0$ and $z = 1$.

TABLE 3 Eigenvalues of the Jacobi matrix.

Balance point	Eigenvalue 1	Eigenvalue 2	Eigenvalue 3
$E_1(0,0,0)$	$-C_1 - L_1 + R_1 + 1$	$-C_2$	$C_3 + L + L_1 + R_2$
$E_2(0,0,1)$	$-C_1 - L_1 + R_1 + 1$	$-C_2$	$-C_3 - L - L_1 - R_2$
$E_3(0,1,0)$	$-C_1 - L_1 + R_1 - P + 1$	C_2	$R_2 + C_4 + T_1$
$E_4(1,0,0)$	$C_1 + L_1 - R_1 - 1$	$-C_2 + A + P + C_4 + L$	$C_3 + R_2 + C_4$
$E_5(0,1,1)$	$-C_1 - L_1 + R_1 - P + A - 1$	C_2	$-R_2 - 2C_4 - T_1$
$E_6(1,0,1)$	$C_1 + L_1 - R_1 - 1$	$-C_2 + A + P$	$-C_3 - R_2$
$E_7(1,1,0)$	$C_1 + L_1 - R_1 + P - 1$	$C_2 - A - P - C_4 - L$	$R_2 + C_4$
$E_8(1,1,1)$	$C_1 + L_1 - R_1 + P + A - 1$	$C_2 - A - P$	$-R_2 - C_4$

Perform the derivation on $F(z)$:

$$\frac{dF(z)}{dz} = (2z-1) \begin{pmatrix} -C_3 - L - L_1 - R_2 - C_4x + C_3y - C_4y \\ +Lx + L_1x + Ly + L_1y - T_1y + C_4xy \\ -Lxy - L_1xy + T_1xy \end{pmatrix}$$

When $y > \frac{C_3 + L_1 + L - R_1 + xC_4 - xL - xL_1}{C_3 - C_4 + L + L_1 - T_1 + xC_4 - xL - xL_1 + xT_1}$, $\left. \frac{dF(z)}{dz} \right|_{z=1} > 0$, $\left. \frac{dF(z)}{dz} \right|_{z=0} < 0$, $z^* = 0$ is an evolutionarily stable strategy. When $y < \frac{C_3 + L_1 + L - R_1 + xC_4 - xL - xL_1}{C_3 - C_4 + L + L_1 - T_1 + xC_4 - xL - xL_1 + xT_1}$, $\left. \frac{dF(z)}{dz} \right|_{z=1} < 0$, $\left. \frac{dF(z)}{dz} \right|_{z=0} > 0$, $z^* = 1$ is an evolutionarily stable strategy.

3.4 Stability analysis

The system equilibrium point is $E_1(0,0,0)$, $E_2(0,0,1)$, $E_3(0,1,0)$, $E_4(1,0,0)$, $E_5(0,1,1)$, $E_6(1,0,1)$, $E_7(1,1,0)$, $E_8(1,1,1)$ from $F(x) = 0$, $F(y) = 0$, $F(z) = 0$. The Jacobi matrix of the three-party

$$\text{evolutionary game } J = \begin{bmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \end{bmatrix}$$

$$A_{11} = x(C_1 + L_1 - R_1 + Py + Ayz - 1) + (x-1)(C_1 + L_1 - R_1 + Py + Ayz - 1)$$

$$A_{12} = x(P + Az)(x-1); A_{13} = Axy(x-1)$$

$$A_{21} = y(y-1)[A + P - (z-1)(C_4 + L)]$$

$$A_{22} = y[C_2 - Ax - Px + x(z-1)(C_4 + L)] + (y-1)[C_2 - Ax - Px + x(z-1)(C_4 + L)]$$

$$A_{23} = xy(y-1)(C_4 + L);$$

$$A_{31} = z(z-1) \begin{pmatrix} L - C_4 + L_1 + C_4y \\ -Ly - L_1y + T_1y \end{pmatrix}$$

$$A_{32} = z(z-1)(C_3 - C_4 + L + L_1 - T_1 + C_4x - Lx - L_1x + T_1x)$$

$$A_{33} = -(z-1)(C_3 + L + L_1 + R_2 + C_4x - C_3y + C_4y - Lx - L_1x - Ly - L_1y + T_1y - C_4xy\theta + Lxy + L_1xy - T_1xy) - z(C_3 + L + L_1 + R_2 + C_4y - C_3y + C_4y - Lx - L_1x - Ly - L_1y + T_1y - C_4xy + Lxy + L_1xy - T_1xy)$$

Substituting the eight equilibrium points into the Jacobi matrix, respectively, the corresponding eigenvalues of each equilibrium point can be obtained, as shown in Table 3. According to the evolutionary game theory, the equilibrium point that satisfies the Jacobi matrix when all the eigenvalues are negative is the evolutionary equilibrium point.

Scenario 1 When $-C_1 - L_1 + R_1 + 1 < 0$, the trust loss of the government choosing not to regulate is smaller than the cost of choosing to regulate. The punishment of the government that the agricultural product producer chooses not to build the digital agricultural product traceability system is smaller than the cost of choosing to build it. The benefit the consumer gets when satisfied is more significant than the cost of defending his rights when dissatisfied. At this point, as can be seen from Table 4, the eigenvalues of the Jacobian matrix corresponding to the equilibrium point $E_2(0,0,1)$ are all less than 0. The equilibrium point $E_2(0,0,1)$ is stable, and its corresponding evolutionary strategy is (Not regulate, Not build, Satisfied).

Scenario 2 When $C_1 + L_1 - R_1 - 1 < 0$ and $-C_2 + A + P < 0$, the cost to the government of choosing to regulate is less than the benefit of choosing to regulate. The penalties imposed on agricultural producers for choosing not to build a traceability system are greater than the sum of the benefits and incentives of choosing to build one. When satisfied, the benefits of food safety to consumers are more significant than the costs of defending their rights when dissatisfied. At this point, as can be seen from Table 4, the eigenvalues of the Jacobian matrix corresponding to the equilibrium point $E_6(1,0,1)$ are all less than 0. The equilibrium point $E_6(1,0,1)$ is stable, and its corresponding evolutionary strategy is (Regulate, Not build, Satisfied).

Scenario 3 When $C_1 + L_1 - R_1 + P + A - 1 < 0$ and $C_1 + L_1 - R_1 + P + A - 1 < 0$, the cost to the government of choosing

TABLE 4 Stability analysis of the equilibrium solution.

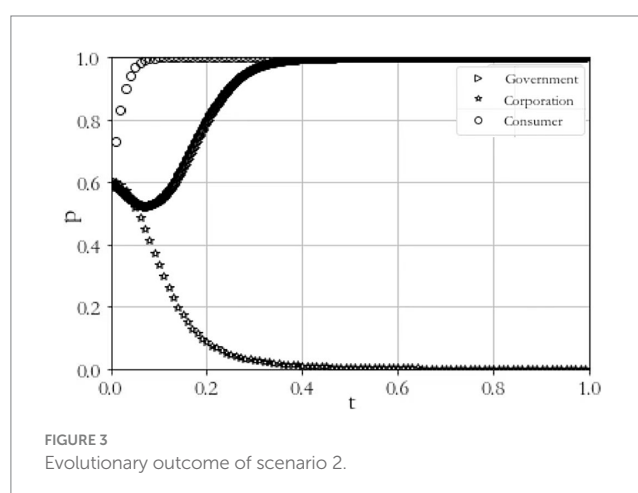
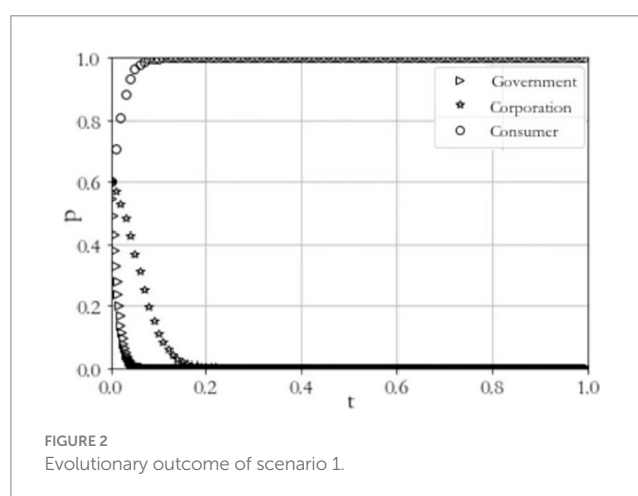
Balance point	Eigenvalue symbol	Stability
$E_1(0,0,0)$	Having positive value	Unsteady point
$E_2(0,0,1)$	When $-C_1 - L_1 + R_1 + 1 < 0$, all negative values	ESS
$E_3(0,1,0)$	Having positive value	Unsteady point
$E_4(1,0,0)$	Having positive value	Unsteady point
$E_5(0,1,1)$	Having positive value	Unsteady point
$E_6(1,0,1)$	When $C_1 + L_1 - R_1 - 1 < 0$ and $-C_2 + A + P < 0$, all negative values	ESS
$E_7(1,1,0)$	Having positive value	Unsteady point
$E_8(1,1,1)$	When $C_1 + L_1 - R_1 + P + A - 1 < 0$ and $C_2 - A - P < 0$, all negative values	ESS

to regulate is less than the benefit it receives from choosing to regulate, and the cost to agricultural producers of constructing a digital traceability system is less than the penalties imposed by the government in the event of consumer dissatisfaction. At this point, as can be seen from Table 4, the eigenvalues of the Jacobian matrix corresponding to the equilibrium point $E_8(1,1,1)$ are all less than 0. The equilibrium point $E_8(1,1,1)$ is stable, and its corresponding evolutionary strategy is (Regulate, Build, Satisfied).

4 Simulation analysis

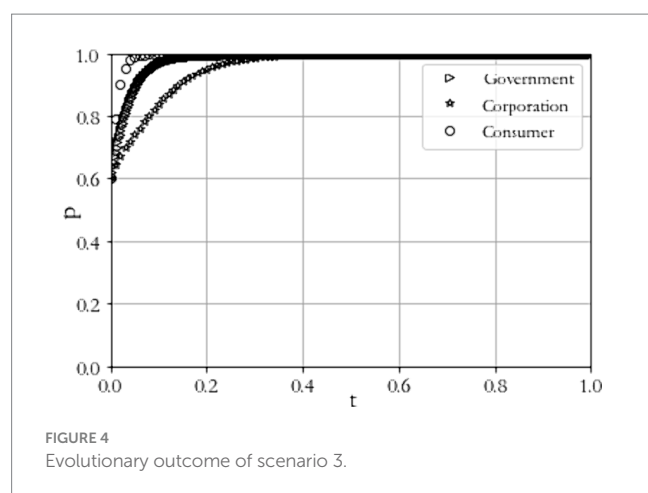
Scenario 1 $-C_1 - L_1 + R_1 + 1 < 0$. When $C_1 = 8$, $R_1 = 6$, $L_1 = 4$, $C_2 = 6$, $A = 5$, $P = 3$, $R_2 = 7$, $C_3 = 2$, $C_4 = 6$, $L = 4$. The results of the simulation experiment are shown in Figure 2. As can be seen from the figure, the probability that the government chooses to regulate keeps decreasing until it is 0; the probability that the agricultural producer chooses to construct keeps decreasing until it is 0; and the probability that the consumer is satisfied keeps increasing until it is 1. Therefore, the evolutionary equilibrium state tends to be $(0,0,1)$. In this case, consumers choose not to file complaints due to the high cost of defending their rights, and the probability of government regulation will be very low, which makes agricultural producers not to build a digital traceability system.

Scenario 2 $C_1 + L_1 - R_1 - 1 < 0$ and $-C_2 + A + P < 0$. When $C_1 = 8$, $R_1 = 9$, $L_1 = 4$, $C_2 = 8$, $A = 5$, $P = 3$, $R_2 = 7$, $C_3 = 2$, $C_4 = 6$, $L = 4$. The results of the simulation experiment are shown in Figure 3. From the figure, it can be seen that the probability that the government chooses to regulate keeps rising until it is 1; the probability that the agricultural producer chooses to construct keeps falling until it is 0; and the probability that the consumer is satisfied keeps rising until it is 1, so the evolutionary equilibrium state tends to $(1, 0, 1)$. Compared with Case 1, the benefit R_1 gained from the regulation of agricultural product producers increases, and the probability of their choosing to regulate increases, the cost C_2 of agricultural product producers constructing a digital traceability system increases, and even though the government will penalize them, the cost of constructing a digital traceability system is higher than that of penalizing them, so that agricultural product producers will still tend to choose not to construct it. The consumer cannot obtain the quality traceability information of agricultural products they purchase, and the cost of



consumers defending their rights is high, so the probability that the consumer chooses to file a complaint decreases.

Scenario 3 $C_1 + L_1 - R_1 + P + A - 1 < 0$ and $C_2 - A - P < 0$. When $C_1 = 8$, $R_1 = 9$, $L_1 = 4$, $C_2 = 6$, $A = 5$, $P = 7$, $R_2 = 7$, $C_3 = 2$, $C_4 = 6$, $L = 4$. The results of the simulation experiment are shown in Figure 4. From the figure, it can be seen that the probability of the government choosing to regulate has been rising until it is 1; the probability of the



agricultural production enterprise choosing to build has been rising until it is 1; the probability of the consumer being satisfied has been rising until it is 1, so the evolutionary equilibrium state tends to (1). Compared to Case 1, the gain R_1 gained from government regulation increases, the probability of its regulation increases, the penalty P for not constructing a digital traceability system for agricultural product producers increases, the probability of agricultural product producers constructing it increases, consumers can obtain traceability information about their products, agricultural product producers tend to produce high-quality products, and the probability of consumer satisfaction increases.

5 Conclusion and recommendation

This paper constructs a three-party evolutionary game model among the government, agricultural product producers, and consumers in the digital environment, analyzes the evolutionary process of agricultural product quality and safety issues involving the government, agricultural product producers, and consumers, and studies the strategic choices of the government, agricultural product producers and consumers as well as their influencing factors through the analysis of arithmetic examples. It is found that there are multiple evolutionary stabilization strategies in the tripartite evolutionary game model of agricultural product quality and safety regulation. When the benefits gained from government regulation, the cost of constructing a digital traceability system for agricultural product producers, and the penalties imposed on agricultural product producers are constantly changing, there will be (Not regulate, Not build, Satisfied), (Regulate, Not build, Satisfied), and (Regulate, Build, Satisfied) in order.

From this, the following recommendations can be drawn: (1) The government should set appropriate penalties and impose severe penalties for agricultural producers who violate production standards and quality requirements to force agricultural producers to improve quality (53). (2) Reduce the cost of enterprises to build a digital traceability system for agricultural products (54). The government can provide relevant financial support and reduce or waive relevant taxes and fees, etc., to reduce the cost of building a digital agricultural product traceability system for agricultural product production enterprises and encourage more enterprises to join the ranks of digital management (3). Actively guide consumers' understanding of the quality and safety traceability of agricultural products and teach them

to inquire about product origin and quality information through the traceability system (55, 56). Advocating that priority be given to agricultural products with digital quality and safety traceability marks to increase consumers' confidence and sense of security in purchasing. Consumers should also actively report suspected agricultural product quality problems to government regulators and actively participate in supervision and public opinion monitoring to safeguard the quality and safety of agricultural products. This study also has some limitations. In the next step, we will expand the scope of the study to include third-party testing organizations and the public, and explore the characteristics and laws of multi-body behavioral decision-making in agricultural product quality and safety supervision. In addition, the game model we chose has a bias in describing the real decision-making environment, and we will also choose a more appropriate model to improve our study in the subsequent research.

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

HH: Conceptualization, Formal analysis, Resources, Validation, Writing – original draft, Writing – review & editing. XL: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Resources, Software, Supervision, Validation, Visualization, 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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Achieving sustainable medical tourism: unpacking privacy concerns through a tripartite game theoretic lens

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Introduction: Medical tourism has grown significantly, raising critical concerns about the privacy of medical tourists. This study investigates privacy issues in medical tourism from a game theoretic perspective, focusing on how stakeholders' strategies impact privacy protection.

Methods: We employed an evolutionary game model to explore the interactions between medical institutions, medical tourists, and government departments. The model identifies stable strategies that stakeholders may adopt to protect the privacy of medical tourists.

Results: Two primary stable strategies were identified, with $E_6(1,0,1)$ emerging as the optimal strategy. This strategy involves active protection measures by medical institutions, the decision by tourists to forgo accountability, and strict supervision by government departments. The evolution of the system's strategy is significantly influenced by the government's penalty intensity, subsidies, incentives, and the compensatory measures of medical institutions.

Discussion: The findings suggest that medical institutions are quick to make decisions favoring privacy protection, while medical tourists tend to follow learning and conformity. Government strategy remains consistent, with increased subsidies and penalties encouraging medical institutions towards proactive privacy protection strategies. We recommend policies to enhance privacy protection in medical tourism, contributing to the industry's sustainable growth.

KEYWORDS

medical tourism, privacy protection, evolutionary game theory, incentives and penalties, sustainable growth

1 Introduction

Medical tourism has evolved into a global phenomenon, characterized by patients seeking medical procedures across borders, motivated by factors such as cost-efficiency, timely care, and access to specialized services (1–3). According to Market.us Media, the industry is expanding at a rate of 15–25% annually, with countries like India, Thailand, and Singapore leading as preferred destinations due to their combination of advanced healthcare facilities and competitive pricing (4). However, the burgeoning growth raises questions about the sustainability of such practices in the face of increasing demand for cross-border medical services and the corresponding need for international healthcare policy harmonization (5).

Privacy in the medical tourism industry is not merely a legal requirement but also a fundamental patient right and a critical component of quality care (6). Confidentiality concerns are heightened in this context due to diverse cultural expectations, legal systems, and potential language barriers that can result in misunderstandings and breaches of privacy (7).

Ensuring the security of sensitive personal health information becomes paramount as it can impact patient well-being and trust in the healthcare system (8).

Protecting the privacy of medical tourists is fraught with challenges that range from regulatory disparities to technological vulnerabilities (9). Variances in national laws regarding data protection can lead to inconsistencies in personal health information handling and increase the complexity of legal recourse for patients in the event of a privacy breach (10). The inter-jurisdictional transfer of health data often lacks a unified legal framework to guide practice and policy (11). Furthermore, the rise of digital health records and telemedicine consultations necessitates stringent cybersecurity protocols to mitigate risks such as unauthorized access and data theft (12). Such complexities underscore the need for an international consensus on privacy standards in medical tourism.

Despite burgeoning literature on medical tourism, significant gaps remain in understanding how privacy protection is operationalized across different jurisdictions. While some nations have robust data protection laws, others offer little to no protection for medical tourists, leading to an uneven patchwork of regulations that do not adequately address the transnational nature of medical tourism (13, 14). Further research is needed to identify specific weaknesses in existing privacy protection frameworks and to propose solutions that can work across borders.

Privacy breaches in medical tourism can have severe consequences for both patients and service providers. For patients, breaches can lead to discrimination, financial loss, and emotional distress, while for service providers, they can result in reputational damage, loss of business, and legal liabilities (15, 16). The global nature of medical tourism calls for a strategic approach to privacy protection that is multi-faceted and international in scope. Existing strategies often focus on national regulations, which are insufficient given the cross-border flow of health information (17). A comprehensive strategy must include international legal frameworks, standardized protocols for data security, and cooperation between destination and source countries to ensure that the rights of medical tourists are safeguarded (18, 19). Only through such a strategic approach can privacy risks be mitigated and the sustainable growth of the medical tourism industry be supported.

In summation, concerning the realm of privacy protection within medical tourism, existing literature, though progressive, presents certain persisting quandaries and challenges. Specifically: (1) How can an evolutionary game-theoretic model be constructed to incorporate interactions among government departments, medical institutions, and medical tourists? (2) What delineates the optimal evolutionary strategies among pivotal stakeholders? (3) What characteristics define the decision-making processes of these evolutionary game participants? (4) Which determinants, when modulated, expedite the attainment of the optimal evolutionary stability strategy?

This study highlights significant advancements in understanding the dynamic nature of privacy strategies in medical tourism, offering benefits in theory, industry practice, and policy-making. Theoretically, it moves beyond static models, providing a more intricate view of real-world healthcare interactions and improving the predictive capabilities of these models. Practically, it presents strategies that can help medical tourism providers gain a competitive advantage through enhanced trust and patient loyalty, emphasizing that effective privacy management is key to quality care and the industry's sustainable

growth. Finally, the study forms a base for policy development, suggesting a flexible framework informed by evolutionary game theory, promoting international cooperation, and positioning privacy as crucial in medical tourism. Governments are encouraged to support institutions following these privacy norms, fostering innovation while ensuring industry growth and protecting patient privacy.

2 Literature review

2.1 Origin and background of privacy issues in medical tourism

The convergence of medical tourism and technological advancements has reshaped the healthcare landscape, introducing both transformative benefits and novel challenges (20). The adoption of information technology (IT) in the medical field has revolutionized patient care, offering streamlined operations, real-time communication, and enhanced diagnosis and treatment (21). Electronic health records (EHRs), telemedicine, and mobile health apps have brought unprecedented convenience and efficiency (22, 23). However, the digital nature of these tools also introduces vulnerabilities. Unauthorized access, data breaches, and cybersecurity threats pose significant risks to the confidentiality and integrity of patient information, especially when data crosses borders in medical tourism scenarios (24).

Medical tourism's rise has been inextricably tied to globalization, characterized by the free flow of people, information, and technology across borders (25). While this interconnectivity has facilitated access to world-class healthcare, it has also exposed medical tourists to heterogeneous data protection standards. Several incidents, particularly in emerging medical tourism hubs, have spotlighted the repercussions of lax privacy protocols and diverse regulatory frameworks. During the period from 2015 to 2019, approximately 250 million individuals experienced breaches in healthcare privacy (16). Hackers and other IT incidents accounted for the largest proportion of healthcare data breaches reported in 2020. During the year, there were 429 reported incidents related to hacking/IT incidents, making up 66.82% of all breach events, with the number of records affected by these breaches reaching an even higher percentage of 91.99% (26). From inadvertent data leaks to orchestrated cyber-attacks (27, 28), medical tourists have become targets, underscoring the imperative of establishing robust, universally acknowledged privacy norms (29).

In summary, the emergence of medical tourism as a formidable sector in global healthcare is a double-edged sword. While it offers myriad opportunities for economic growth and global collaboration, it also surfaces challenges related to patient data privacy, cultural congruence, and equitable access to healthcare resources.

2.2 Behavioral patterns of medical tourists in privacy protection

Understanding the motivations and behaviors of medical tourists is pivotal when addressing privacy concerns, which stand out among the numerous factors influencing their decisions to seek treatment abroad (30). Privacy concerns are not just theoretical but have real-world implications, as evidenced by recent studies showing a trend of

increased privacy awareness among medical tourists, a consequence of the digitization boom in healthcare (31). This vigilance is rooted in high-profile incidents of data breaches and the unauthorized sharing of sensitive health information, which have not only legal ramifications but also profound personal impacts, such as the threat of stigmatization or discrimination following the disclosure of certain health conditions (32).

The influence of cultural background on privacy concerns is notable and diverse (33). For example, Western patients often demand high levels of anonymity and stringent data protection, a stance likely influenced by a regulatory environment that emphasizes individual privacy rights. On the contrary, in certain Asian cultures, where communal decision-making is prevalent, there might be a more relaxed attitude toward data sharing within the extended family network (34). However, this cultural tendency does not diminish the necessity for privacy protection but rather emphasizes the need for culturally sensitive privacy protocols that cater to the expectations of medical tourists from different backgrounds (35).

Medical institutions must recognize and respond to these cultural subtleties by tailoring their privacy protocols. Incorporating evolutionary game theory, we can anticipate and model these varied behavioral patterns as strategies that evolve over time. Medical tourists adapt their privacy demands based on experiences and information about past privacy breaches, and medical providers, in turn, evolve their privacy protections to meet these expectations and to maintain their reputational standing in a competitive market. As such, the cultural and behavioral dimensions of privacy concerns become dynamic factors in the game-theoretical analysis of medical tourism, informing the evolution of privacy protection strategies and policy development.

2.3 Evolutionary game theory in privacy protection

Evolutionary game theory (EGT) offers a pertinent model for addressing privacy issues in medical tourism due to its ability to capture the dynamic nature of interactions among diverse stakeholders (36). Unlike classical game theory, which assumes perfect rationality, EGT assumes that players adapt their strategies over time based on their experiences (37). This is especially relevant in medical tourism, where providers and consumers continuously adjust their behavior in response to privacy concerns and policy changes.

In the realm of healthcare, privacy protection is a dynamic process involving multiple stakeholders—patients, healthcare providers, and policy-makers—who interact repeatedly. These interactions often resemble a complex adaptive system where strategies evolve based on past outcomes and anticipated future risks (38). EGT encapsulates this process by modeling how stakeholders may adapt their privacy strategies in response to the evolving digital landscape and its associated threats, such as data breaches (39, 40). For example, the shift toward digital health records has heightened the risk of privacy breaches. This has led healthcare providers to engage in an evolutionary “arms race,” constantly developing and adopting more advanced privacy protection measures to safeguard patient data and comply with tightening regulations (41).

In medical tourism, the temporary and overlapping relationships between medical tourists, healthcare providers, and

regulators across borders create a complex network of interactions. EGT serves as a useful analytical tool to understand and predict how privacy norms and protection strategies may evolve in this context (42). For instance, as healthcare providers strive to attract international patients, they are motivated to enhance their privacy protections. In turn, patients seek out destinations that not only provide high-quality medical services but also ensure the confidentiality of their health information (43).

Evolutionary Game Theory (EGT) provides a useful framework for understanding privacy protection strategies in medical tourism, but it has limitations. It may not fully capture the impact of diverse cultural values and regulatory environments on stakeholders' decisions. Therefore, empirical research, such as case studies and surveys, is essential to validate EGT's effectiveness in real-world healthcare settings. Additionally, concrete policy recommendations are needed to apply EGT effectively in medical tourism. This involves integrating EGT insights into policy-making, considering cultural differences and international regulatory complexities. Bridging the gap between EGT's theoretical aspects and practical applications in medical tourism is crucial. This can be achieved by adapting the model to the specific needs of the medical tourism industry and using real-life examples to guide its application in developing effective privacy strategies and regulations.

In conclusion, EGT provides a robust theoretical foundation for understanding and guiding the evolution of privacy protection strategies in medical tourism. Its application helps to predict how stakeholders might adapt their behaviors to ensure privacy, given the sector's unique challenges. This analysis paves the way for more informed policy-making and a better understanding of the strategic considerations underlying privacy protection in the healthcare sector.

In sum, privacy concerns in medical tourism are multi-faceted, shaped by technological advancements, individual behaviors, and the dynamics among governments, medical institutions, and tourists. The challenge lies in striking a balance, ensuring that while medical tourism thrives, patient privacy remains uncompromised. This study presents an innovative examination of the mechanisms underlying medical tourism privacy protection through the formulation of a tripartite evolutionary game model. Such a model offers a comprehensive theoretical foundation for enhancing privacy measures in medical tourism, thereby ensuring its robust and efficient progression.

The salient contributions of this research are enumerated as follows: (1) The initiative to use a three-party evolutionary game theory stands as a novel approach in the academic discourse surrounding medical tourism, aiming to bring a deeper understanding of the privacy protection dynamics at play. (2) This research undertakes a rigorous exploration of the ramifications associated with privacy protection in medical tourism, emphasizing governmental punitive intensities, subsidy mechanisms, reward dynamics, and compensatory frameworks implemented by healthcare institutions. The insights procured from this study hold substantial pragmatic implications, proffering pivotal guidance for bolstering privacy safeguards within the medical tourism paradigm. (3) The study is positioned to offer rich insights that can potentially guide and influence policy formulations, thereby encouraging a safe and trustworthy environment for medical tourism.

3 Model construction

3.1 Problem description

In the evolving landscape of medical tourism, the preservation of privacy stands out as a paramount concern. The game relationship among medical tourists, medical institutions, and government departments presents a complex dynamic, underpinned by diverse interests, incentives, and potential outcomes.

Medical Tourists: Medical tourists are primarily driven by the need for quality, affordable healthcare coupled with the expectation of privacy concerning their medical records and personal data. Their decisions, shaped by trust, often pivot on perceived confidentiality assurances and past privacy preservation reputation of medical institutions and destination countries (44). Simultaneously, medical tourists form and adjust their cognitive and emotional impressions of medical tourism destinations based on various motivations and risk factors, thereby influencing their travel decisions and behaviors (45).

Medical Institutions: Due to the negative impact of risks associated with healthcare attributes on the image of a destination (46), healthcare providers in the medical tourism sector are eager to maintain a competitive advantage by making significant investments in privacy measures. They understand the crucial role these measures play in attracting and retaining international patients to avoid damage to the destination's image caused by risks of privacy breaches in medical tourism. However, these institutions also face pressure to share data for research, marketing, and sometimes, with governmental bodies for regulatory reasons (47).

Government Departments: Governments play a dual role. On one hand, they are regulators, setting privacy standards and ensuring compliance. Their policies influence the privacy landscape, either bolstering trust through stringent regulations or diluting it by allowing data access and sharing for broader societal or economic reasons (48). On the other hand, governments are also promoters of medical tourism, where data might be used to enhance the sector's competitive positioning.

The dynamic interplay among these stakeholders can be likened to a three-party game, where each party's strategy is influenced not only by their individual payoffs but also by the actions and expected responses of the other players. This interdependence, often non-linear, is governed by trust, information asymmetry, and the changing privacy regulations landscape (49).

While this triad game relationship underscores the significance of collaborative strategy formulation, it also emphasizes the need for transparent communication, robust privacy protection mechanisms, and adaptive regulations that align with the rapidly evolving medical tourism sector's demands.

3.2 Model assumptions

Based on the analysis of the interests and conflicts of the parties involved in the protection of privacy for medical tourists, three main stakeholder groups have been selected for the study: medical institutions, medical tourists, and government departments. The following hypotheses are made regarding the behavior of the three parties.

Hypothesis 1: The three parties involved in protecting the privacy of medical tourists are all boundedly rational and prioritize maximizing their own interests as the primary goal in the process.

Hypothesis 2: The strategy choices of medical institutions are (active protection, negative protection). When medical institutions fail to adequately protect the privacy of medical tourists, they may exploit the personal information of medical tourists for financial gain. Medical tourists' strategic choices are (seek accountability, forgo accountability). When medical tourists discover that their privacy has been violated, they may choose to hold medical institutions accountable or not. However, medical tourists may also mistakenly blame the medical institution that diligently safeguards their privacy due to insufficient information and cognitive bias. The strategic choices of the government departments are (strict supervision, loose supervision). Under strict supervision, if medical tourists hold medical institutions accountable for privacy breaches, the institutions can be investigated and penalized. If medical institutions are not held accountable for privacy breaches, the probability of government departments being able to investigate and prosecute these institutions for a breach is p ($0 < p < 1$). Under loose supervision, the probability of successfully holding medical institutions accountable by medical tourists is m , ($0 < m < 1$). It is assumed that the probability of medical institutions actively safeguarding privacy is $(1-x)$, the probability of passively safeguarding privacy is y , the probability of medical tourists holding medical institutions accountable for privacy breaches is x , and the probability of strict supervision is z . Correspondingly, $(1-y)$ and $(1-z)$ are the probabilities of forgoing accountability and loose supervision, respectively. The probabilities of x , y , z range $[0, 1]$.

Hypothesis 3: The business revenue for medical institutions in the process of providing services to medical tourists is recorded as I . When selecting the "active protection" strategy, there will be certain costs involved in purchasing privacy protection equipment, network security hardware and software, as well as importing information protection technology and hiring professionals. These costs are recorded as C_1 . When government departments actively supervise, they will subsidize medical institutions that adopt the "active protection" strategy, which is recorded as S . When medical institutions passively protect privacy, the cost of protection is denoted as C_2 , and $C_2 < C_1$. Meanwhile, medical institutions stand to benefit ΔI from actions that disclose privacy, but they are also at risk of being held accountable by medical tourists and investigated by government departments. When medical institutions are held accountable and investigated for a privacy breach, the compensation to the medical tourists is recorded as C_0 , the government penalty is recorded as P_0 , and $P_0 \leq \Delta I$. The image loss when a medical institution actively protects the privacy of medical tourists but is held accountable is recorded as L_1 , and the image loss caused by a medical institution being held accountable for leaks that occur in the context of negatively protecting the privacy is recorded as L_2 , and $L_1 < L_2$.

Hypothesis 4: Medical tourists are the beneficiaries of privacy protection. They engage in medical tourism at a cost (C_3), in exchange for a valuable experience (V). When their privacy is compromised, it can result in emotional and economic losses, which will be recorded as L_3 . The cost of seeking accountability, in terms of time and money, incurred by medical tourists is C_4 .

When medical institutions are successfully held accountable by medical tourists, the latter can receive compensation from medical institutions, which is recorded as C_0 , and $C_0 \leq C_4$. When government departments actively regulate the medical tourism market to ensure its proper functioning, they may offer rewards to medical tourists who report privacy breaches by medical institutions. This is recorded as R .

Hypothesis 5: Government departments incur specific costs (C_5) in the regulatory process of safeguarding privacy during the expansion of the medical tourism industry. These costs include formulating relevant policies and regulations, conducting publicity and supervision, as well as managing tourists' accountable behaviors and social governance. Therefore, government departments will gain social credibility and be able to shape the image of destinations for medical tourism. Furthermore, they will gain economic and social benefits from the development of medical tourism, which will be recorded as B . These benefits include socio-economic growth, increased tax revenue generated by medical tourism, and the creation of employment opportunities. Choosing a "loose supervision" strategy means government departments will not bear the regulatory costs. However, the absence of regulation will result in an unfavorable social environment for the development of the medical tourism industry and leading to a decline in economic and social benefits, it is B' .

The relevant model parameters are set as shown in Table 1, and all parameters are non-negative.

3.3 Construction of gain function

The benefits of protecting the privacy of medical tourist participants are calculated based on the above assumption, as shown in Figure 1.

Based on the benefits, the payoffs for medical institutions, medical tourists, and government departments can be calculated.

For medical institutions, when choosing between the active protection strategy and the negative protection strategy, the expected benefits are U_{11} and U_{12} , respectively. Therefore, the average expected benefit is U_1 .

$$U_{11} = yz(I + S - C_1 - L_1) + y(1-z)(I - C_1 - L_1) + z(1-y)(I + S - C_1) + (1-y)(1-z)(I - C_1)$$

$$U_{12} = yz(I + \Delta I - C_2 - C_0 - P_0 - L_2) + y(1-z)(I + \Delta I - C_2 - L_2 - mC_0) + z(1-y)(I + I - pP_0 - C_2) + (1-y)(1-z)(I + I - C_2)$$

$$U_1 = xU_{11} + (1-x)U_{12}$$

For medical tourists, when they choose between "seek accountability strategy" and "forgo accountability" strategy, the

TABLE 1 Meaning of parameter symbols and their representations.

Parameters	Indicates meaning
C_0	Compensation to medical tourists under "negative protection" and "strict supervision" strategies.
C_1	Costs to medical institutions under "active protection" strategy.
C_2	Costs to medical institutions under "negative protection" strategy ($C_2 < C_1$).
I	Revenue from operations of medical institutions while providing services to medical tourists.
ΔI	Benefits gained by medical institutions under "negative protection."
S	Subsidies to medical institutions under "active protection" and "strict supervision" strategies.
P_0	Fines for medical institutions under "strict supervision" strategy ($P_0 \leq \Delta I$).
L_1	The image loss of medical institutions under "active protection" and "seek accountability" strategies.
L_2	The image loss of medical institutions under "negative protection" and "strict supervision" strategies ($L_1 < L_2$).
C_3	Costs for medical tourists when participating in medical tourism.
C_4	Costs for medical tourists under "seek accountability" strategy ($C_0 < C_4$).
L_3	Losses when medical tourists' privacy is compromised.
V	The experiential value gained by medical tourists who participate in medical tourism.
R	Rewards for medical tourists under "seek accountability" and "strict supervision" strategies.
m	Probability of successful complaints by medical tourists under "loose supervision" strategy ($0 < m < 1$).
C_5	Costs of government departments under "strict supervision" strategy.
B	Benefits gained by government departments under "strict supervision" strategy
B'	Benefits gained by government departments under "loose supervision" strategy
p	Probability of successful investigation and prosecution by government departments under "forgo accountability" ($0 < p < 1$)

expected benefits are U_{21} and U_{22} , so the average expected benefit is U_2 .

$$U_{21} = xz(V - C_3 - C_4) + x(1-z)(V - C_3 - C_4) + z(1-x)(V - C_3 - C_4 - L_3 + R + C_0) + (1-x)(1-z)(V - C_3 - C_4 - L_3 + mC_0)$$

$$U_{22} = xz(V - C_3) + x(1-z)(V - C_3) + z(1-x)(V - C_3 - L_3) + (1-x)(1-z)(V - C_3 - L_3)$$

$$U_2 = yU_{21} + (1-y)U_{22}$$

For government departments, when choosing between strict supervision and loose supervision strategies, the expected benefits are U_{31} and U_{32} , respectively. Therefore, the average expected benefit is U_3 .

$$U_{31} = xy(B - C_5 - S) + x(1-y)(B - C_5 - S) + y(1-x)(B - C_5 - R + P_0) + (1-x)(1-y)(B - C_5 + pP_0)$$

$$U_{22} = xyB' + x(1-y)B' + y(1-x)B' + (1-x)(1-y)B'$$

$$U_3 = zU_{31} + (1-z)U_{32}$$

When medical institutions choose the active protection strategy, the replication dynamic equation is:

$$F(x) = \frac{dx}{dt} = x(U_{11} - U_1) = x(1-x)(U_{11} - U_{12}) = x(1-x) \left[y(L_2 - L_1 + mC_0) + z(S + pP_0) + yz(C_0 + P_0 - mC_0 - pP_0) + C_2 - C_1 - \Delta I \right]$$

When medical tourists choose “seek accountability” strategy, the replication dynamic equation is:

$$F(y) = \frac{dy}{dt} = y(U_{21} - U_2) = y(1-y)(U_{21} - U_{22}) = y(y-1) \left[xmC_0 - z(C_0 + R - mC_0) + xz(C_0 + R - mC_0) - mC_0 \right]$$

When government departments choose a strict supervision strategy, the replication dynamic equation is:

$$F(z) = \frac{dz}{dt} = z(U_{31} - U_3) = z(1-z)(U_{31} - U_{32}) = z(z-1) \left[x(S + pP_0) + y(R - P_0 + pP_0) - xy(R - P_0 + pP_0) + B' - B + C_5 - pP_0 \right]$$

3.4 Replicator dynamic equations for a three-party game

Based on the analysis of the expected benefits for the three parties involved in the game, the replicator dynamic equation can be derived.

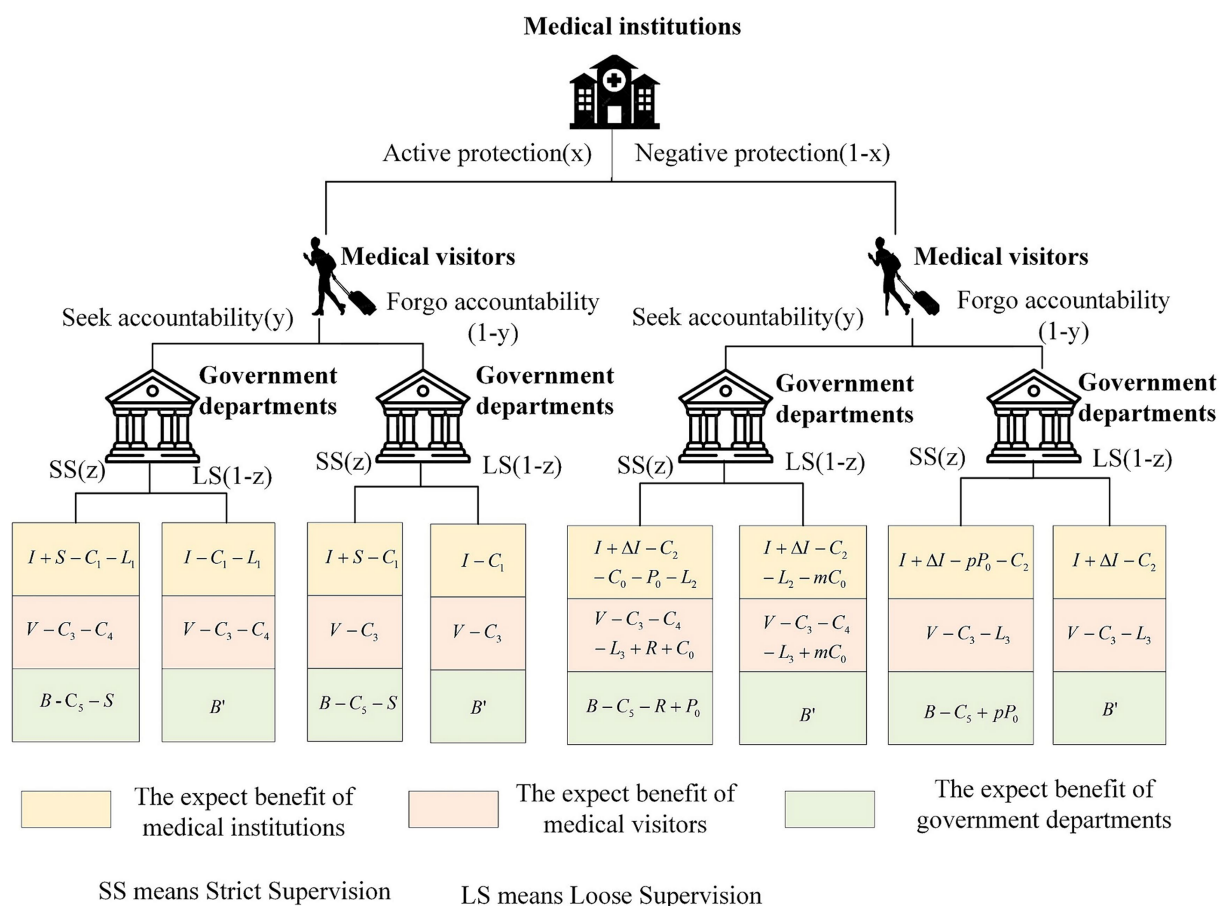


FIGURE 1
Benefits of each player.

The three equations $F(x)$, $F(y)$, and $F(z)$ are combined to create a replicator dynamic set of equations, namely:

$$\begin{cases} F(x) = x(1-x) \left[\frac{y(L_2 - L_1 + mC_0) + z(S + pP_0)}{+yz(C_0 + P_0 - mC_0 - pP_0) + C_2 - C_1 - \Delta I} \right] \\ F(y) = y(y-1) \left[\frac{xmC_0 - z(C_0 + R - mC_0)}{+xz(C_0 + R - mC_0) - mC_0} \right] \\ F(z) = z(z-1) \left[\frac{x(S + pP_0) + y(R - P_0 + pP_0)}{-xy(R - P_0 + pP_0) + B' - B + C_5 - pP_0} \right] \end{cases}$$

4 Model analysis

Based on the replicator dynamic equation system presented above, when $F(x)=0$, $F(y)=0$, and $F(z)=0$, there are 8 partial equilibrium points that can be calculated as $E_1(0,0,0)$, $E_2(0,0,1)$, $E_3(0,1,0)$, $E_4(0,1,1)$, $E_5(1,0,0)$, $E_6(1,0,1)$, $E_7(1,1,0)$, $E_8(1,1,1)$. Among these points, $E_1(0,0,0)$ represents the equilibrium for the choices of “negative protection” by medical institutions, “forgo accountability” by medical tourists, and “loose supervision” by government departments. The other seven points have analogous interpretations. The asymptotically stable solution of the multi-group evolutionary game replicating dynamic system must be a strict Nash equilibrium solution, and it is a pure strategic Nash equilibrium (50). Thus, none of the state points are asymptotically stable, except for the eight local equilibria mentioned above, are asymptotically stable. Based on this, the stability of the evolutionary strategy of each participant in this game model is analyzed. Firstly, this study analyzes the asymptotic stability of medical institutions, medical tourists, and government departments. It then explores the evolutionary stability of the privacy protection system for medical tourists in the context of these measures.

4.1 Stability analysis of medical institutions

When analyzing the stability of medical institutions, the evolutionary stabilization strategy of medical institutions, denoted as x , is determined based on the replicator dynamic equation theorem, given $F(x)=0$ and $F'(x)<0$. Setting $F(x)=0$, three solutions can be obtained: $x=0$, $x=1$, and $y = [\Delta I + C_1 - C_2 - z(S + pP_0)] / [L_2 - L_1 + mC_0 + z(C_0 + P_0 - mC_0 - pP_0)]$. For ease of presentation, $[\Delta I + C_1 - C_2 - z(S + pP_0)] / [L_2 - L_1 + mC_0 + z(C_0 + P_0 - mC_0 - pP_0)]$ is simplified as Π_1 . When $y = \Pi_1$, $F(x)=0$, thus x takes any value in the interval is a steady state, and the probability of medical institutions' strategy choice will not change over time. When $y \neq \Pi_1$, consider the two strategies for medical institutions, where $x=0$ and $x=1$. The analysis regarding the stability of the group is divided into the following two scenarios: ① When $0 < y < \Pi_1$, it can be judged that $F'(0) < 0$ and $F'(1) > 0$, therefore $x=0$ is the evolutionary stabilization point. This indicates that when the probability that medical tourists choose to hold accountable is lower than Π_1 , the medical institutions will choose a negative protection strategy. ② When $\Pi_1 < y < 1$, it can be judged

that $F'(0) > 0$ and $F'(1) < 0$, therefore $x=1$ is the evolutionary stabilization point. This indicates that when the probability that medical tourists choose to hold accountable is higher than Π_1 , the medical institutions will choose an active protection strategy.

4.2 Stability analysis of medical tourists

When analyzing the stability of medical tourists, in accordance with the replicator dynamic equation theorem and considering situations $F(y)=0$ and $F'(y)<0$, the evolutionary stabilization strategy of medical tourists will be determined and denoted as y . Setting $F(y)=0$, three solutions can be obtained: $y=0$, $y=1$, and $z = (mC_0 - mC_0x - C_4) / [(x-1)(C_0 + R - mC_0)]$. For ease of presentation, $(mC_0 - mC_0x - C_4) / [(x-1)(C_0 + R - mC_0)]$ is simplified as Π_2 . When $z = \Pi_2$ and $F(y)=0$, y can take any value within the interval, resulting in a steady state, and the probability of medical tourists' strategy choice will not change over time. For $z \neq \Pi_2$, consider $y=0$ and $y=1$ as the two potential strategies for medical tourists. The analysis regarding the stability of the group is divided into the following two scenarios: ① When $0 < z < \Pi_2$, it can be judged that $F'(0) > 0$ and $F'(1) < 0$, therefore, $y=1$ is the evolutionary stabilization point. This suggests that if the probability of government departments opting for strict supervision is below Π_2 , medical tourists will favor seeking accountability strategies. ② When $\Pi_2 < z < 1$, it can be judged that $F'(0) < 0$ and $F'(1) > 0$, therefore, $y=0$ is the evolutionary stabilization point. This implies that if the probability of government departments opting for strict supervision exceeds Π_2 , medical tourists will lean toward strategies forgoing accountability.

4.3 Stability analysis of government departments

When analyzing the stability of government departments, the evolutionary stabilization strategy of this group will be determined and denoted as z . This analysis is based on the replicator dynamic equation theorem and takes into consideration situation $F(z)=0$ and $F'(z)<0$. Setting $F(z)=0$, three solutions can be obtained: $z=0$, $z=1$, and $x = [B + pP_0 - B' - C_5 - y(R - P_0 + pP_0)] / [S + pP_0 - y(R - P_0 + pP_0)]$. For ease of presentation, $[B + pP_0 - B' - C_5 - y(R - P_0 + pP_0)] / [S + pP_0 - y(R - P_0 + pP_0)]$ is simplified as Π_3 . When $x = \Pi_3$ and $F(z)=0$, z can take any value within the interval, leading to a steady state, and the probability of government departments' strategy choice will not change over time. When $x \neq \Pi_3$, consider $z=0$ and $z=1$ as the two potential strategies for government departments. The analysis regarding the stability of the group is divided into the following two scenarios: ① When $0 < x < \Pi_3$, it can be judged that $F'(0) > 0$ and $F'(1) < 0$, therefore $z=1$ is the evolutionary stabilization point. This indicates that when the probability that medical institutions choose an active protection strategy is lower than Π_3 , the government departments will choose strict supervision strategies. ② When $\Pi_3 < x < 1$, it can be judged that $F'(0) < 0$ and $F'(1) > 0$, therefore, $z=0$ is the evolutionary stabilization points. This indicates that when the probability of medical institutions choosing an active protection strategy is higher than Π_3 , government departments will choose loose supervision strategies.

4.4 Stability analysis of the decision-making system for privacy-protecting behaviors of medical tourists

The stability of the decision-making system concerning the privacy-protecting behaviors of medical tourists can be assessed by analyzing the eigenvalues of the Jacobian matrix. According to the first law of Lyapunov, if all the eigenvalues of the matrix are negative, the point is considered to be an asymptotically stable equilibrium point (51). Conversely, if there are positive eigenvalues, the point is considered unstable. The Jacobian matrix of the decision-making system for privacy protection behavior of medical tourists is as follows:

$$J_{(x,y,z)} = \begin{bmatrix} \frac{\partial F(x)}{\partial x} & \frac{\partial F(x)}{\partial y} & \frac{\partial F(x)}{\partial z} \\ \frac{\partial F(y)}{\partial x} & \frac{\partial F(y)}{\partial y} & \frac{\partial F(y)}{\partial z} \\ \frac{\partial F(z)}{\partial x} & \frac{\partial F(z)}{\partial y} & \frac{\partial F(z)}{\partial z} \end{bmatrix} = \begin{bmatrix} F_{11} & F_{12} & F_{13} \\ F_{21} & F_{22} & F_{23} \\ F_{31} & F_{32} & F_{33} \end{bmatrix}$$

In the above formula:

$$F_{11} = (1-2x) \left[y(L_2 - L_1 + mC_0) + z(S + pP_0) + yz(C_0 + P_0 - mC_0 - pP_0) + C_2 - C_1 - \Delta I \right]$$

$$F_{12} = x(1-x) \left[L_2 - L_1 + mC_0 + z(C_0 + P_0 - mC_0 - pP_0) \right]$$

$$F_{13} = x(1-x) \left[S + pP_0 + y(C_0 + P_0 - mC_0 - pP_0) \right]$$

$$F_{21} = y(y-1) \left[mC_0 + z(C_0 + R - mC_0) \right]$$

$$F_{22} = (2y-1) \left[xmC_0 - z(C_0 + R - mC_0) + xz(C_0 + R - mC_0) + C_4 - mC_0 \right]$$

$$F_{23} = y(y-1) \left[-(C_0 + R - mC_0) + x(C_0 + R - mC_0) \right]$$

$$F_{31} = z(z-1) \left[S + pP_0 - y(R - P_0 + pP_0) \right]$$

$$F_{32} = z(z-1) \left[R - P_0 + pP_0 - x(R - P_0 + pP_0) \right]$$

$$F_{33} = (2z-1) \left[x(S + pP_0) + y(R - P_0 + pP_0) - xy(R - P_0 + pP_0) + B' - B + C_5 - pP_0 \right]$$

By incorporating each of the eight equalization points $E_1(0,0,0)$, $E_2(0,0,1)$, $E_3(0,1,0)$, $E_4(0,1,1)$, $E_5(1,0,0)$, $E_6(1,0,1)$, $E_7(1,1,0)$, and $E_8(1,1,1)$ into the Jacobian matrix, the corresponding eigenvalues will be obtained, as presented in Table 2.

In a real-world scenario, the initial parameters should satisfy the conditions $R + C_0 - C_4 > 0$ and $B - C_5 - S - B_2 > 0$. This implies that medical tourists receive greater compensation from medical institutions and rewards from government departments in the event of successful litigation than the costs of their legal proceedings. Additionally, the economic and social benefits of strict supervision by government departments exceed the gains from lax supervision. Based on previous assumptions, namely $C_1 > C_2$, $L_1 < L_2$, $B > B'$, and $C_0 < C_4$, the equilibrium points $E_1(0,0,0)$, $E_2(0,0,1)$, $E_3(0,1,0)$, $E_4(0,1,1)$, $E_5(1,0,0)$, and $E_8(1,1,1)$ do not satisfy the conditions necessary for determining the sign of the eigenvalue of a stable point. The eigenvalue sign determinations for $E_6(1,0,1)$ and $E_7(1,1,0)$ warrant further discussion. Based on the provided conditions, the stability analysis for each equilibrium point can be found in Table 3.

As can be seen from Table 3, the evolutionary game equilibrium of the behavioral strategies of subjects involved in protecting the privacy of medical tourists is influenced by various factors. The detailed analysis of the two evolutionary stabilization strategies $E_6(1,0,1)$ and $E_7(1,1,0)$ are as follows:

When $S - C_1 > \Delta I - C_2 - pP_0$ and $B' < B - C_5 - S$, $E_6(1,0,1)$ — represented as (active protection, forgo accountability, strict supervision) — emerges as an evolutionary stabilization strategy. Under these conditions: ① The difference between the government subsidy and the costs borne by medical institutions for actively protecting the privacy of medical tourists exceeds the gap between the profit they earn from breaching this privacy and the combined expenses and fines levied by government departments. Given this, medical institutions have a stronger inclination to prioritize the protection of medical tourists' privacy. ② In situations where medical institutions proactively ensure privacy and face strict government regulations, medical tourists adopting seeking accountability strategy end up shouldering the related costs without any accompanying compensation. Consequently, the "forgo accountability" option is more appealing for medical tourists. ③ When the overall benefits obtained by government departments from actively supervising the privacy protection behaviors of medical institutions exceed the costs of active supervision and the subsidies for the institutions' proactive protection actions, and are greater than the economic and social benefits from passive supervision, the government departments, based on the principle of maximizing benefits, have sufficient motivation to maintain the order of the medical tourism market development and to actively oversee the privacy protection measures of medical institutions.

When $S - L_1 - C_1 < \Delta I - C_2 - L_2 - C_0 - P_0$, $C_4 < C_0 + R$ and $B - C_5 - R + P_0 > B'$, $E_7(1,1,0)$, representing the (negative protection, seek accountability, strict supervision) strategy, emerges as an evolutionary stabilization strategy. The primary reason behind this outcome is the disparity between the profits gained and potential repercussions for medical institutions that compromise the privacy of medical tourists. This includes costs arising from breaches of privacy, reputation damage, potential compensation to affected tourists, and fines imposed by government departments. This disparity outweighs the difference between government subsidies, the cost of proactive

TABLE 2 Eigenvalues of the Jacobian matrix.

Balance points	Eigenvalue λ_1	Eigenvalue λ_2	Eigenvalue λ_3
$E_1(0,0,0)$	$C_2 - C_1 - \Delta I$	$-(C_4 - mC_0)$	$-(B' - B + C_5 - pP_0)$
$E_2(0,0,1)$	$-(C_2 - C_1 - \Delta I)$	$-C_4$	$-(S + B' - B + C_5)$
$E_3(0,1,0)$	$L_2 - L_2 + mC_0 + C_2 - C_1 - \Delta I$	$C_4 - mC_0$	$-(R - P_0 + B' - B + C_5)$
$E_4(0,1,1)$	$S + pP_0 + C_2 - C_1 - \Delta I$	$-(C_4 - C_0 - R)$	$B' - B + C_5 - pP_0$
$E_5(1,0,0)$	$-(L_2 - L_2 + mC_0 + C_2 - C_1 - \Delta I)$	C_4	$-(S + B' - B + C_5)$
$E_6(1,0,1)$	$-(S + pP_0 + C_2 - C_1 - \Delta I)$	$-C_4$	$S + B' - B + C_5$
$E_7(1,1,0)$	$L_2 - L_1 + S + C_0 + P_0 + C_2 - C_1 - \Delta I$	$C_4 - C_0 - R$	$R - P_0 + B' - B + C_5$
$E_8(1,1,1)$	$-(L_2 - L_1 + S + C_0 + P_0 + C_2 - C_1 - \Delta I)$	C_4	$S + B' - B + C_5$

TABLE 3 Stability analysis of equilibrium points.

Balance points	Eigenvalue λ_1	Eigenvalue λ_2	Eigenvalue λ_3	Stability conditions
$E_1(0,0,0)$	—	—	+	Unstable point
$E_2(0,0,1)$	+	—	+	Unstable point
$E_3(0,1,0)$	\pm	+	\pm	Unstable point
$E_4(0,1,1)$	\pm	+	—	Unstable point
$E_5(1,0,0)$	\pm	+	+	Unstable point
$E_6(1,0,1)$	\pm	—	—	When $S - C_1 > \Delta I - C_2 - pP_0$, it's an evolutionary stabilization strategy.
$E_7(1,1,0)$	\pm	—	\pm	When $S - L_1 - C_1 < \Delta I - C_2 - L_2 - C_0 - P_0$ and $B - C_5 - R + P_0 > B'$, it's an evolutionary stabilization strategy.
$E_8(1,1,1)$	\pm	+	—	Unstable point

protection, and the reputational damage to medical tourists when they are erroneously held accountable. Consequently, medical institutions frequently choose negative protection measures to prioritize their interests. When medical tourists experience privacy breaches and decide to hold medical institutions accountable, the total compensation they receive, combined with the government's rewards, surpasses the cost of seeking accountability. In this scenario, holding medical institutions responsible is the most favorable strategy for medical tourists. Regarding government departments, they stringently monitor the malpractices of medical institutions. Even though they shoulder the costs of regulation and incentives for medical tourists, they also levy fines on medical institutions for any breaches. Nevertheless, the net benefit ($B - C_5 - R + P_0$) still surpasses the economic and social benefits B' derived from the government's lenient supervision approach. Thus, the government department leans toward a "strict supervision" strategy.

Comparing the two evolutionary stabilization strategies mentioned above and considering the processes of collecting, utilizing, and safeguarding the privacy of medical tourists, the optimal strategy for evolutionary stabilization should be $E_6(1,0,1)$. In other words, the optimal strategy is achieved when medical institutions choose "active protection," medical tourists opt for "forgo accountability," and government departments select "strict supervision." In this case, medical institutions demonstrate a strong subjective initiative in the process of collecting, storing, sharing, and analyzing the private

information of medical tourists during the provision of medical services. Under the strict supervision of government departments, they continuously optimize privacy protection technologies and systems to help prevent unauthorized access, tampering, and disclosure of medical tourists' personal information. This fortifies the foundation for the sustainable development of the medical tourism industry. Beyond experiential value, the effective protection of personal information has become the primary concern for medical tourists. The collaboration between medical institutions and government departments in fostering a robust medical tourism market and enhancing the healthcare environment can diminish privacy and security worries for medical tourists. In turn, this encourages tourists to actively and willingly engage in medical tourism activities. As an emerging industry, the medical tourism sector is pivotal in stimulating domestic demand, stabilizing economic growth, creating job opportunities, elevating people's quality of life, and ensuring the health of residents. It stands as one of the future industries in healthcare poised to boost regional competitiveness.

5 Simulation analysis

To more clearly and intuitively depict the dynamic evolution process of strategy choices among medical institutions, medical tourists, and government departments, the Matlab R2016b software is

employed to numerically simulate the established three-party evolution game model. The primary goal is to compare the effects of various participants on the protection of medical tourists' privacy under a system of incentives and penalties. This study aims to understand the principles and regulations that govern the impact of government departments' regulatory methods and efforts on the effectiveness of privacy protection for medical tourists, especially when there's limited supervision cost. Specifically, the study examines how punitive measures imposed by government departments on medical institutions, the compensation provided by these institutions to medical tourists, the subsidies from government departments to medical institutions, and the rewards given to medical tourists for lodging valid complaints influence the dynamics of this evolutionary game.

5.1 The effect of reward and punishment factors on the evolutionary path of participating subjects in the scenario $E_6(1,0,1)$

In light of the current situation and the stability analysis conditions of $E_6(1,0,1)$, the initial values of the parameters used in this study are provided in Table 4. For the behavioral strategy choices in the three-party evolutionary game, the initial probabilities of strategy choices for medical institutions, medical tourists, and government departments are set to $(x=0.5, y=0.5, z=0.5)$. This setup allows for simulation under various reward and punishment intensities.

5.1.1 The effect of different initial strategy selection probabilities on the evolutionary path of participating subjects

This study assumes that the initial probability for a medical institution to choose the "active protection" strategy is x_0 , for medical tourists to select the "seek accountability" strategy is y_0 , and for government departments to opt for the "strict supervision" strategy is z_0 . The combined initial probability for the tripartite evolutionary game system is represented as (x_0, y_0, z_0) . We consider three sets of probability values: $(0.2, 0.2, 0.2)$, $(0.5, 0.5, 0.5)$, and $(0.8, 0.8, 0.8)$. The evolutionary trajectories based on these initial probabilities are illustrated in Figure 2.

The key observations from Figure 2 are as follows: Medical institutions, when leaning toward the "active protection" strategy from the onset, exhibit a faster evolutionary speed, which reduces the time required to achieve strategy stability. Their decision-making is swift and independent, often tailored to their specific circumstances and benefits. Across all initial probabilities, medical tourists predominantly opt for the "forgo accountability" strategy. With an initial probability of 0.2, there's a preference for the "seek accountability" strategy, but this gradually shifts to "forgo accountability." The most rapid stabilization is observed when the initial probability is 0.5. This suggests that medical tourists' behaviors are influenced by public

sentiment and are characterized by a pattern of learning and conformity. Regardless of variations in initial probability, the time taken for government departments to stabilize their strategy remains consistent. This indicates a characteristic stability in their strategic evolution.

5.1.2 The effect of the government department's punishment of medical institutions on the behavior of the three-party evolutionary game

In order to represent varying degrees of punishment, it is assumed that P_0 takes the values of 30, 20, and 10, symbolizing high, medium, and low punishment levels, respectively. Figure 3 depicts the simulation results of the three parties under these different punishment strengths.

The results indicate that escalating penalties imposed by the government can expedite the attainment of the evolutionary stable state in the three-party evolutionary game system. For medical institutions, a rise in government fines directly increases the cost of neglectfully protecting the privacy of medical tourists. Such fines deter opportunistic behaviors by medical institutions aiming to benefit at the expense of the privacy of medical tourists, thus steering the strategy evolution toward "active protection."

For medical tourists, irrespective of the punishment's severity, they consistently lean toward "forgo accountability" strategies. Notably, evolution is swifter with stiffer penalties. In other words, the more stringent the fines imposed by government departments for privacy breaches, the more inclined medical tourists are to opt for a "forgo accountability" strategy. This inclination stems from medical tourists' heightened trust in robust government regulation underpinned by stringent penalties. With this trust, they believe their privacy will be effectively upheld, rendering them less likely to hold medical institutions accountable.

For government departments, the three penalty tiers exhibit minimal influence over the likelihood of them selecting the "strict supervision" strategy. Nonetheless, there's a discernible acceleration in evolution as penalty levels escalate. The reason being, under the purview of government departments with stringent penalties, medical institutions more actively safeguard the privacy of medical tourists, thereby amplifying societal benefits. This enhancement aligns with the primary objective of government departments' proactive regulation. Hence, punitive measures emerge as a pivotal regulatory instrument for government departments in ensuring the seamless functioning of the medical tourism market.

5.1.3 The effect of medical institutions' compensation efforts for medical tourists on the behavior of the three-party evolutionary game

To investigate the influence of compensation levels offered by medical institutions on the evolutionary trajectory of the tripartite behaviors, we assign values of 8, 5, and 2 to C_0 , representing high, medium, and low compensation strengths, respectively. The simulation results under these different compensation levels are presented in Figure 4.

TABLE 4 Initial value of the parameter.

Parameters	C_1	C_2	C_4	C_5	L_1	L_2	I	ΔI	S	R	B	B'	C_0	P_0	p	m
Initial value	20	10	5	25	8	20	25	20	35	10	90	20	5	20	0.1	0.05

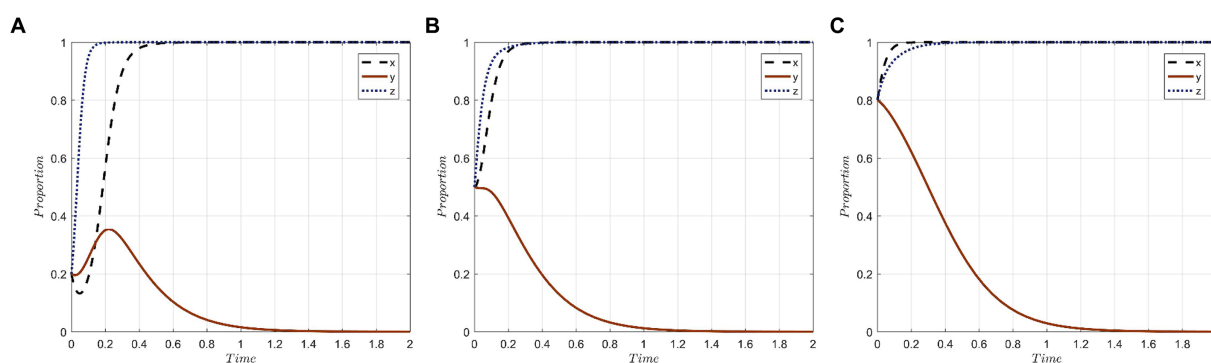


FIGURE 2

Evolutionary trajectories of the system under different initial probabilities of x, y, z : (A) The initial probability is 0.2; (B) The initial probability is 0.5; (C) The initial probability is 0.8.

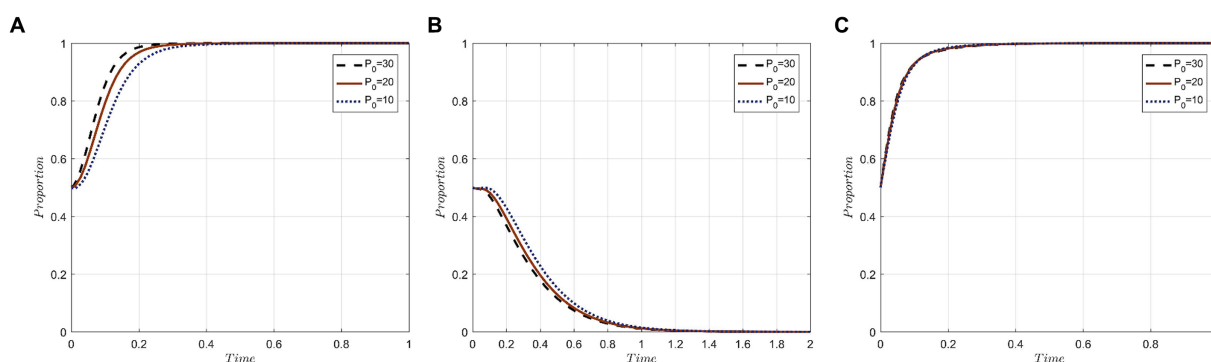


FIGURE 3

Evolutionary trajectory of tripartite behavior under different punishment strengths: (A) Evolutionary trajectories of x ; (B) Evolutionary trajectories of y ; (C) Evolutionary trajectories of z .

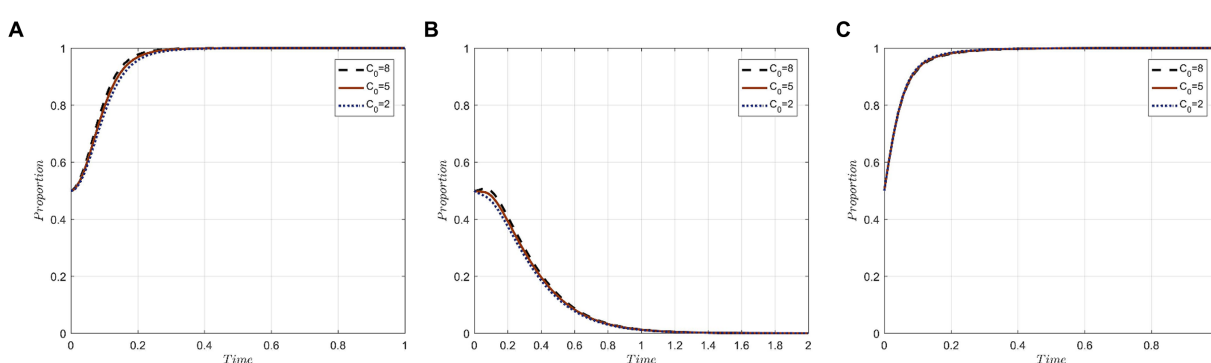


FIGURE 4

Evolutionary trajectory of tripartite behavior under different levels of compensation: (A) Evolutionary trajectories of x ; (B) Evolutionary trajectories of y ; (C) Evolutionary trajectories of z .

The results indicate that compensation levels significantly impact the strategic choices of both medical institutions and medical tourists. However, the government sector remains relatively unaffected by these variations. The rationale behind this lies in the core objectives of each party.

For medical institutions, their primary goal is revenue generation and profit maximization through the provision of medical tourism services. Although employing a negative protection strategy could lead to cost savings and potential profits from unauthorized privacy disclosures, the costs associated with violations increase with the

magnitude of the required compensation when breaches are identified and penalized. Thus, facing higher compensation demands makes medical institutions more inclined toward the “active protection” strategy.

For medical tourists, their participation in medical tourism aims at physical rejuvenation, mental well-being, and overall satisfaction. When their privacy gets compromised, it tarnishes their perception of both the individual medical institutions and the broader medical tourism industry. In scenarios of higher compensation, medical tourists are increasingly motivated to hold the institutions accountable, both to protect their rights and to mitigate potential financial setbacks.

For government departments, their regulatory interventions precede the compensation actions by medical institutions. Consequently, the degree of compensation has a negligible influence on the strategic decisions of government entities.

5.1.4 The effect of government departments' subsidy strength to medical institutions on the behavior of the three-party evolutionary game

We assume values of 40, 35, and 30 for S , representing different levels of subsidies provided by government departments to medical institutions. The corresponding simulation results are depicted in Figure 5.

In the realm of medical institutions and medical tourists, the subsidy level offered by government departments serves as a direct indicator of governmental support for the growth of the medical tourism industry. This subsidy level also symbolizes a conducive market environment for the industry. Within such a setting, medical institutions tend to favor an “active protection” strategy, whereas medical tourists lean toward a “forgo accountability” approach. This dynamic facilitates value creation through collaboration among various stakeholders in the medical tourism sector.

As for government departments, a preference for “strict supervision” is observed across different subsidy levels. However, it's notable that when offering substantial subsidies to medical institutions, it takes a longer duration for these government departments to achieve strategic stability. Consequently, the magnitude of subsidy expenditure emerges as a pivotal factor influencing the strategic decisions of government departments.

5.1.5 The effects of government department incentives for medical tourists on the behavior of the three-way evolutionary game

Values of 15, 10, and 5 are assigned to R , representing the extent to which government departments reward medical tourists for holding medical institutions accountable when their privacy is breached. The simulation results are depicted in Figure 6. As observed in the figure, the strength of incentives influences the strategic choices of medical institutions. With medium and high reward strengths, medical institutions achieve an evolutionary stable state more swiftly. However, the impact of an exceedingly high reward strength on the strategic choices of medical institutions plateaus, with medium reward strength exerting the most influence. It suggests that moderate public scrutiny boosts the likelihood of medical institutions actively safeguarding medical tourists' privacy. For medical tourists, there's an initial inclination toward being swayed by regulatory incentives from government departments, advocating for active privacy protection by medical institutions. Over time, however, “forgo accountability” emerges as the predominant preference among medical tourists. Concurrently, the time required for medical institutions to achieve stability extends, pointing to an inverse relationship between evolutionary rate and incentive strength. To ensure a secure and structured medical tourism environment, government departments proactively regulate the market by incentivizing medical tourists to uphold responsible behaviors. The strict supervision approach of government departments remains relatively constant, regardless of incentive variations, underscoring their commitment to ensuring positive experiences for medical tourists. This promotes a healthy medical tourism industry, where the privacy of medical tourists is paramount for medical institutions.

5.2 The analysis of evolution path from $E_7(1,1,0)$ to $E_6(1,0,1)$

Given the initial parameters, S and P_0 are set to values of 5 and 6, respectively. These values ensure the parameter combinations meet the conditions for the evolutionary stabilization strategy $E_7(1,1,0)$: $S - I_1 - C_1 < \Delta I - C_2 - I_2 - C_0 - P_0$, $C_4 < C_0 + R$, while $B - C_5 - R + P_0 > B'$. For the pairs (S, P_0) , values (5, 6), (20, 13), and

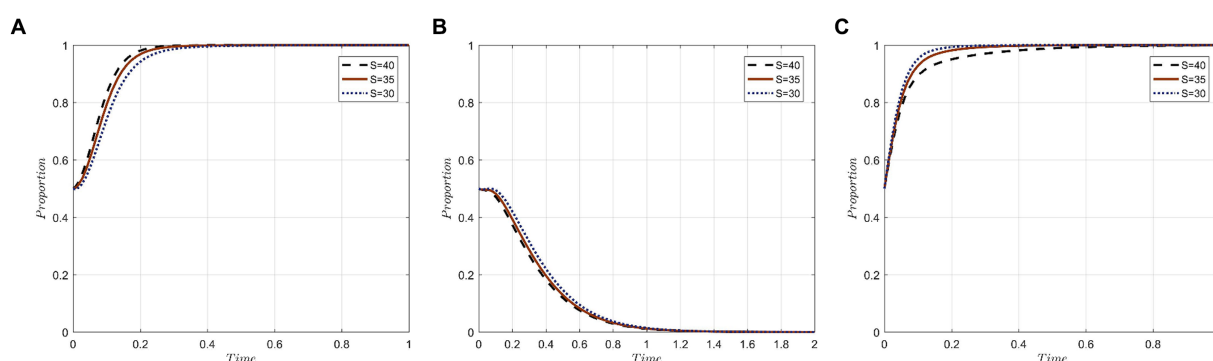


FIGURE 5

Evolutionary trajectories of tripartite behavior under different subsidy strengths: (A) Evolutionary trajectories of x ; (B) Evolutionary trajectories of y ; (C) Evolutionary trajectories of z .

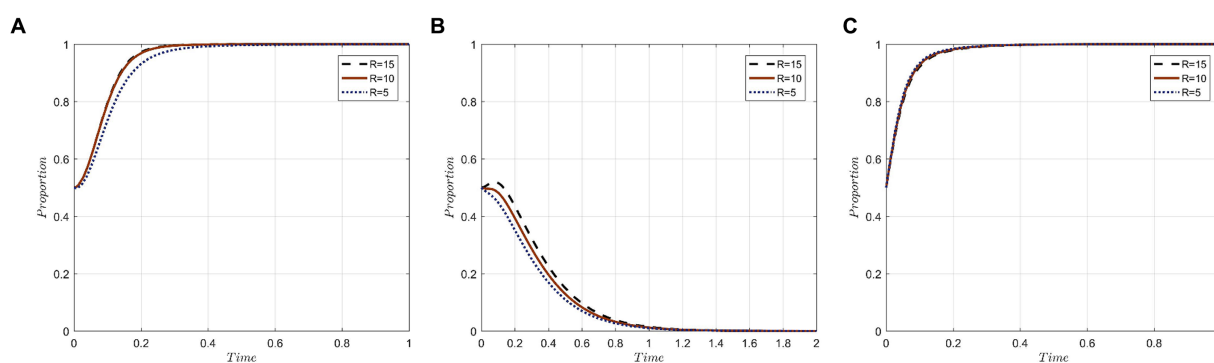


FIGURE 6

Evolutionary trajectory of tripartite behavior under different reward strengths: (A) Evolutionary trajectories of x ; (B) Evolutionary trajectories of y ; (C) Evolutionary trajectories of z .

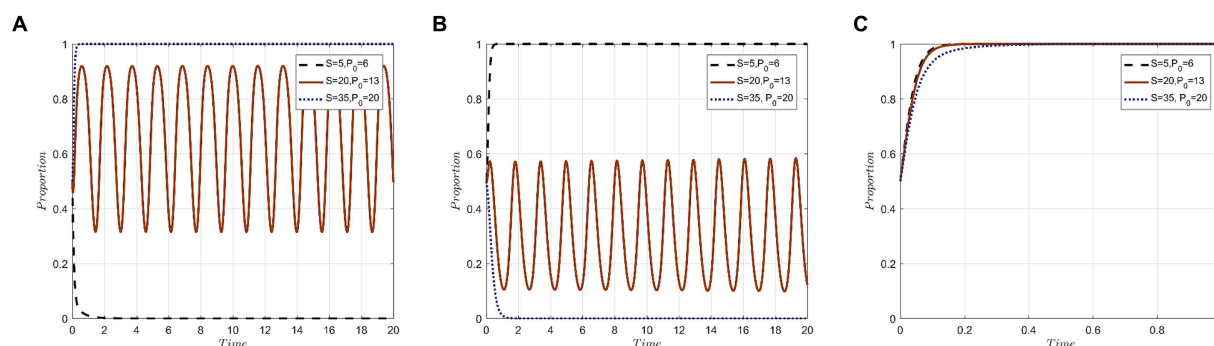


FIGURE 7

Evolution results of simultaneous changes of S and P_0 under condition $E_7(0,1,1)$: (A) Evolutionary trajectories of x ; (B) Evolutionary trajectories of y ; (C) Evolutionary trajectories of z .

(35, 20) are assigned to simulate scenarios where government departments amplify regulations alongside increasing subsidies and penalties. Starting from an initial state of (0.5, 0.5, 0.5), the outcomes are displayed in Figure 7. The evolutionary results pinpoint two transitions in the steady state of the tripartite game system: first, from $E_7(1,1,0)$ to an unstable state with no stabilization strategy, and second, from the unstable state to strategy $E_6(1,0,1)$. The end result highlights the “active protection” by medical institutions, “forgo accountability” by medical tourists, and “strict supervision” by government departments. This can be attributed to heightened regulatory efforts by government departments, which leads to compliant medical institutions gaining more in subsidies, while non-compliant ones face stiffer penalties. In an ecosystem balanced with ample incentives and strict punitive measures, medical institutions lean more toward safeguarding medical tourists’ privacy. When governmental oversight is lax, medical institutions might lean toward a “negative protection” strategy, reducing trust among medical tourists and prompting them to lean into “seek accountability” strategy. However, as governmental regulations tighten, marked by increased subsidies and penalties, the trust in medical institutions grows among medical tourists. Consequently, the strategy of medical tourists gradually shifts to “forgo accountability.”

6 Conclusion and limitations

6.1 Conclusion

Through an evolutionary game theoretic lens, two primary stable strategies have emerged: $E_6(1,0,1)$ and $E_7(1,1,0)$. Of these, $E_6(1,0,1)$ is identified as the pinnacle strategy for assuring medical tourists’ privacy. This optimal strategy is a confluence of the “active protection” by medical institutions, “forgo accountability” taken up by medical tourists, and the “strict supervision” by government departments. The stability of this evolutionary strategy is predominantly swayed by factors such as penalties from government bodies for lax privacy protection, compensations from institutions to tourists, governmental aids to institutions, and accolades to tourists who rightly pinpoint institutions for privacy lapses.

Simulations based on the preferred stabilization strategy, $E_6(1,0,1)$, reveal the following: decision-making by medical institutions is swift and autonomous; medical tourists’ decisions are influenced by learning and societal norms; and government actions remain consistent. Enhancing incentives and penalties bolsters institutions’ efforts to actively protect the privacy of medical tourists. Furthermore, when medical tourists receive significant incentives, either through compensation from institutions or rewards from the government,

there is a noticeable extension in the time required to converge to the “forgo accountability” evolutionary stabilization approach. This highlights the critical influence of tourists’ vested interests. An increase in governmental subsidies to medical institutions might deter their willingness for “strict supervision.” Exorbitantly high subsidy amounts increase the government’s regulatory costs, resulting in a more lenient supervision approach in the medical tourism market.

A recalibration of incentives and penalties by government bodies effectively encourages institutions to adopt “active protection,” guides tourists toward “forgo accountability,” and reinforces “strict supervision” by government departments. This recalibration facilitates a transition from strategy $E_7(1,1,0)$ to the optimal strategy $E_6(1,0,1)$, promoting sustainable medical tourism.

6.2 Implications

This study articulates strategies for a sustainable medical tourism industry, emphasizing regulatory cost management and a rational incentive system based on tripartite evolutionary game theory simulations. Government bodies are encouraged to optimize subsidies and penalties, focusing on merit-based rewards for medical institutions that excel in privacy protection. This approach aims to balance regulatory efficiency with fiscal prudence, promoting comprehensive privacy safeguards. Moderate penalties are recommended to avoid covert privacy breaches, while interdepartmental collaboration is highlighted as crucial for unified governance. The integration of advanced technologies and the establishment of an information disclosure platform are identified as key measures to enhance transparency and facilitate dual oversight. These strategies advocate for a sustainable medical tourism framework that prioritizes privacy protection, technological innovation, and transparent governance, ultimately improving the medical tourism experience by safeguarding patient privacy and enhancing service efficiency.

In light of the findings from an evolutionary game theoretic analysis of medical tourism, this study proposes several practical implications for academic scholars and organizations within the field. The identification of $E_6(1,0,1)$ as the optimal strategy for ensuring the privacy of medical tourists underscores the need for a multifaceted approach, encompassing active protection by medical institutions, a redefined sense of accountability among tourists, and stringent government supervision. To translate these insights into practice, it is recommended that scholars engage in further research to refine models simulating the effects of various incentive structures, thereby enriching the empirical basis for policy adjustments. Concurrently, organizations should leverage these insights to advocate for policy reforms that align with the optimal strategy, emphasizing the balance of incentives and penalties to encourage privacy protection without compromising the viability of the medical tourism sector. Additionally, educational initiatives aimed at stakeholders across the medical tourism spectrum can enhance understanding and implementation of best practices in privacy protection. The development of technological solutions, facilitated by collaborations between academics, technology firms, and medical tourism practitioners, can further support the enactment of the identified strategy. Finally, cross-sector collaboration is essential for fostering a unified approach to privacy protection, ensuring that the medical

tourism industry advances in a manner that is sustainable, ethical, and respectful of privacy rights. Through these concerted efforts, the theoretical insights derived from evolutionary game theory can be effectively applied to address the complex dynamics of privacy protection in medical tourism, contributing to the field’s ongoing development and the establishment of robust privacy safeguards.

6.3 Limitations

This study, centered on the evolutionary game model’s insights into the privacy protection behaviors of medical tourists, exhibits certain limitations. Primarily, the model may not encapsulate the entire spectrum of real-world intricacies inherent in the interactions among the principal actors: medical tourists, institutions, and government entities. The research somewhat confines itself to predetermined strategic sets, with a predominant focus on economic drivers, potentially sidelining psychological or cultural nuances. Furthermore, the primary emphasis on strategies $E_6(1,0,1)$ and $E_7(1,1,0)$ might restrict its universal applicability across diverse healthcare landscapes. Future research avenues could delve deeper into introducing varied strategic combinations, understanding non-economic determinants of behavior, and appraising the model’s validity across different healthcare systems. Incorporation of technological impacts on privacy strategies, given the ascent of digital health paradigms, remains a promising domain for subsequent inquiries.

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

RW: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. SG: 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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An unintended consequence of COVID-19 immunity passports—quasi-experimental evidence of moral hazard observed after implementing the domestic Green Pass policy during the second wave of the COVID-19 pandemic in Italy

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Objectives: Amidst the second wave of the COVID-19 pandemic, Italian policymakers mandated to exhibit evidence of vaccination or immunity (the Green Pass) as a condition to access retail premises and public offices. This study aims to offer evidence, in a quasi-experimental setting, suggesting that an unintended consequence of this policy was the emergence of moral hazard.

Methods: Google visit duration data measured the time customers typically spend on retail premises or public offices. A pairwise comparison of median visit time per premise was performed at a six-week interval before and after the introduction of the Green Pass.

Results: This study is the first to provide evidence of “ex-post” moral hazard associated with introducing a domestic Green Pass policy. The median visiting time on premises that required digital immunity control significantly increased after introducing the domestic Green Pass policy, contrary to other public premises where access remained free of limitations. The increase in median visit time in premises with faster customer turnaround, such as coffee shops (+49%) and fast-food restaurants (+45%), was lower than the increase observed for fine-dining restaurants (+74%) and pizzerias (+163%). No significant increase in median visit time was observed in premises where the Green Pass was not required, such as food supermarkets, retail non-food shops, post offices, banks, pharmacies, and gas stations.

Conclusion: The evidence of moral hazard highlights the critical issue of unintended consequences stemming from public health policies. This discovery is pivotal for policymakers, indicating that unforeseen behavioral adjustments could offset the intended benefits despite the intent to reduce risk through measures like the Green Pass.

KEYWORDS

public health policy, unintended consequences, moral hazard, COVID-19, immunity certificates, Green Pass policy

Introduction

Public health policies throughout the COVID-19 pandemic were characterized by rapid and decisive actions aimed at combining efforts to contain the spread of the disease and mitigate its impacts. The primary goal was to delay the pandemic's peak, ensure a more level distribution of the demand on limited healthcare resources, and protect vulnerable groups (1). The strict enforcement of policies in this unique situation also uncovered disagreements and showed how these decisions led to opinion differences among policymakers and the general public (2).

Given the significant changes brought about by the COVID-19 pandemic and its profound effects on societal norms, digital proof of immunity rapidly emerged as a contentious point of deliberation within most liberal democracies (3). The Green Pass, as it was commonly called in Italy, was an entry permit to public premises or facilities, a digital proof that an individual had either been vaccinated against COVID-19, received a negative test result, or recovered from COVID-19 (4).

Advocates emphasized that the Green Pass could potentially enhance freedom of movement, stimulate economic resurgence, and facilitate unhindered access to employment and educational avenues without compromising public health. Conversely, concerns abounded regarding their potential to precipitate unequal treatments, accentuate existing societal disparities, infringe on individual privacy rights, and inadvertently jeopardize public health by fostering complacency. An evolving body of academic work has begun to interrogate these ethical dimensions, offering a nuanced exploration of the advantages and pitfalls of such measures (5–7). Unintended responses to public health policies could lead to a maleficent “paradox effect” when riskier behaviors stem from heightened confidence (8).

Under severe epidemiological, economic, and social pressures, Italian policymakers began to explore the idea of a domestic Green Pass policy aimed at increasing the number of activities that could be subject to the possession of proof of vaccination or immunity. Therefore, since August 6, 2021, individuals showing their Green Pass would have complete freedom of access to indoor leisure activities such as restaurants, cafeterias, coffee shops, sports events, shows, museums, cultural exhibitions, swimming pools, gyms, and recreational facilities (9). The introduction of the domestic Green Pass policy was controversial, raising fierce media and political debates about its constitutional validity, practical impact on public health, respect for data privacy, and limitations of personal freedom (10).

The Green Pass domestic policy rests on a single epidemiological premise: individuals vaccinated or previously infected with COVID-19 who produce antibodies to the virus will then be immune to re-infection (at least for some nontrivial length of time) (11). Under this epidemiological condition, limiting access to public premises for Green Pass holders would create a sort of safe “immunity bubble” where the close contact risk of getting infected by COVID-19 would be virtually equal to zero. The Green Pass would implicitly signal to the community that the certificate holders were safe and others would be safe around them.

This study examines how the perceived “immunity” against COVID-19 risks possibly reduced risk-mitigating behaviors (ex-ante moral hazard). In economics, a moral hazard is a situation in which an economic actor has an incentive to increase its exposure to risk because it does not bear the full costs of that risk (12). In the

COVID-19 infectious disease context, moral hazard applies where individuals who possess a certificate of immunity, such as the Green Pass, may relax protective behaviors, consequently increasing chances of close contact exposure to COVID-19 (13).

The study's main aim is to provide quasi-experimental evidence of moral hazard determined by the certification of immunity by measuring differences in median visit duration by public premises and the consequent change in protective behavior observed among the holders before and after the introduction of the Green Pass.

The rationale behind the retrospective policy analysis of the domestic Green Pass implementation in Italy hinges on a single pivotal consideration. Understanding how the introduction of the Green Pass influenced individual and collective behaviors, the study seeks to assess whether the Green Pass motivated adherence to health measures or inadvertently led to complacency. The study is positioned to inform future policy adaptations where behavioral choices under moral hazard are rational and can be anticipated “ex-ante.”

Methods

Close contact risk of exposure to COVID-19

COVID-19 spreads mainly among people in close contact (14). When defining close contact, factors include proximity (closer distance likely increases exposure risk) and exposure duration (longer exposure time likely increases exposure risk). A working definition of the risk of exposure to COVID-19 for daily activities was developed based on the CDC's definition of close contact (15):

$$\text{Risk of exposure} = \text{crowding} \times \text{visit duration} \quad (1)$$

As recommended by the CDC, close contact should generally be determined irrespective of whether the contact was wearing respiratory personal protective equipment (PPE).

In Italy, maximum crowding standards are regulated by norms, which set the maximum number of people allowable for design purposes for each square meter of floor area concerning various categories of public offices and retail premises. In March 2020, a decree from the Prime Minister introduced urgent actions to mitigate the impact of the COVID-19 epidemiological crisis. It set a new maximum occupancy limit for all commercial premises based on the requirement to maintain a one-meter distance between individuals for social distancing (16). Consequently, since the introduction of the domestic Green Pass policy in August 2021, Equation (1) could be rewritten as the product of a constant (K_c) and visit duration Equation (2):

$$\text{Risk of exposure} = K_c \times \text{visit duration} \quad (2)$$

Data collection and inclusion

Google data was used to measure visit duration, the time customers typically spend on a specific retail premise or public office. Google uses aggregated and anonymized data from users who have opted for Google Location History. Data on visit duration indicate the

average amount of time (in minutes) customers spend in a particular location, such as a restaurant, coffee shop, or supermarket. These estimates are derived from analyzing patterns in customer visits over the preceding weeks. No personally identifiable information, such as an individual's location, contact, or movement, will be made available at any point (17).

Visit duration data was collected from all the Genoa metropolitan area retail activities visible on Google Maps and reported visit duration times. Interpreting mobility data in metropolitan areas required an in-depth understanding of urbanism and road mapping in the selected area. The choice of location was determined by the fact that the author was born and raised in a metropolitan area of Genoa. This methodological choice was consistent with Google's recommendation to avoid comparing places across regions because of local differences in the data, which might be misleading (18).

Visit duration times (in minutes) for individual premises located by Google Maps in the metropolitan area of Genoa, Italy, were then aggregated into median visit duration time (in minutes) by ten categories according to their primary use: coffee shops, fast food restaurants, pizzerias, fine-dining restaurants, food supermarkets, retail non-food shops, post offices, banks, pharmacies, and gas stations.

Two main factors informed the choice of the time interval between the two observations. The first was the date of introduction of the domestic Green Pass policy (August 6, 2021), which could not be anticipated ex-ante. The second was the availability of a convenience sample of visit duration data dated six weeks before the introduction of the Green Pass policy (June 28, 2021). Visit duration data had been collected following a method perfectly consistent with the one adopted for the second observation, and the data set had been published (19). Based on the date of the first implementation of the domestic Green Pass in Italy and the availability of a convenience sample collected six weeks before, the second sample of visit duration data was collected six weeks after the introduction of the domestic Green Pass (September 13, 2021).

Visit duration data were manually transcribed from Google Maps during two specific working weeks, with data collected within five consecutive days: from Monday, June 28th to Friday, July 2nd, 2021 (Observation 1) and from Monday, September 13th to Friday, September 17th, 2021 (Observation 2). The dates of the two observations spanned the summer season, reducing the bias of seasonality, which could have impacted visit duration and, consequently, changes in customers' behavior. This aspect is particularly relevant to the location of the study: Genoa, a medieval city on the Italian Riviera, is a popular resort rich in art and museums, with an evocative old town, a varied food and wine culture, and a sprawling seafront (Figure 1).

Google determines peak hours, expected wait times, and the length of visits by utilizing aggregated and anonymized data from users who have activated Google Location History. The average visit duration was displayed if a business receives sufficient visits from these users. This data will only appear if enough visitation data is available for that business through Google (20). Due to this limitation, the list of retail premises whose visit duration data were collected in the second observation did not match the list of premises included in the first observation. This discrepancy could lead to a methodological bias since premises grouped in the same cluster can have different features that can significantly impact visit time duration. For example, a coffee shop can have a bar counter and a few tables where the customers quickly consume an espresso or a soft drink. Another coffee

shop can have a patisserie and a vast seating area, inviting customers to a significantly longer visit time. Due to this limitation, there were discrepancies between retail premises with visit duration data for the first and second observation. Only retail premises with data for the first and second observations were included for analyses to reduce potential bias and ensure consistency between observations.

In normal distribution, the mean value per cluster would be used as a variable to be compared between observations. In contrast, the median value would have been the variable of choice in skewed distribution since outliers could distort the mean value (21). To reduce the bias of validity when including pairwise samples of premises showing different sizes (e.g., fine dining restaurant $n = 34$, and food supermarket $n = 155$), all mean/median values were resampled with replacement one thousand times (22).

The final sample was then clustered into ten groups of premises: four of which required the Green Pass (fine dining restaurants, pizzerias, fast food, and coffee shops) and six that did not require the Green Pass (food supermarkets, retail stores, banks, post offices, gas stations, and pharmacies).

The data collected for the study, including individual location data and a data dictionary defining each field in the set, are available in the [Supplementary material](#).

Hypothesis testing

As discussed earlier, since the introduction of the domestic Green Pass policy in Italy, the risk of exposure for each retail activity is dependent on a single variable: the visit duration time. Consequently, to test the moral hazard hypothesis, the following null hypothesis was formulated for each retail activity included in the sample:

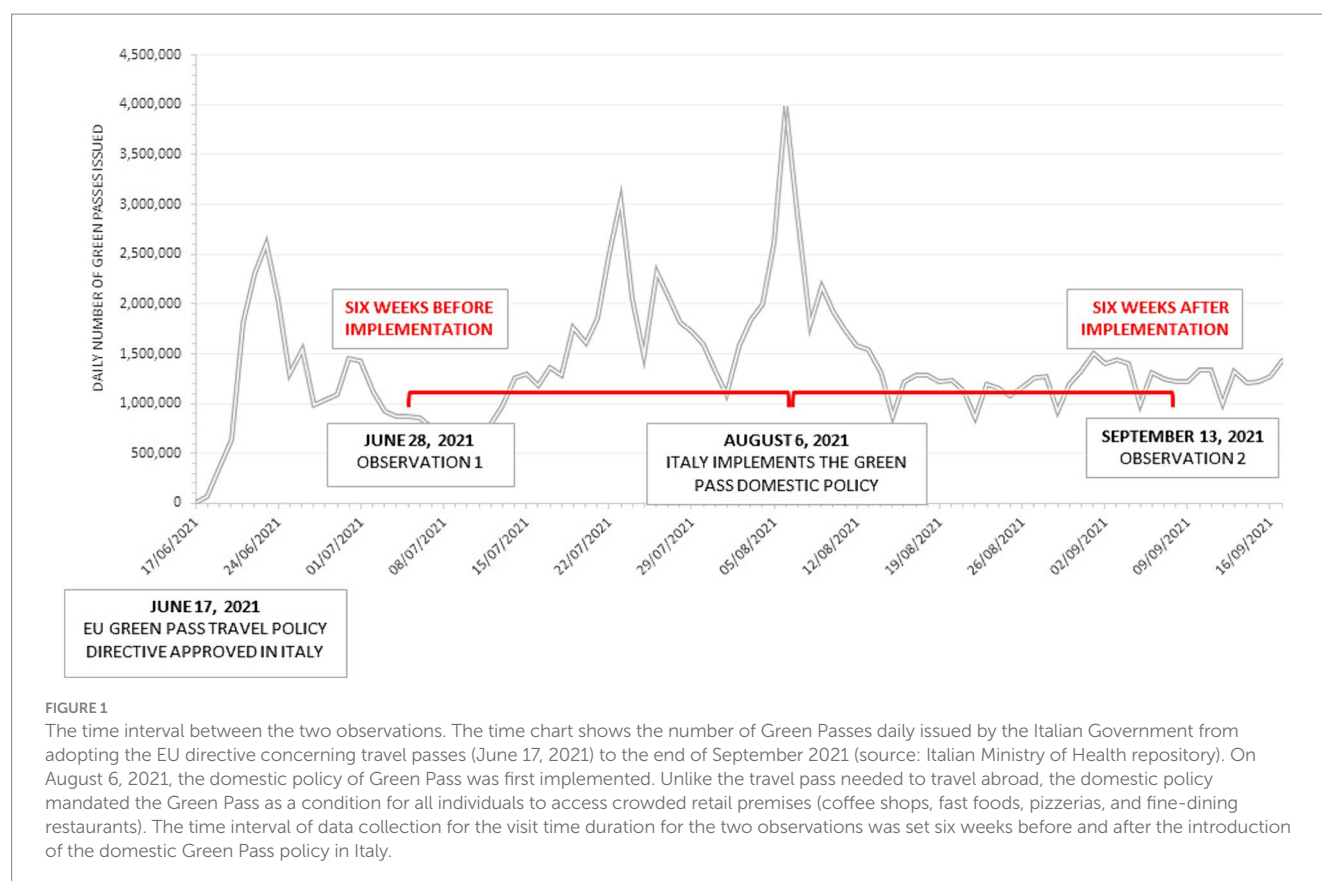
H_0 : Visit duration times obtained six weeks before and after the introduction of the domestic Green Pass policy have the same means/medians.

H_a : Visit duration times obtained six weeks before and after the introduction of the domestic Green Pass policy have different means/medians.

Suppose the null hypothesis H_0 cannot be rejected for all retail activities or most activities requiring Green Pass; in this case, the conclusion would be that implementing the domestic policy in Italy did not generate moral hazard, as previously defined. If the null hypothesis is rejected, accepting the alternative hypothesis implies that the mean/median visit time duration differed between the two observations. Suppose the mean/median visit duration time related to the premises that required a Green Pass increased. In that case, while the mean/median duration time of the premises where the Green Pass was not required did not change, then moral hazard was the unintended consequence of the introduction of the domestic Green Pass and ultimately resulted in a higher close contact risk of COVID-19 infection for the holders.

Data analysis

The choice of method for comparing mean/median visit duration time between the two observations will be informed by the normality



test of each sample of data aggregated by premises. In the case of normal distribution of the data, a one-way analysis of variance (ANOVA) will be used to compare whether paired samples' means are significantly different.

In case of skewed data distribution observed in each sample, medians will be first resampled with replacement (1,000 iterations). Then, the Mood test, a special case of Pearson's chi-squared test, will be used to compare pairwise medians. The Mood test is a non-parametric method for comparing k independent samples (23). The null hypothesis is that the distributions of k groups are equal. The Mood test assumes independence of observations and no assumption of normality. If Mood's median test result is significant, a post-hoc test will be conducted to investigate which medians differ (24).

XLSTAT statistical software for Excel by Addinsoft was used for resampling and statistical analysis.

Results

Significance of differences in median visit duration time by premise

The study included a total sample of 506 retail premises and public offices in the metropolitan area of Genoa, Italy. Typical visit duration time (in minutes) was reported by Google Maps and observed at two specific time points during the second half of 2021. The store data was then clustered into ten groups of premises according to their primary activity. A graphical representation of the pairwise comparison of the observed median visit time by premise seemed to indicate a significant

increase in the average time spent by customers in the premises where the Green Pass was mandatory compared to the premises that did not require the Green Pass as a condition to access (Figure 2).

Were these differences significant?

The normal distribution hypothesis was rejected for all data samples included in the analysis. Consequently, bootstrapped estimators of median values were obtained by resampling with 1,000 replacements for all samples included in the analysis. Moreover, the non-normality condition justified the choice of non-parametric tests, such as Mood's tests, to compare the bootstrapped estimators of median values.

The four premises with conditional access to the exhibition of the Green Pass (namely, coffee shops, fast foods, pizzerias, and fine-dining restaurants) showed a significant increase in visit duration time compared to the one observed before its introduction (June 28, 2021). On the other hand, the remaining stores or offices that did not require the Green Pass showed no noticeable increase in the typical time spent inside the premises.

Based on the observed data and the results of Mood's statistically significant differences in median values, the null hypothesis (H_0) that visit duration times obtained six weeks before and after the introduction of the domestic Green Pass policy have the same medians can be rejected. The alternative hypothesis (H_a) should be accepted: introducing the domestic Green Pass policy increased the median visit duration observed in the premises where possession was required.

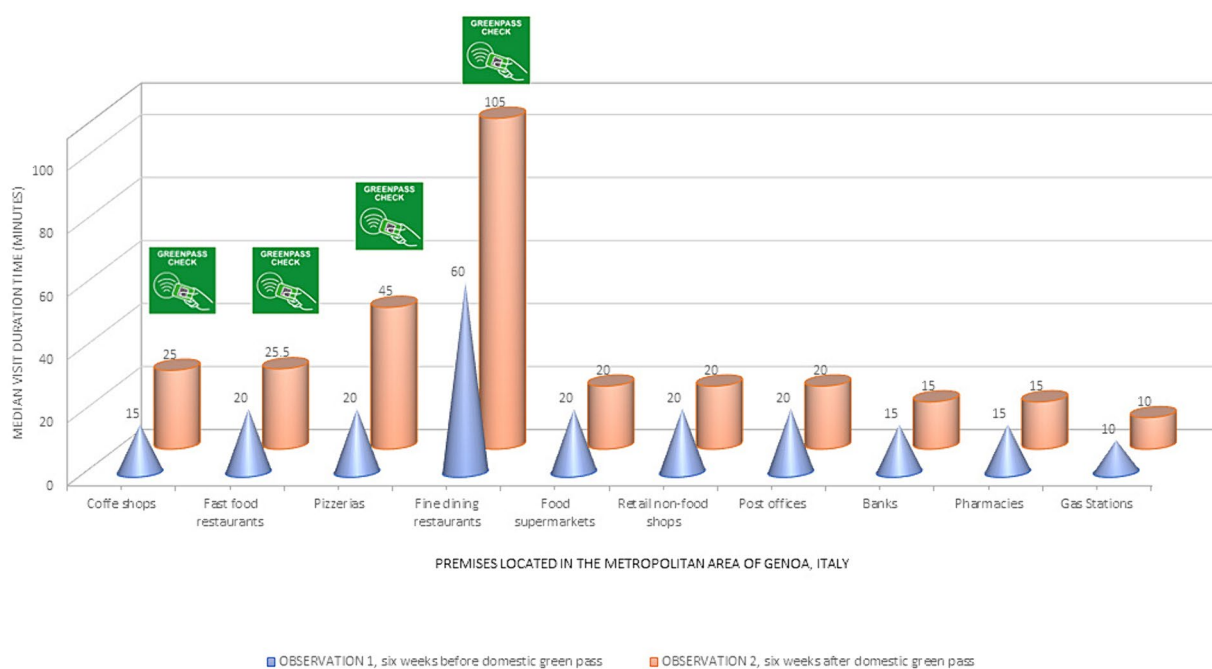


FIGURE 2

Median visit duration time for retail and public premises. The graph shows the median visit duration time (in minutes) obtained by Google Maps for the two samples of premises in the metropolitan area of Genoa, Italy, aggregated by main activity. The cones indicate the median visit time for the first observation (six weeks before the domestic Green Pass policy). The cylinders show the median visit time at the second observation (six weeks after the mandatory Green Pass). The label "Green Pass check" indicates the crowded premises where the pass was mandated as a condition to access (coffee shops, fast foods, pizzerias, and fine-dining restaurants).

Table 1 summarizes this study's main results, while the complete statistical analysis is available in the [Supplementary material](#).

What are the implications of this finding for public health?

Table 2, reported below, shows the horizontal and vertical analysis of the change in visit duration, which provides valuable insights into the incremental risk of exposure to COVID-19 observed after introducing the domestic Green Pass policy in Italy.

A horizontal comparison of visit duration times observed in similar premises at different time intervals showed that by the end of June 2021, just six weeks after the introduction of the domestic Green Pass, the time typically spent by customers in pizzerias more than doubled while the time spent in fine dining restaurants increased by 74.42%. In addition, the duration of visits for more casual and frequent activities in our everyday lives, such as getting an espresso in a coffee shop or grabbing a burger in a fast food restaurant, increased by 48.60 and 45.48%, respectively. The vertical analysis confirmed the relevance of the changes in typical visit time to the risk of close contact in the premises where the Green Pass was required. Relative to gas stations (risk = 1), introducing the Green Pass determined a significant increase in exposure in the four activities already at the highest risk of close contact. The close contact risk increased for restaurants (from 6.01 to 10.48), pizzerias (from 1.82 to 4.78), fast foods (from 1.84 to 2.67), and coffee shops (from 1.54 to 2.28). Restaurants (of any kind), coffee shops, and bars did not require customers to wear facial protection (masks) when having a meal or a drink. Consequently, after

introducing the domestic Green Pass policy, individuals paradoxically spent significantly more time on the premises that were most vulnerable to close contact risk.

On the other hand, the incremental and relative risk of exposure remained unchanged for all the premises where the Green Pass was not a condition of access.

Generalizing the outcomes by accepting the alternative hypothesis H_a , this study provided the first evidence of moral hazard observed after introducing a domestic Green Pass policy.

The introduction of the Green Pass indicated that social activities should remain a key priority to contain the spread of COVID-19.

Discussion

The COVID-19 pandemic has imposed an unprecedented social and economic burden on the global population. Although mass vaccination offers a promising exit strategy for the pandemic, limitations in personal freedom and social distancing have been enacted with varying degrees of severity at various points in time to contain the spread of the virus (25).

The benefits and challenges of the Green Pass remain controversial in the infection-acquired and vaccination-acquired immunity framework (26). In August 2021, Italy was the first mover to extend the remit of the Green Pass by enacting a domestic Green Pass policy to allow vaccinated individuals to return to their pre-COVID lives and do so safely. The domestic policy turned the Green Pass into proof of vaccination in a printed personal certificate or a digital version downloaded on a smartphone. As a result, the Green Pass became a

TABLE 1 Change in median visit duration time by premise after the implementation of the Green Pass domestic policy.

Retail premises and public offices		Sample <i>n</i> = 506	Observation 1 (28 June – 02 July, 2021)			Observation 2 (13–17 September, 2021)			OBS 1 v OBS 2 significance of paired differences
			Median visit duration time (minutes)	Resampled median (1,000 iterations; significance level = 5%)	Shapiro–Wilk test of normality <i>p</i> - value two- tailed (α 0.05) (*)	Median visit duration time (minutes)	Resampled median (1,000 iterations; significance level = 5%)	Shapiro–Wilk test of normality <i>p</i> - value two- tailed (α 0.05) (*)	Mood test <i>p</i> - value (α 0.05) (**)
Green Pass required	Coffee shops	39	15.00	15.35	<0.0001	25.00	22.81	0.001	0.002
	Fast food restaurants	26	20.00	18.36	0.015	25.50	26.71	<0.0001	0.001
	Pizzerias	36	20.00	18.17	<0.0001	45.00	47.82	0.002	<0.0001
	Fine dining restaurants	32	60.00	60.09	<0.0001	105.00	104.81	0.000	<0.0001
Green Pass not required	Food supermarkets	155	20.00	17.98	<0.0001	20.00	18.64	<0.0001	0.877
	Retail non-food shops	44	20.00	20.84	0.001	20.00	20.86	0.000	0.823
	Post offices	60	20.00	18.01	<0.0001	20.00	18.95	<0.0001	0.798
	Banks	37	15.00	15.00	0.000	15.00	14.99	<0.0001	1.000
	Pharmacies	80	15.00	15.00	<0.0001	15.00	15.00	<0.0001	0.634
	Gas stations	26	10.00	10.00	<0.0001	10.00	10.00	<0.0001	1.000

(*) Shapiro–Wilk test interpretation: H0: The variable from which the sample was extracted follows a normal distribution. H_a: The variable from which the sample was extracted does not follow a normal distribution. As the computed *p*-value is lower/higher than the significance level $\alpha=0.05$, one should reject/accept the null hypothesis H0, and accept/reject the alternative hypothesis H_a. (**) Mood test interpretation: H0: The medians of Observation 1 and Observation 2 are equal. H_a: Medians of Observation 1 and Observation 2 are not equal. As the computed *p*-value is lower/higher than the significance level $\alpha=0.05$, one should reject/accept the null hypothesis H0, and accept/reject the alternative hypothesis, H_a.

TABLE 2 Change in relative and incremental risk of exposure by premise after introducing the Green Pass domestic policy.

Retail premises and public offices		Resampled median visit duration time (minutes)			Relative risk of exposure (gas stations = 1)		Incremental risk of exposure after introduction of the Green Pass
		Observation		Significance of paired differences p -value (α 0.05) (*)	Observation		OBS 2 v OBS 1(%)
		1	2		1	2	
Green Pass required	Coffee shops	15.35	22.81	0.002	1.54	2.28	49%
	Fast food restaurants	18.36	26.71	0.001	1.84	2.67	45%
	Pizzerias	18.17	47.82	<0.0001	1.82	4.78	163%
	Fine dining restaurants	60.09	104.81	<0.0001	6.01	10.48	74%
Green Pass not required	Food supermarkets	17.98	18.64	0.877	1.80	1.86	4%
	Retail non-food shops	20.84	20.86	0.823	2.08	2.09	0%
	Post offices	18.01	18.95	0.798	1.80	1.90	5%
	Banks	15.00	14.99	1.000	1.50	1.50	0%
	Pharmacies	15.00	15.00	0.634	1.50	1.50	0%
	Gas stations	10.00	10.00	1.000	1.00	1.00	0%

(*) Interpretation of Mood test of difference in paired medians: H_0 : The medians of Observation 1 and Observation 2 are equal. H_a : Medians of Observation 1 and Observation 2 are not equal. As the computed p -value is lower/higher than the significance level $\alpha=0.05$, one should reject/accept the null hypothesis H_0 , and accept/reject the alternative hypothesis, H_a .

mandatory prerequisite to attend particularly high-risk events in any indoor setting, whether a dinner in a restaurant, a movie theater, or a sports match.

This study is the first to provide evidence of “ex-post” moral hazard associated with introducing a domestic Green Pass policy. The median visiting time on premises that required digital immunity control significantly increased after the policy was introduced, contrary to other public premises where access remained free of limitations.

COVID Pass’s “ex-ante” impact on moral hazard is unambiguous: conceptually, the marginal disutility of risk-mitigating behavior (social distancing) should equal the marginal benefit of self-protection. The marginal benefit of self-protection is simply the marginal change in the probability of infection times the difference in utility between the uninfected and infected states of the world (27). Since the Green Pass certifies immunity, it reduces the marginal disutility of health loss from infection virtually to zero, consequently reducing the incentives for self-protection. This substitution effect would argue that the COVID-19 domestic Green Pass policy should increase ex-ante moral hazard.

Policymakers could have anticipated the behavioral reaction of Green Pass holders to lifting any precaution while dining out or having coffee at a table in a coffee shop. Eating out is an essential part of the Italian lifestyle. Therefore, the prolonged closure of restaurants, followed by a severe limitation of their opening hours (takeaway and delivery only after 6 p.m.), generated a vast dissatisfaction in the population craving social contact after a full year of distancing. It was conceivable that, under the “immunity” premise, Green Pass holders would increase their typical visit duration in these premises since the utility gained from additional time spent in social activities was higher than the perceived risk (close to zero) of incremental close contact risk of COVID-19. Therefore, as shown by comparing median visit duration data,

citizens did just that. It was a rational behavioral choice, perfectly predictable.

Limitations

The research aims to establish the impact of the introduction of the domestic Green Pass on the duration of customers’ visits to various retail premises and public offices. While the study offers valuable insights into this topic, several potential limitations exist.

The study relies on Google data to measure visit duration, dependent on users opting for Google Location History. The sample may not be representative of the entire population. The data does not account for non-Google users or those who have turned off their location history, which might introduce bias. Only businesses with sufficient Google visitation data are included, potentially excluding numerous other businesses.

Data collection is limited to the metropolitan area of Genoa, Italy. Results might not be generalized to other cities or regions of Italy or countries with different sociocultural or economic contexts.

The two one-week observations took place over 12 weeks in the course of the summer season. Despite the intention to reduce seasonality bias, this timeframe might not fully capture the domestic Green Pass policy’s long-term effects or behavior changes during other seasons.

The study assumes that visit duration time directly correlates with exposure risk. However, factors such as airflow, sanitation practices, and individual behaviors during visits could also influence risk.

In summary, while the research provides evidence of the domestic Green Pass policy’s unintended effect on consumer behavior in Genoa, Italy, several limitations exist. These should be acknowledged when interpreting or using the results to inform decision-making.

Conclusion

The study provides insight into the effects of the domestic Green Pass on visit durations within certain premises and the subsequent increase in exposure risk provide a critical lens through which to reassess and refine pandemic response strategies. Acknowledging a paradoxical increase in exposure risk despite implementing a safety policy highlights the complexity of managing public health in the context of social and economic activities.

This finding is crucial for policymakers, suggesting that while policies like the Green Pass are designed to mitigate risk, they must also consider potential behavioral changes that could offset their benefits. Policymakers could have foreseen the “ex-ante” moral hazard consequent to implementing the domestic Green Pass policy in Italy and could have observed “ex-post” the unintended behavioral changes determined by the policy. The domestic Green Pass policy depended on the immunological condition of acquired immunity. When this condition was violated, the observed moral hazard significantly increased the close contact risk of infection caused by COVID-19 variants for the entire community. The World Health Organization (WHO) also suggested that the Green Pass could increase the risks of continued transmission because those carrying one would ignore public health advice about physical distancing. Vaccinated people could still be able to spread the virus and put others at risk, so experts have stressed the importance of continuing to distance and wear masks (28).

The balance between economic activity and health safety, as well as the call for continuous monitoring and adjustment of policies, further underlines the ongoing challenges in public health policymaking. These aspects of the study’s implications suggest that effective COVID-19 containment requires a multifaceted approach that includes initial policy implementation and continuing assessment and adaptation. To sustain Green Pass’ social and economic benefits, the risk of moral hazard could have been mitigated using Google visit duration data to inform the public and potentially influence social distancing decisions during public health crises.

The pandemic has revealed the importance of developing a shared awareness of threats for resilience in interconnected societies. This collective understanding encourages individuals to collaborate on common goals and mitigate shared dangers. A shared understanding of what constitutes a threat versus a desirable outcome may depend on how risk is communicated (29).

The COVID-19 health crisis has led to an unprecedented use of surveillance measures from public health authorities. The acceptance of the use of smartphone location data could mitigate the unintended consequences of moral hazard by helping people self-regulate their behavior to align with societal norms and expectations, essentially surveilling themselves without the need for external oversight (30).

Suppose the public knows the average visit duration for specific locations, such as coffee shops or restaurants. In that case, they can make informed decisions about the incremental risk of exposure of indulging in a conversation while sipping a cappuccino or having a three-course gourmet meal with a large group of friends. Moreover, suppose a store has a notably long visit duration. In that case, some might interpret that as potential inefficiency in social distancing measures and choose to visit at off-peak times or select another location.

In conclusion, the unintended consequences of future public health policies during a crisis can be mitigated by paying closer

attention to the data, promoting transparency, encouraging participatory governance, and embracing innovative solutions, all while safeguarding privacy and advancing equity.

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

Ethics approval and/or informed consent were not sought for this study. Publicly available Google data were collected to measure the time customers typically spend on a specific retail premise or public office. Google uses aggregated and anonymized data from users who have opted for Google Location History to determine visit duration. No personally identifiable information, such as an individual’s location, contact, or movement, will be made available at any point.

Author contributions

CO: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing.

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Supplementary material

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Effects of COVID-19-targeted non-pharmaceutical interventions on pediatric hospital admissions in North Italian hospitals, 2017 to 2022: a quasi-experimental study interrupted time-series analysis

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Background: The use of Non-Pharmaceutical Interventions (NPIs), such as lockdowns, social distancing and school closures, against the COVID-19 epidemic is debated, particularly for the possible negative effects on vulnerable populations, including children and adolescents. This study therefore aimed to quantify the impact of NPIs on the trend of pediatric hospitalizations during 2 years of pandemic compared to the previous 3 years, also considering two pandemic phases according to the type of adopted NPIs.

Methods: This is a multicenter, quasi-experimental before-after study conducted in 12 hospitals of the Emilia-Romagna Region, Northern Italy, with NPI implementation as the intervention event. The 3 years preceding the beginning of NPI implementation (in March 2020) constituted the pre-pandemic phase. The subsequent 2 years were further subdivided into a school closure phase (up to September 2020) and a subsequent mitigation measures phase with less stringent restrictions. School closure was chosen as delimitation as it particularly concerns young people. Interrupted Time Series (ITS) regression analysis was applied to calculate Hospitalization Rate Ratios (HRR) on the diagnostic

categories exhibiting the greatest variation. ITS allows the estimation of changes attributable to an intervention, both in terms of immediate (level change) and sustained (slope change) effects, while accounting for pre-intervention secular trends.

Results: Overall, in the 60 months of the study there were 84,368 cases. Compared to the pre-pandemic years, statistically significant 35 and 19% decreases in hospitalizations were observed during school closure and in the following mitigation measures phase, respectively. The greatest reduction was recorded for “Respiratory Diseases,” whereas the “Mental Disorders” category exhibited a significant increase during mitigation measures. ITS analysis confirms a high reduction of level change during school closure for Respiratory Diseases (HRR 0.19, 95%CI 0.08–0.47) and a similar but smaller significant reduction when mitigation measures were enacted. Level change for Mental Disorders significantly decreased during school closure (HRR 0.50, 95%CI 0.30–0.82) but increased during mitigation measures by 28% (HRR 1.28, 95%CI 0.98–1.69).

Conclusion: Our findings provide information on the impact of COVID-19 NPIs which may inform public health policies in future health crises, plan effective control and preventative interventions and target resources where needed.

KEYWORDS

COVID-19 epidemiology, non-pharmaceutical intervention (NPI), quasi-experimental design, observational study, Interrupted Time Series (ITS) regression analysis, time series analysis, diseases of the respiratory system, Mental Disorders

1 Introduction

The SARS-CoV-2 epidemic has had little medical consequences for children and adolescents, as incidence of severe forms of COVID-19 in the pediatric population was low and symptoms of infection were generally mild (1, 2). However, young people were deeply affected by the restrictive measures imposed globally to reduce transmission, such as quarantine, lockdown, and social distancing, often referred to as Non-Pharmaceutical Interventions (NPIs), which considerably changed their daily lives (3). They were confined at home for long periods, with limited opportunity for learning and reduced peer contact, together with adults who were often anxious or psychologically stressed by the circumstances, which added to their own discomfort (3, 4). School closure, enforced in many countries with different durations, was particularly relevant for these age groups, as school is where children and adolescents spend most of their time, and have opportunity for both social interactions and intellectual stimulation (5).

The debate on the pros and cons of population-wide restrictions enacted during the COVID-19 pandemic is ongoing. On the one hand, data seems to support the positive effects of NPIs (6–10), particularly in terms of control of virus spread and consequent reduction in mortality (10). On the other hand, some authors emphasize a range of “side effects” of NPIs, including economic, educational, and health repercussions, disproportionately affecting more vulnerable populations, including children, with little health benefits (11). To manage future health crises, therefore, it is crucial that these strategies are further assessed to inform future pandemic policy and avoid past mistakes (12).

The timing and intensity of NPIs against COVID-19 all over the world varied greatly according to local situations (7). Italy, starting

from the Northern regions, was the first European country to be affected by the pandemic (13), and enacted very aggressive restrictive policies, including one of the longest school closures in the world (14).

The analysis of hospitalization trends can provide valuable insights into the repercussions of different restrictions adopted over time, needed to prepare for future pandemics. In particular, to estimate the effectiveness of population-level health interventions that have been implemented at a clearly defined point in time, Interrupted Time Series (ITS) regression analysis is the recommended method (15). However, the majority of research on this topic is monocentric (16–19), is restricted to specific pediatric age classes or considers all ages including adults (17, 19–26), focuses on specific diagnoses (9, 16, 17, 19, 21, 25, 27), only looks at Emergency Department (ED) visits (16, 17, 19, 21, 23, 26, 28, 29), or addresses the time period immediately following the pandemic onset without evaluating ongoing effects (18, 25, 30).

We therefore aimed to quantify the impact of NPIs adopted to prevent or control COVID-19 transmission on the trend of hospitalizations, in 12 hospitals in the Emilia-Romagna Region, Northern Italy, during the 2 years following the start of the pandemic, compared with the previous 3 years, considering two pandemic phases according to the type of adopted NPIs.

2 Materials and methods

2.1 Study design and setting

This is a multicenter, quasi-experimental controlled before-after study, conducted to estimate the change in pediatric hospital

admissions during the COVID-19 pandemic compared to the previous period. For disease categories exhibiting the greatest variations, we investigated the effect during school closure and in the subsequent phase when schools were re-opened and mitigation measures were implemented.

This study was conducted in the Emilia-Romagna Region, Northern Italy, which has an overall pediatric population (from 0 to 17 years) of 673,818 subjects (year 2020) (31), who were potentially affected by NPIs.

The overall study period covered from March 2017 to February 2022 (60 months), defining the implementation of NPIs as an intervention event.

2.2 Intervention

National lockdown in Italy was imposed from March 11 through May 4th, 2020, after which economic and social activities were gradually resumed. Restrictions were relaxed over the summer and then reintroduced gradually to counter the second wave of the pandemic. On November 6th, 2020, the Italian Government enforced a three-tiered restriction system on a regional basis, using periodic risk assessments by the Ministry of Health (32). Italy also enforced one of the longest school closures in the world (14). Educational institutions of any grade were shut down from late February up to September 2020, after which schools were reopened and mitigation measures were kept in place, such as mask wearing and reduced student social contact, as well as mandatory distance learning for at least 75% of the time in high schools (32). On March 31, 2022, the state of emergency ended in Italy.

In this study, the beginning of NPI implementation was used as delimitation, defining the 3 years prior to March 2020 (from March 2017 to February 2020, 36 months) as the pre-COVID19 phase (PC). Since school closure is thought to have had a more direct impact on young people than other NPIs, the subsequent 2 years were further subdivided into a school closure phase (SC), from March 2020 to September 2020 (7 months) and a mitigation measures phase (MM), from October 2020 to February 2022 (17 months).

2.3 Participants

We analyzed data from 12 of the 15 (80%) hospitals in the Emilia-Romagna Region, which provided complete data throughout the study duration. These centers had a catchment area of 574,760 minor inhabitants in 2020 (equal to 85% of the Emilia Romagna region), comprising 211/269 (78%) pediatric beds. Included subjects were patients aged between 0 and 17 years, hospitalized in the considered time frame. Healthy new-borns were excluded from the analysis.

2.4 Data sources

Study data were anonymously extracted from the electronic hospital discharge forms (eHDFs), contained in the administrative databases of the Emilia-Romagna Regional Health Trust, and included the following: age, sex, dates of admission and discharge, main diagnosis and up to five secondary diagnoses (i.e., any conditions existing at admission or occurring during hospitalization which

influence treatment or length of stay). The diagnoses were coded according to the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM).

2.5 Statistical analysis

As outcome variables, we considered the monthly frequency of hospitalizations, total and for ICD9-CM categories (the first three characters), during the 60 months considered by the study. To identify which major ICD9-CM categories had the greatest impact, the Standardized Hospitalization Rates (SHR) per 100,000 person-year were used, considering as standard the resident population in Europe in 2020 (the intermediate of the 5 years considered in this study) (33) and adjusting for age and sex. For each diagnostic category, we measured how any of the time periods changed with respect to the previous phase (SC vs. PC, MM vs. PC and MM vs. SC), by estimating the Standardized Hospitalization Rate Ratios (SHRR) and their 95% Confidence Intervals (95% CI). To investigate the effect of NPIs, the ICD9-CM categories exhibiting the greatest change were assessed using ITS regression analysis. This segmented approach allows to estimate changes attributable to an intervention, in terms of overall (as time trend), immediate (as changes in level) and sustained (increase or decrease in the slope) effects, while accounting for pre-intervention secular trends. Since ITS regression models were applied to analyze count data through time, over-dispersion parameter was also evaluated and tested by graphical diagnostic plot and overdispersion test. We modeled admissions using a Poisson generalized linear model; in case p -value from Chi-square test of “estat gof” STATA function was less than 0.05 the model switched from Poisson to Quasi Poisson by specifying the parameter scale (x2). The seasonality components were also included into the ITS models to estimate recurrence undulatory patterns of admissions. Winter was defined as January/February/March, Spring as April/May/June, Summer as July/August/September and Autumn as October/ November/ December. In all ITS models, the annual population of the considered provinces was used as off-set allowing to estimate the hospitalization rate. Post-hoc sensitivity analyses were conducted to investigate the impact of children aged 0–1 years old on HRR estimates from ITS modeling, since we assumed that a very small proportion of children in this age group attends day-care. This is an important factor since the school closure is one of the main NPIs under study. All statistical analyses were centralized and performed with STATA (StataCorp. 2023. Stata Statistical Software: Release 18. College Station, TX: StataCorp LLC).

3 Results

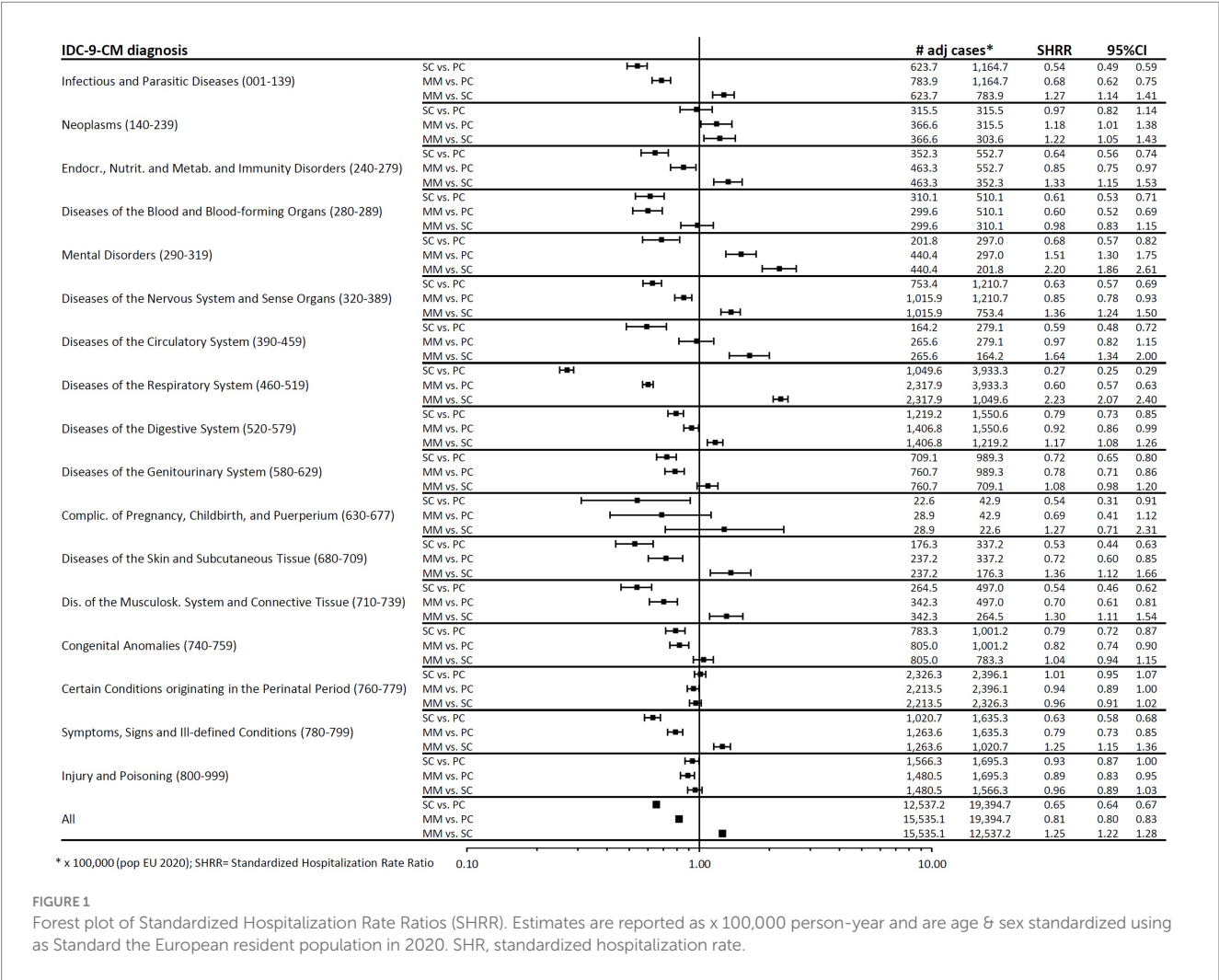
Overall, in the 5 years of the study and in the 12 participating centers, there were 84,368 cases. Case demographics are shown in Table 1 for each of the three phases: PC, SC, and MM. The sample of admissions was made up of 57.0% males, with the predominant age group being between 0 and 1 year (38.0%). As expected, the hospitalization rate decreased considerably when school closure was enforced with respect to the pre-pandemic time period (2,548 vs. $3,915 \times 100,000$ person-year). Supplementary Table S1 shows the standardized hospitalization rates by type of primary diagnosis, from highest to lowest.

Figure 1 shows the comparisons in terms of SHRR, overall and for individual ICD9-CM categories, between SC, MM and PC. Overall, a

TABLE 1 Demographic and clinical characteristics of the analyzed sample.

	PC (Mar 1, 2017- Feb 28, 2020) <i>n</i> = 56,449		SC (Mar 1, 2020- Sep 30, 2020) <i>n</i> = 7,003		MM (Oct 1, 2020- Feb 28, 2022) <i>n</i> = 20,916		Whole period (Mar 1, 2017- Feb 28, 2022) <i>n</i> = 84,368	
Sex, <i>n</i> (%) <i>males</i>	32,262	(57.2)	3,915	(55.9)	11,883	(56.8)	48,060	(57.0)
Age class, <i>y n</i> (%)								
0–1	21,285	(37.7)	2,800	(40.0)	7,940	(40.0)	32,025	(38.0)
2–5	14,135	(25.0)	1,383	(19.8)	4,334	(20.7)	19,852	(23.5)
6–11	9,500	(16.8)	1,228	(17.5)	3,406	(16.3)	14,134	(16.8)
12–17	11,529	(20.4)	1,592	(22.7)	5,236	(25.0)	18,357	(21.8)
Secondary diagnoses, <i>n</i> (%)								
1st	27,043	(47.9)	3,687	(52.6)	10,447	(50.0)	41,177	(48.8)
2nd	10,723	(19.0)	1,616	(23.1)	4,336	(20.7)	16,675	(19.8)
3rd	4,468	(7.9)	751	(10.7)	1,797	(8.6)	7,016	(8.3)
4th	2,153	(3.8)	361	(5.2)	854	(4.1)	3,368	(4.0)
5th	994	(1.8)	168	(2.4)	378	(1.8)	1,540	(1.8)
Hospitalization annual rate, (95%CI)*	3,915.4 (3,862.4–3,968.5)		2,547.7 (2,504.0–2,591.5)		3,191.0 (3,141.8–3240.1)		3,609.1 (3,557.4–3,660.8)	

PC, pre-COVID19; SC, School closure; MM, Mitigation measures. * Standardized × 100,000 (pop EU 2020).



statistically significant decrease in hospitalizations with respect to pre-pandemic rates was observed both in SC (−35%, SHRR 0.65, 95%CI: 0.64–0.67) and MM (−19%, SHRR 0.81, 0.80–0.83), while a 25% increase (SHRR 1.25, 1.22–1.28) was recorded in MM with respect to SC.

Considering individual ICD-9-CM diagnoses, a generalized reduction was detected during SC for all categories. The greatest reduction (−73%, SHRR 0.27, 95%CI 0.25–0.29) occurred in the “Respiratory Diseases” category, which exhibited the highest frequency of hospitalizations (approximately 4,000 cases/year in the 3 years before the pandemic). In MM, the reduction compared to PC persisted, although less prominent. Only the Mental Disorders category showed a large increase (51%, SHRR 1.51, 95%CI 1.30–1.75).

To measure NPI effects, ITS regression analysis was carried out on overall hospital admissions and on the two categories which stood out for the greatest variation (Respiratory Diseases and Mental Disorders).

Results of the ITS analysis are presented in the following paragraphs.

3.1 Any hospitalization

As shown in [Figure 2](#) and [Table 2](#), we observed a highly significant decrease in hospitalizations in SC (level change, HRR 0.44, 95%CI 0.35–0.55) and in MM (although of lesser impact, HRR 0.65, 95%CI 0.57–0.75) compared to PC. Unlike the constant hospitalization rate recorded throughout the 3 years before the pandemic, immediately after the collapse of admissions an increasing trend occurred, particularly in SC (slope change, 11% per month, HRR 1.11, 95%CI

1.06–1.16), but also to a lesser extent in MM (slope change, 2% per month, HRR 1.02, 95%CI 1.01–1.03). Hospitalization rates returned to pre-pandemic levels only in autumn 2021 (18 months since the start of the pandemic).

3.2 Respiratory diseases

The most frequent types of respiratory diseases as primary diagnosis are shown in [Supplementary Table S2](#). This category, which contributed the most to the hospitalization decline, exhibited in SC a statistically significant reduction of 81% in the number of admissions in terms of level change (HRR 0.19, 95%CI 0.08–0.47), and an increase of the monthly slope change of 17% (HRR 1.17, 95%CI 0.97–1.42). A similar but less pronounced decrease was seen during MM, with a statistically significant reduction in terms of level change (HRR 0.26, 95%CI 0.16–0.41), and a 7% increase of the monthly slope change (HRR 1.07, 95%CI 1.03–1.11). The seasonality component analysis showed statistically significant increases from autumn to spring compared to summer ([Table 3](#) and [Figure 3A](#)).

3.3 Mental disorders

As evident in [Figure 3B](#), although hospitalizations in this category underwent a substantial decrease at the start of SC, we observed a sharp increasing trend until MM, when hospitalization rates exceeded pre-pandemic levels. ITS analysis ([Table 3](#)) detected in SC a statistically significant 50% reduction in

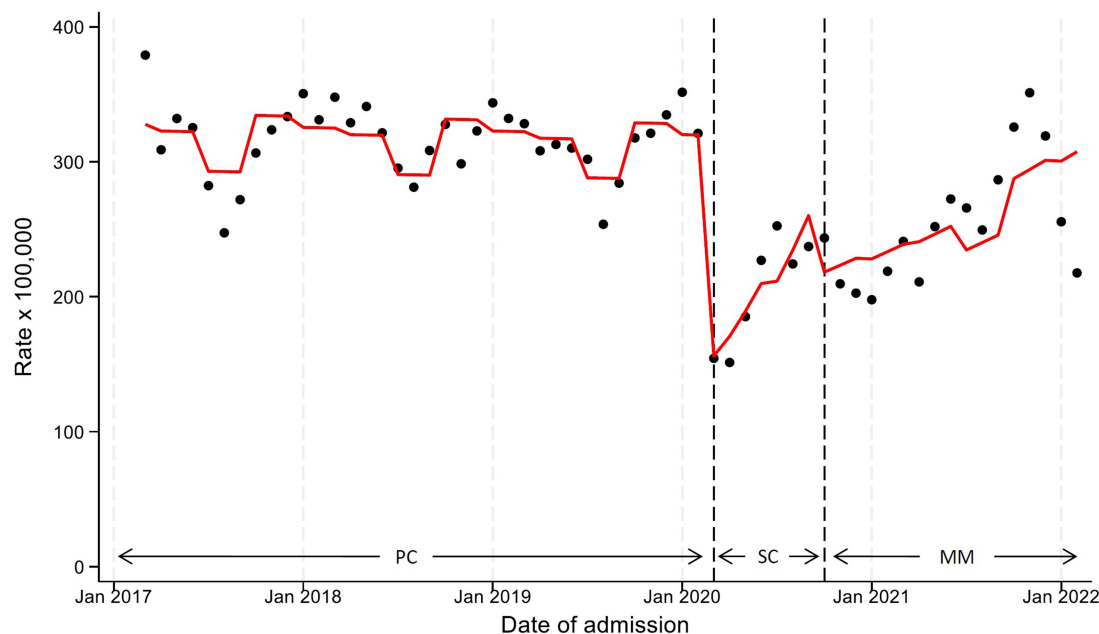


FIGURE 2

Monthly hospitalization rate any disease with line trend from ITS regression analysis. PC, pre-COVID19 phase; SC, School closure phase; MM, Mitigation measures phase.

TABLE 2 Interrupted time series analysis results on hospitalizations.

Variable	HRR	95%CI	p-value
<i>Level change^a</i>			
SC vs. PC	0.44	0.35–0.55	<0.001
MM vs. PC	0.65	0.57–0.75	<0.001
MM vs. SC	1.48	1.18–1.87	0.001
<i>Slope change^b</i>			
SC vs. PC	1.11	1.06–1.16	<0.001
MM vs. PC	1.02	1.01–1.03	<0.001
MM vs. SC	0.92	0.89–0.95	<0.001
<i>Time trend^c</i>			
1.00	0.99–1.01	0.639	
<i>Season</i>			
Summer	1.00		
Winter	1.12	1.04–1.20	0.003
Spring	1.10	1.02–1.18	0.012
Autumn	1.14	1.06–1.23	<0.001

^a Level change refers to an abrupt level change of the Incidence rate between the periods;
^b Slope change refers to slope change of the incidence rate over time between the periods;
^c Time trend refers to the change of Incidence rate associated with a time unit increase. PC, pre-COVID19 phase; SC, School closure phase; MM, Mitigation measures phase. HRR, Hospitalization Rate Ratio; 95%CI: 95% confidence interval. Pseudo R2=0.68. MM vs. SC contrast was manually added for interpretative purposes without p-value adjustment for multiple comparison.

level change (HRR 0.50, 95%CI 0.30–0.82) and a borderline statistically significant 11% increase in the monthly slope change (HRR 1.11, 95%CI 1.00–1.23), compared to PC. Comparing MM with the pre-pandemic situation, a 28% level change increase was observed (HRR 1.28, 95%CI 0.98–1.69), while the monthly slope change remained unchanged (HRR 1.01, 95%CI 0.99–1.03). Finally, comparing MM vs. SC, we recorded a strong increase in the level change of about 2.6 times (HRR 2.59, 95%CI 1.55–4.34). The seasonality component analysis showed statistically significant increases of admission during spring (HRR 1.18, 95%CI 1.00–1.40) versus summer (Table 3 and Figure 3B).

3.4 Subgroup analysis by sex and age

We performed subgroup analyses considering gender and age categories. Gender differences were not found for Respiratory Diseases, whereas for Mental Disorders the increase in MM vs. PC seemed to be significantly stronger in females vs. males (MM vs. PC: 1.66, 1.19–2.33 vs. 1.28, 0.98–1.69, respectively) (Supplementary Figures S1, S2 and Supplementary Tables S4, S5). Although incidence rates of Respiratory Diseases differed between ages 0–5 and 12–17, HRR estimates did not exhibit relevant differences (Supplementary Figures S3, S4 and Supplementary Tables S6, S7). Concerning Mental Disorders, in the 12–17 age subgroup, the HRR of level change in MM increased from a non-statistically significant 1.28 ($p=0.071$) to a highly statistically significant 1.66 ($p<0.001$), even though the slope change was almost absent and identical (HRR 1.01) (Supplementary Figure S5 and Supplementary Table S8).

TABLE 3 Interrupted time series analysis results on hospitalizations for Respiratory Diseases and Mental Disorders categories.

Variable	HRR	95%CI	p-value
Respiratory diseases			
<i>Level change^a</i>			
SC vs. PC	0.19	0.08–0.47	<0.001
MM vs. PC	0.26	0.16–0.41	<0.001
MM vs. SC	1.34	0.52–3.51	0.546
<i>Slope change^b</i>			
SC vs. PC	1.17	0.97–1.42	0.099
MM vs. PC	1.07	1.03–1.11	<0.001
MM vs. SC	0.91	0.75–1.11	0.346
<i>Time trend^c</i>			
1.00	0.99–1.01	0.675	
<i>Season</i>			
Summer	1.00		
Winter	2.25	1.74–2.90	<0.001
Spring	1.42	1.08–1.88	0.012
Autumn	2.10	1.63–2.72	<0.001
Mental disorders			
<i>Level change^a</i>			
SC vs. PC	0.50	0.30–0.82	0.006
MM vs. PC	1.28	0.98–1.69	0.071
MM vs. SC	2.59	1.55–4.34	<0.001
<i>Slope change^b</i>			
SC vs. PC	1.11	1.00–1.23	0.052
MM vs. PC	1.01	0.99–1.03	0.449
MM vs. SC	0.91	0.82–1.01	0.076
<i>Time trend^c</i>			
1.00	0.99–1.01	0.541	
<i>Season</i>			
Summer	1.00		
Winter	1.06	0.90–1.26	0.474
Spring	1.18	1.00–1.40	0.053
Autumn	1.10	0.93–1.30	0.252

^a Level change refers to an abrupt level change of the Incidence rate between the periods;
^b Slope change refers to slope change of the incidence rate over time between the periods;
^c Time trend refers to the change of Incidence rate associated with a time unit increase. PC, Pre-COVID19 phase; SC, School Closure phase; MM, Mitigation Measures phase. HRR, Hospitalization Rate Ratio; 95%CI: 95% confidence interval. Pseudo R2 for respiratory diseases model=0.69, for mental disorders model=0.23. MM vs. SC contrasts were manually added for interpretative purposes without p-value adjustment for multiple comparison.

3.5 Sensitivity analyses

Supplementary Tables S9, S10 display the results of sensitivity analyses performed excluding children aged 0–1 years old, who represent about 38% of overall hospital admissions. Considering both admissions for any cause and for the Respiratory Diseases and Mental Disorders categories, sensitivity analyses did not reveal differences sufficient to suggest that the proportion of children aged 0 to 1 year significantly skewed the results of our analyses.

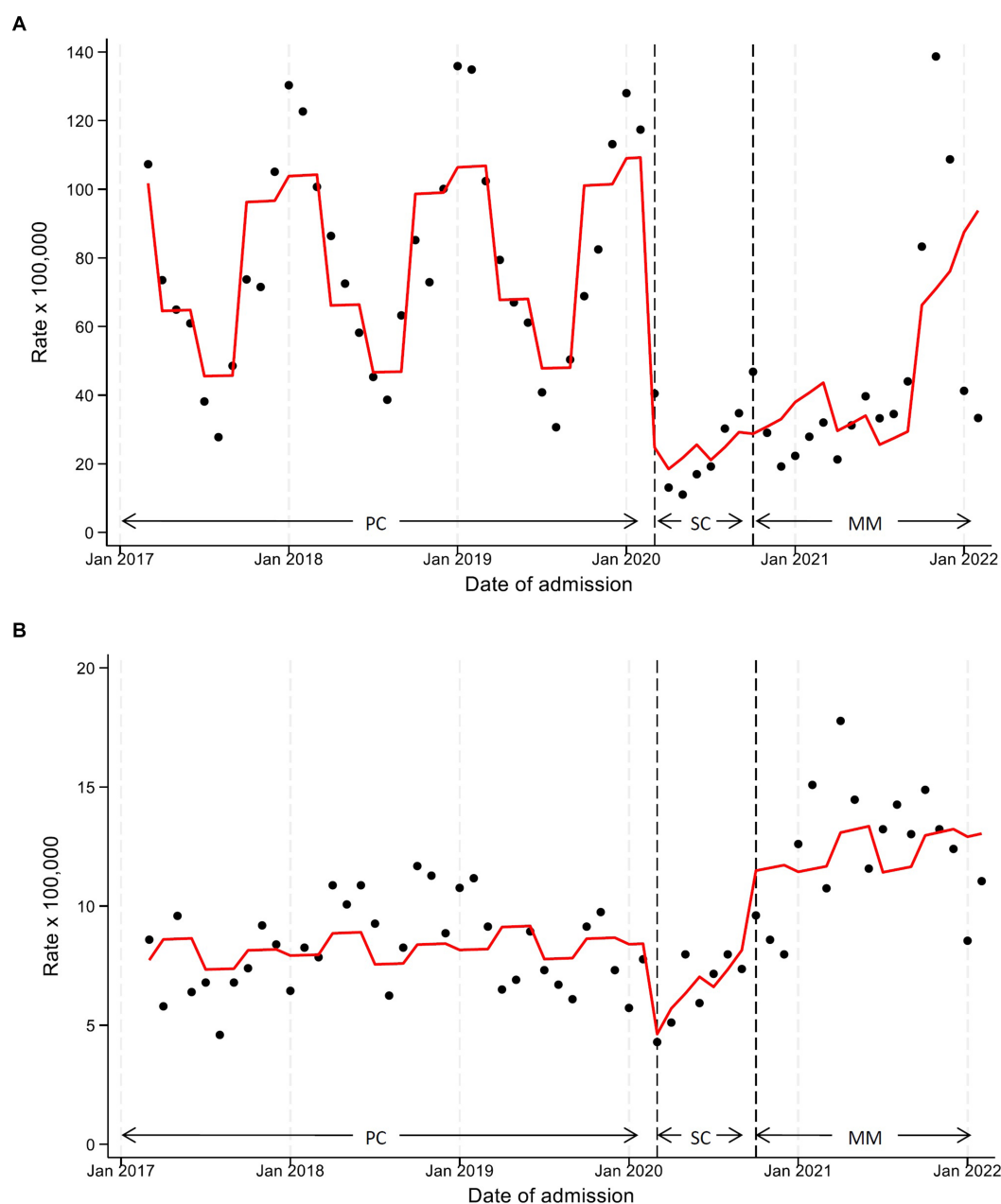


FIGURE 3

Monthly hospitalization rate for respiratory diseases (A) and mental disorders (B) with line trend from ITS regression analysis. PC, pre-COVID19 phase; SC, School closure phase; MM, Mitigation measures phase.

4 Discussion

This is the first European study on the impact of COVID-19 NPIs on the trend of pediatric hospitalizations conducted in a wide area severely hit by the pandemic, covering an extended pandemic period (24 months). The use of appropriate analysis through ITS regression makes our findings and corresponding conclusions reliable. In fact, existing research on the effects of NPIs mostly consists of modeling studies, implying a lack of empirical, real-world data, or uses descriptive statistics on admission trends (34).

Overall, our results showed that the number of pediatric hospital admissions dropped by more than 50% in the first months of the

lockdown period, and then began to rise, achieving pre-pandemic hospitalization levels only 2 years later. This considerable, long-lasting reduction appears to be mainly determined by a decrease in the occurrence of infectious diseases (the most frequent cause for hospitalization in children), mainly affecting the respiratory system. However, these results may also be due to a change in health-seeking behaviors of parents, who might have chosen not to attend hospital with their sick children for fear of contagion (9, 35). Moreover, the decrease may be attributed to a tendency to avoid hospitalizing children with minor health problems. Supporting this hypothesis is the fact that admissions for childhood neoplasms remained constant, suggesting that healthcare services were maintained for severe

illnesses. A similar observation was made by Wang et al. (9), who found a 55% reduction in admissions for all-cause respiratory diseases, in line with our finding, and a smaller reduction in admissions for childhood neoplasms.

Interesting results emerged from ITS analyses conducted on the two disease categories exhibiting the largest variation, which recorded opposite trends. For Respiratory Diseases, we observed a marked reduction of hospitalizations which persisted throughout school closure and for the most part of the subsequent time period when less stringent mitigation measures were enforced, in the absence of typical seasonal epidemic peaks. Conversely, for Mental Disorders an immediate decline of admissions was detected in the first 2 months of lockdown, followed by an incremental trend, on average by 11% monthly. These trends need to be further investigated using hospitalization data recorded in the following years, to understand whether the effects persist, or whether at the end of the pandemic hospitalizations return to pre-pandemic levels.

Some plausible reasons for these results exist. Regarding Respiratory Diseases, the drop in admissions is likely to be related to the impact of mask-wearing, hand washing, and social distancing on the interruption of person-to-person viral or bacterial transmission, as also discussed by Wang et al. (9). The reduction may also be partly due to a “virus interference phenomenon” among respiratory viruses, whereby the infection of one virus can partially prevent or inhibit the infection of another virus in the same host (36). The contribution of this factor is however likely to be marginal compared to the absence of influenza epidemics and other respiratory infections following social distancing, which has been reported and commented in the literature (37, 38). Concerning mental health, the negative effects may have taken longer to manifest, but once developed they may not resolve easily even if restrictions are lifted, instead requiring much time and specific care to be removed (3).

The results of this study can contribute to the current debate on benefits and harms of individual NPIs, which is not a simple one, also because it is hard to separate the impact of one measure from that of other interventions introduced simultaneously. Concerning the pediatric population in particular, it would be essential to elucidate the role of school closures on the control of pandemic spread (39). Recent reviews (12, 34, 40) suggested that measures implemented in the school setting may have limited the number or proportion of cases and deaths among adults, and delayed the progression of the pandemic. This seems to contrast with a report on data from Sweden, where school closure was only reserved for upper secondary schools, indicating that the number of deaths per population unit was lower than most other high-income countries that applied stringent school closure policies (41). On the other hand, the literature also highlights negative consequences of these measures on children's health and education. As reported by UNICEF (42), school closures disrupted the provision of educational (and in some cases health and nutritional) services, increased emotional distress and mental health problems, prevented access to a wide range of school-provided services, including school meals, monitoring of health and welfare, social skills training, and services targeted to children with special needs. Furthermore, as schools moved online, impoverished children experienced dramatic educational setbacks contributing to inequalities and long-term hardship (42).

Within the current debate, our findings also highlight that evaluating the trade-offs between positive and negative consequences of NPI implementation during pandemics is a complex task. In

particular, as commented above, the decrease in hospitalizations for Respiratory Diseases after the beginning of the outbreak may be due both to the hesitancy in attending hospitals, certainly an undesired effect, and to the reduction of respiratory infections due to lockdown measures, a welcome benefit.

One of the main strengths of this research lies in the use of ITS analysis, one of the strongest evaluative designs when randomization is not possible (15). Furthermore, the study involves numerous hospitals, which makes results robust and increases their generalizability. Also, analyzed data concern the first European area hit by the pandemic, where aggressive restrictive measures were immediately adopted since the start of the outbreak and maintained for an extended period, are restricted to one endpoint (pediatric hospitalizations) and include COVID and non-COVID hospitalizations. Finally, the study covers a wide timeframe, longer than most similar research, which enabled to verify the impact of NPIs in the long-term.

This study has some limitations. Firstly, data were taken from hospital administrative databases and were not collected prospectively for this research. However, the data quality is supposed to be similar in the years we compared; thus, this aspect should not impact interpretation. Secondly, we did not attempt to discriminate between new versus recurrent hospitalizations. Such discrimination would be important to understand whether the observed changes were due to the onset of a new condition or to the exacerbation of existing problems. Thirdly, since the analysis used data collected retrospectively without formal power analysis, we cannot exclude the risk of false negative findings in the case of low-prevalence diagnoses. Lastly, we did not attempt to investigate the potential role of different waves of variants of the SARS-CoV-2 virus which were predominant in the 2 years covered by the study, because it was not an objective of our research. This may have led to an overestimation of the effect of NPIs on hospital admissions.

5 Conclusion

The results of this and other studies on the impact of COVID-19 NPIs on children provide information needed to guide and target interventions in the event of future pandemics, and to plan the allocation of resources where they are needed most. However, the different plausible interpretations of our findings make it difficult to inform about the trade-offs between benefits and negative consequences of NPI strategies during pandemics. Rigorous research should be conducted to understand whether the reduction in pediatric hospital admissions we observed over a two-year period has affected child and adolescent health. Meta-analyses are needed to quantify the contribution to observed effects of individual mitigation actions, to better determine the appropriateness of their introduction, timing and intensity.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: the raw data supporting the conclusions of this article will be made available by the authors upon a motivated request to the corresponding author. Requests to access these datasets should be directed to ccaminiti@ao.pr.it.

Ethics statement

The studies involving humans were approved by AVEN (Area Vasta Emilia Nord) Ethics Committee. The studies were conducted in accordance with the local legislation and institutional requirements. The ethics committee/institutional review board waived the requirement of written informed consent for participation from the participants or the participants' legal guardians/next of kin because waiver for informed consent was obtained from the Italian Data Protection Authority (Garante della Privacy), because of feasibility issues (more than 80,000 subjects should have been contacted).

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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.2024.1393677/full#supplementary-material>

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The time has come to protect healthcare workers and patients from aerosol transmissible disease

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KEYWORDS

respirator, pandemic, SARS-CoV-2, respiratory protection, mask, aerosol transmission, indoor air, N95

Introduction

In order to protect patients and healthcare workers from aerosol transmissible diseases, healthcare facilities should improve ventilation and air purification and in addition should consider universal use of respirators (e.g., N95, FFP2 or equivalent) when aerosol-transmissible pathogens are widespread in the community. A study of SARS-CoV-2 within 288 United States hospitals documented more than 14,000 infections potentially acquired in the hospital over a 2-year period and found that more than 8% of patients hospitalized with SARS-CoV-2 may have acquired their infection in the hospital (1). Despite the frequency of nosocomial respiratory viral transmission most countries have no national mandate for masks or respirators in healthcare facilities. We propose that healthcare facilities should anticipate that aerosol transmissible disease will continue to be of major importance to public health for the foreseeable future.

Aerosol transmissible disease

Early in the COVID pandemic, some argued that SARS CoV-2 was transmitted primarily by larger respiratory particles known as “droplets,” produced during coughing and sneezing and propelled into the mouth or nose of someone nearby (2). Surgical masks were thought by many to provide adequate protection; respirators were only recommended for healthcare workers performing a limited and variable set of procedures.

Examination of a large body of evidence has shown that transmission of SARS-CoV-2 is primarily through inhalation of smaller respiratory particles generated by breathing, talking, singing and other ordinary respiratory activities (3–7). These smaller particles are predominantly <5 microns in size, can remain suspended in air for many minutes or even hours, diffuse or move by air currents throughout an indoor space, and are easily inhaled both near and far from a source (8). Optimal protection from inhaling these small particles requires respirators, not surgical masks (4, 9). While recent attention has been focused on SARS-CoV-2, the importance of aerosol transmission for a wide variety of pathogens has

been recognized for many years; examples of aerosol transmissible viruses and bacteria are shown in the [Table 1](#), along with examples of pertinent literature.

Variable performance of face coverings

Recognition of the importance of aerosol transmission has critical implications for healthcare workers and patients. However, the conversation about appropriate protection has been obscured by the widespread use of the terms “mask” and “masking” to encompass anything worn on the face. These terms lack precision and suggest that everything worn on the face provides similar levels of source control and personal protection. In fact, there are large differences in the performance characteristics and effectiveness of different face coverings.

The most common face coverings in health care facilities are surgical masks (a term which encompasses procedure masks). Most surgical masks are not designed to fit tightly against the face and thus have a limited impact on inward and outward movement of smaller particles because air can move freely around the edges of the mask instead of through the filtering material. In addition, surgical masks are typically constructed of filtering material that is not as effective as the material used for respirators. Surgical masks have been worn during surgery with the intention of preventing bacterial infection of surgical wounds from droplets generated by surgical personnel, although efficacy for this purpose is questionable (24). Since the HIV epidemic, surgical masks have also been deployed as protection against splashes with blood or other body fluids. Efficacy of surgical masks for protection against aerosol transmission is limited (25–27).

Respirators (which should not be referred to as “masks”) are designed to fit tightly to the face, are constructed of highly effective filtering material and can provide substantial protection against aerosol transmission. They typically undergo a rigorous testing and approval process supervised by governmental agencies. The most common disposable “filtering facepiece” respirators are designated as N95 in the United States and Canada and FFP2 in the United Kingdom, European Union, Australia and New Zealand.

There are some in healthcare who question the relative effectiveness of respirators in comparison to surgical masks. Laboratory and workplace measurements have clearly and consistently demonstrated the superior performance of respirators for all types of hazardous aerosols (26–28). However, some have suggested that evidence from randomized clinical trials is needed. This is problematic because most trials have only assigned healthcare workers to wear respirators when caring for patients with known or suspected respiratory viral infections, ignoring the fact that workers are continuously exposed to viruses in other contexts, at home, in the community and from exposure to co-workers and pre-symptomatic or asymptomatic patients. Nevertheless, the limited clinical evidence we have suggests that respirators reduce the risk of infection to a greater degree than surgical masks (29–31), consistent with the strong evidence from laboratory and workplace measurements of respirator performance.

Discussion

The HIV epidemic transformed healthcare worker behavior, making contact between the healthcare worker and patient body fluids something to be strictly avoided. Similarly, the COVID-

TABLE 1 Examples of aerosol transmissible pathogens.

Pathogen	Early evidence of aerosol transmission	Person to person transmission
Adenovirus	Couch et al. (10)	Yes
Coxiella burnetii (Q fever)*	Welsh et al. (11)	No
Coxsackie A21 virus	Couch et al. (12)	Yes
Influenza virus	Alford et al. (13)	Yes
Legionella pneumophila	Nguyen et al. (14)	No
Mycobacterium tuberculosis	Riley et al. (15)	Yes
Respiratory syncytial virus	Kulkarni et al. (16)	Yes
Rubella virus (measles)	Marks et al. (17)	Yes
Rubeola virus (measles)	Riley et al. (18)	Yes
SARS-CoV-2 virus (COVID)	Hamner et al. (19)	Yes
Staphylococcus aureus	Eichenwald et al. (20)	Yes
Varicella virus (chicken pox)	Leclair et al. (21)	Yes
Variola virus (smallpox)*	Wehrle et al. (22)	Yes
Yersinia pestis (pneumonic plague)*	Meyer (23)	Yes

*Potential bioweapon.

Examples of pathogens with significant aerosol transmission, along with a single representative citation for each. This list of pathogens and citations is not intended to be inclusive or exhaustive. The citations were selected to emphasize that evidence for aerosol transmission of a number of pathogens has been available for more than 60 years.

19 pandemic has heightened awareness about the importance of preventing transmission of aerosolized pathogens (32). Prior to COVID-19, precautions against aerosol-transmissible pathogens were considered important for only a few specific pathogens, such as tuberculosis and measles and most healthcare workers seldom if ever donned a respirator. In fact, evidence for aerosol transmission of influenza has been accumulating since the 1960s (33) along with evidence for aerosol transmission of a variety of viruses (10, 34), bacteria (35) and fungi (36). Coronaviruses and influenza viruses are especially noteworthy because of their proven pandemic potential (37), but their mode of transmission is not unique. Some pathogens, not classically thought to spread by aerosols, can become airborne pathogens in some circumstances, for example *Yersinia pestis* in primary plague pneumonia (23, 38). While not all aerosol transmissible diseases result in a significant incidence of hospitalization and death, many are serious threats to public health.

The importance of aerosol transmission has fundamental importance for health policy, because traditional droplet precautions, such as staying six feet away from a source or wearing a surgical mask, will not provide adequate protection from aerosols. Prevention of aerosol transmission requires attention to indoor air quality through adequate ventilation and air purification and the use of respirators rather than surgical masks for personal protection and source control.

Since universal masking with either respirators or surgical masks has been largely abandoned by healthcare facilities, it is critical to understand the appropriate triggers for reinstating universal respiratory protection. This has been the subject of considerable discussion but unfortunately remains unclear (39). Knowing when to upgrade or relax precautions depends upon reliable and timely assessment of transmission and the consequences of infection. This is not a trivial problem. For instance, in many places around the world including some parts of the United States, testing and reporting of COVID-19 infection, hospitalization and death has lapsed, and wastewater monitoring has become the main source of data used to infer prevalence.

We need to develop better ways to monitor our environment for indicators of respiratory pathogen risk in near real time and geolocatable terms, and to use this information in quantitative ways to assess respiratory risk. For example, Puthussery et al. (40) recently reported a technology for near real-time analysis of air samples for SARS-CoV-2 or other viruses that might be used to estimate the risk of transmission from indoor air for a specific time and location. Similar technologies might also be used to perform near real-time testing of exhaled air from individuals to identify infection and the need for source control (41). While SARS-CoV-2 has been of greatest concern in recent times, the risks posed by other aerosol transmissible pathogens, or the combined risks from several pathogens circulating simultaneously in a community may warrant elevated precautionary measures; such protocols must become part of preparedness for future pandemics, some of which will involve, no doubt, airborne pathogens.

Lacking methods for sampling infectious aerosol concentrations in indoor spaces, it may be possible to assess risk qualitatively. Important factors include indoor air quality,

based on ventilation and air purification, the likely number of encounters with potential sources (while noting that many infected persons can be asymptomatic or presymptomatic) and duration of exposure. When community transmission of a respiratory pathogen is widespread, exposure to healthcare workers and visitors with occult infections, in addition to infected patients, becomes a risk factor.

Universal masking policies in healthcare facilities have to consider potential obstacles to compliance including the available supply of masks and respirators. In some countries, regulators require periodic fit testing of respirators for employees who may be required to use them in the workplace. While the use of fit tested respirators is more likely to provide optimal protection from aerosol transmission than when respirators are worn without fit testing, a well-designed respirator that fits most people well is likely to provide better protection than surgical masks or other relatively less effective face coverings (26). Thus, providing respirators for use by patients, even when not fit tested, may be a rational protective measure. Whether healthcare workers or patients can or should be compelled to use respirators, surgical masks, or other face coverings is a complex legal, political and administrative problem with no easy answers.

Some have expressed practical concerns about the supply of respirators. At the current time, respirators are in abundant supply, however early in the COVID-19 pandemic this was not the case. When respirators are in short supply, it is important to realize that a single filtering facepiece respirator (e.g., N95, FFP2) can be worn at least a few times without losing its ability to fit and filter effectively. Once trapped in the filtering material of the respirator, particles remain bound indefinitely (42, 43). Greater routine use of respirators might well stimulate improvements in design that improve comfort and ease of donning and doffing; and a steady demand for respirators might make the supply chain more robust. Reusable elastomeric respirators offer advantages in comparison to disposable respirators (44) because they can be cleaned and their filters are very long lasting. Especially in pandemic or surge situations, elastomeric respirators have considerable strategic value.

In conclusion, there is convincing evidence for aerosol transmission of many pathogens, including some with pandemic potential, such as influenza and corona viruses. Healthcare facilities should endeavor to improve ventilation and air purification to reduce exposure of healthcare workers and patients to dangerous aerosols. When the risk of aerosol transmission is elevated, especially when transmission in the community is widespread, masking healthcare workers and patients, preferably with respirators rather than surgical masks, will make healthcare safer for all.

Author contributions

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Decoding Fujian's cervical HPV landscape: unmasking dominance of non-16/18 HR-HPV and tailoring prevention strategies at a large scale

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Background: Persistent HR-HPV causes cervical cancer, exhibiting geographic variance. Europe/Americas have higher HPV16/18 rates, while Asia/Africa predominantly have non-16/18 HR-HPV. This study in Fujian, Asia, explores non-16/18 HR-HPV infections, assessing their epidemiology and cervical lesion association for targeted prevention.

Methods: A total of 101,621 women undergoing HPV screening at a hospital in Fujian Province from 2013 to 2019 were included. HPV genotyping was performed. A subset of 11,666 HPV-positive women with available histopathology results were analyzed to characterize HPV genotype distribution across cervical diagnoses.

Results: In 101,621 samples, 24.5% tested positive for HPV. Among these samples, 17.3% exhibited single infections, while 7.2% showed evidence of multiple infections. The predominant non-16/18 high-risk HPV types identified were HPV 52, 58, 53, 51, and 81. Single HPV infections accounted for 64.1% of all HPV-positive cases, with 71.4% of these being non-16/18 high-risk HPV infections. Age-related variations were observed in 11,666 HPV-positive patients with pathological results. Cancer patients were older. In the cancer group, HPV52 (21.8%) and HPV58 (18.6%) were the predominant types, followed by HPV33, HPV31, and HPV53. Compared to single HPV16/18 infection, non-16/18 HPV predominated in LSIL. Adjusted odds ratios (OR) for LSIL were elevated: multiple HPV16/18 (OR 2.18), multiple non-16/18 HR-HPV (OR 2.53), and multiple LR-HPV (OR 2.38). Notably, solitary HPV16/18 conferred higher odds for HSIL and cancer.

Conclusion: Our large-scale analysis in Fujian Province highlights HPV 52, 58, 53, 51, and 81 as predominant non-16/18 HR-HPV types. Multiple HPV poses increased LSIL risks, while solitary HPV16/18 elevates HSIL and cancer odds. These findings stress tailored cervical cancer prevention, highlighting specific HPV impacts on lesion severity and guiding region-specific strategies for optimal screening in Asia, emphasizing ongoing surveillance in the vaccination era.

KEYWORDS

cervical cancer, human papillomavirus, genotype, prevalence, prevention

1 Introduction

Cervical cancer, a significant global public health burden, exacts a heavy toll in terms of morbidity and mortality (1). The 2020 World Cancer Report underscores this by highlighting that cervical cancer comprises 6.5% of all newly diagnosed cancers in women worldwide and ranks as the fourth leading cause of female cancer deaths (2). In China alone, nearly 20% of the global burden is shouldered, with approximately 98,900 new cases reported annually and an alarming 30,500 women succumbing to the disease each year (3).

Although the exact causes are multifactorial, persistent infection with certain strains of human papillomavirus (HPV) has been identified as the primary driving force behind the development of cervical cancer and precancerous cervical lesions (3). This viral link provides a potential avenue for prevention and control strategies. The pivotal role of persistent infection with high-risk human papillomavirus (HR-HPV) genotypes in the pathogenesis of cervical cancer and its precursor lesions cannot be overstated (3). Over 90% of cervical cancers can be attributed to HR-HPV, making it the primary risk factor (4, 5). HPV16 and HPV18 dominate globally as the most prevalent HR-HPV types detected in cervical cancers (6). However, in recent years, cervical tumors caused by other HPV types have been gradually increasing, warranting sufficient attention (7).

Given the established causal relationship between HPV and cervical cancer, the development of prophylactic HPV vaccines has emerged as a promising preventive strategy. Various HPV vaccines, including bivalent, quadrivalent, and nine-valent formulations, have been developed and introduced into vaccination programs worldwide. The nine-valent vaccine offers the broadest protection against HPV6/11/16/18/31/33/45/52/58, with an estimated potential effectiveness against cervical cancer in China of 75.4% (8). The bivalent HPV16/18 vaccine could prevent 55.4% of cases (9). However, these vaccines do not provide universal protection, as they target specific genotypes.

While current vaccines target the globally prevalent HPV16/18 strains, regional variations exist, with non-16/18 HR-HPV types being more dominant in certain regions like Asia. Therefore, assessing the oncogenicity of non-vaccine HR-HPV types remains crucial, as they may still pose cancer risks in vaccinated groups (10). This study aims to characterize the epidemiology of non-HPV 16/18 high-risk infections in Fujian Province and their association with cervical lesions, considering their dominance in Asia over global prototypical strains. Elucidating prevalent regional genotypes in China and their cancer linkage, alongside prevailing vaccine usage, provides critical insights for optimized, tailored screening and the development of next-generation prophylactics expanding genotype coverage and effectiveness to ultimately enhance cervical cancer prevention in this population.

2 Methods

2.1 Study design and participants

This retrospective cohort study was conducted at Fujian Maternity and Child Health Hospital in Fuzhou, China, covering the period from January 2012 to December 2022. A total of 137,125 clinic records were initially screened. Participants who were under 18 years old, lacked HPV typing, had a history of cervical diseases, had immune defects, or were on immunosuppressive drugs (e.g., HIV or SLE, systemic lupus erythematosus), as well as those with missing or invalid data, were excluded from the study. After the exclusion criteria were applied, 24,924 patients infected with HPV were included for further screening. From this group, patients lacking relevant pathological examinations were excluded, leaving 11,666 patients divided into four groups: normal or inflammation, LSIL, HSIL, and cancer. The study flow chart is depicted in Figure 1.

Ethical approval for this study was obtained from the Research Ethics Committee of Fujian Maternity and Child Health Hospital (2023KY038). To protect patient privacy, all data related to individual identification were removed and remained anonymous throughout the analysis. The study involved retrospective collection of patient information, and an informed consent exemption was obtained.

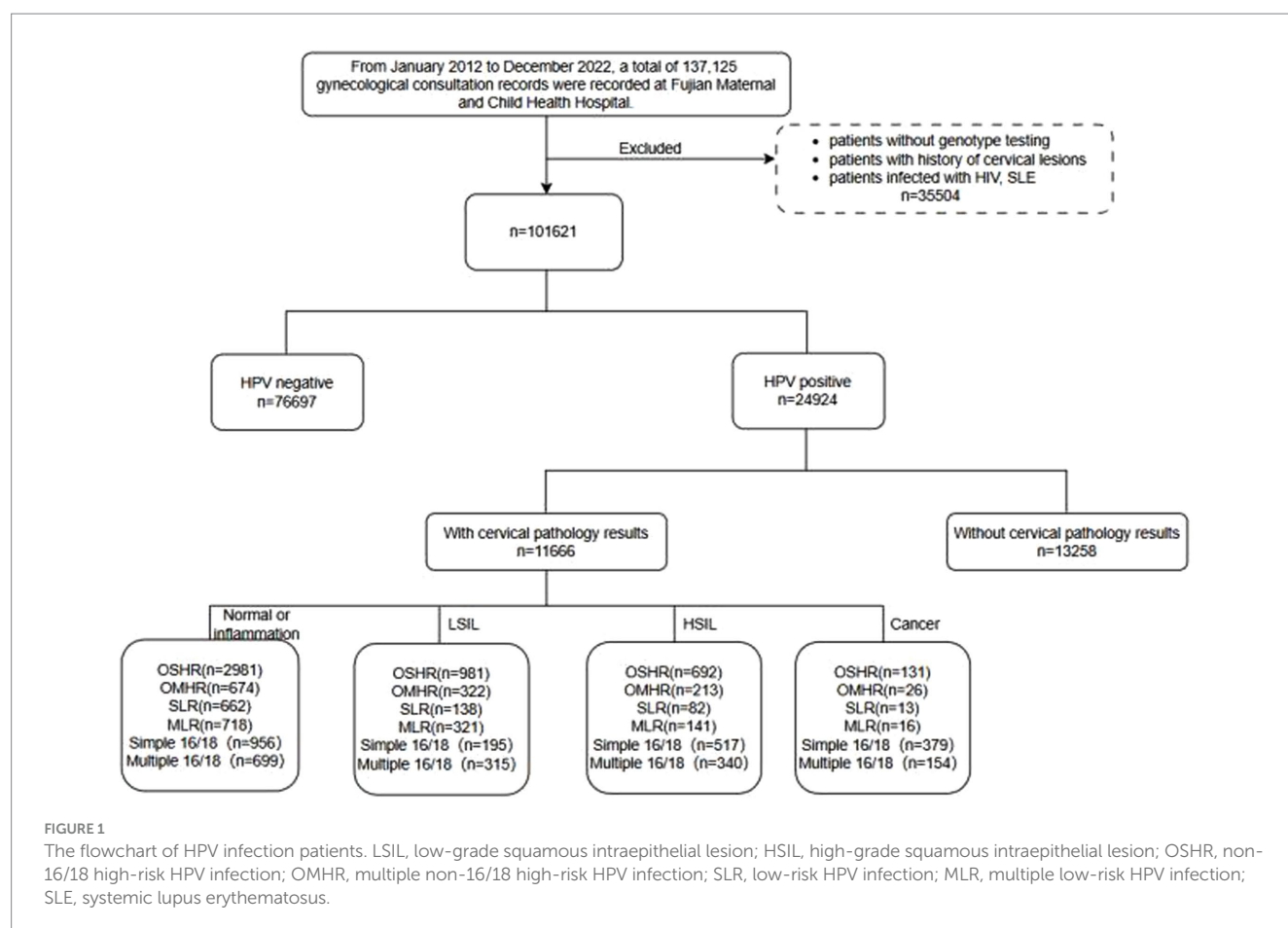
2.2 HPV genotype and cervical pathology

PCR-RDB HPV genotyping (Yaneng Biotech) was conducted to identify 18 types of high-risk HPV (HR-HPV) (16/18/31/33/35/39/45/51/52/53/56/58/59/66/68/73/82/83) and 5 types of low-risk HPV (LR-HPV) (6/11/42/43/81) among the study participants. Based on their HPV infection statuses, the patients were categorized into six groups: 16/18 simplex infection group, 16/18 multiple-infection group, low-risk simplex infection group, non-16/18 high-risk simplex infection group, low-risk multiple-infection group, and non-16/18 high-risk multiple-infection group.

Pathological findings were determined from cervical tissue samples obtained after standardized colposcopy. These samples were diagnosed by a consistent histopathologist who remained blinded to the participants' HPV statuses throughout the study.

2.3 Statistical analysis

All patients were stratified by age into the following categories: < 25, 25–29, 30–34, 35–39, 40–44, 45–49, 50–54, 55–59, 60–64, and ≥ 65 years. Descriptive statistics for continuous variables were presented as mean ± standard deviation and analyzed using one-way analysis of variance (ANOVA). Categorical variables were presented as percentages and analyzed using the chi-square test (or Fisher test).



Additionally, multivariate multinomial logistic regressions were conducted to determine the relationships between the various HPV infection types and final pathological diagnoses, controlling for potential confounding factors such as age and year. The statistical analysis was performed using R software and its software packages (<https://www.r-project.org>, Version 4.2.2). All *p*-values were two-tailed, and a significance level of $p < 0.05$ was considered statistically significant.

3 Results

3.1 General distribution of HPV infections

Out of the 101,621 samples analyzed, 24,924 (24.5%) tested positive for HPV. Among these samples. The patients were categorized into single and multiple infection groups based on the number of HPV types detected. The overall rate of single HPV infection was 17.3%, with 2.8% exhibiting a single infection with HPV16/18, 11.3% showing other high-risk HPV infections (OSHR), and 3.2% demonstrating single low-risk HPV infections (SLR). Multiple HPV infections occurred in 7.2% of samples, with 2.2% having multiple infections with HPV16/18, 2.4% showing other multiple high-risk HPV infections (OMHR), and 2.6% exhibiting multiple low-risk HPV infections (MLR), as shown in Table 1. As depicted in Figure 2, the top five genotypes for single HPV infection were HPV 52 (13%), HPV 16 (11.6%), HPV 53 (5.1%), HPV 58 (5.1%), HPV 81 (4.1%), and HPV

42 (3.7%), with their respective infection rates mentioned in parentheses. The overall non-16/18 HPV infection rate was 71.4%, indicating that the majority of infections were attributed to HPV types other than 16 and 18. Furthermore, the rate of multiple non-16/18 HPV infections (21.3%) exceeded that of multiple 16/18 infections (14.6%), underscoring the significance of non-16/18 HPV types in multiple infections.

3.2 Distribution of HPV subtypes at different ages and years

Age-related variations were observed in Table 1. The HPV-negative group peaked at 78.3% in those aged 25–29 years and gradually declined with increasing age, reaching a nadir of 62.1% in the 55–59 year age group before slightly rebounding in those ≥ 65 years (70.3%). HPV 16/18 single infections exhibited a bimodal pattern, reaching peaks of 2.9% in individuals < 25 years and 4.6% in the 60–64 year age group. Other high-risk (OSHR) genotypes were elevated at 11.5% in individuals < 25 years, remained relatively stable from 25–49 years (9.9–11.9%), then sharply increased after age 55, peaking at 15.4% in the 55–59 year age group. Low-risk (SLR) types showed minor peaks in individuals < 25 years (3.8%) and the 55–59 year age group (4.3%). Multiple HPV 16/18 infections were highest in individuals < 25 years (4.4%), low from 25–49 years (1.6–1.9%), then rose after age 50. Other multiple high-risk (OMHR) infections were 3.6% in individuals < 25 years, 2.1–2.2% from

TABLE 1 HPV infection of different subtypes in different age groups.

Variables	Total (<i>n</i> = 101,621)	<25 (<i>n</i> = 5,766)	25–29 (<i>n</i> = 16,661)	30–34 (<i>n</i> = 20,033)	35–39 (<i>n</i> = 15,951)	40–44 (<i>n</i> = 14,610)	45–49 (<i>n</i> = 12,725)	50–54 (<i>n</i> = 7,872)	55–59 (<i>n</i> = 3,984)	60–64 (<i>n</i> = 2,096)	≥65 (<i>n</i> = 1,923)
HPV genotype, <i>n</i> (%)											
Negative	76,697 (75.5)	3,984 (69.1)	13,040 (78.3)	15,842 (79.1)	12,417 (77.8)	11,117 (76.1)	9,546 (75)	5,666 (72)	2,475 (62.1)	1,259 (60.1)	1,351 (70.3)
hpv16/18single	2,890 (2.8)	166 (2.9)	384 (2.3)	465 (2.3)	420 (2.6)	455 (3.1)	416 (3.3)	272 (3.5)	169 (4.2)	96 (4.6)	47 (2.4)
OSHR	11,480 (11.3)	663 (11.5)	1,643 (9.9)	2,039 (10.2)	1,751 (11)	1,733 (11.9)	1,506 (11.8)	1,012 (12.9)	613 (15.4)	316 (15.1)	204 (10.6)
SLR	3,241 (3.2)	219 (3.8)	528 (3.2)	532 (2.7)	446 (2.8)	486 (3.3)	443 (3.5)	298 (3.8)	171 (4.3)	61 (2.9)	57 (3)
Multiple 16/18	2,195 (2.2)	254 (4.4)	313 (1.9)	356 (1.8)	265 (1.7)	234 (1.6)	244 (1.9)	178 (2.3)	170 (4.3)	105 (5)	76 (4)
OMHR	2,463 (2.4)	207 (3.6)	351 (2.1)	409 (2)	332 (2.1)	318 (2.2)	266 (2.1)	205 (2.6)	175 (4.4)	119 (5.7)	81 (4.2)
MLR	2,655 (2.6)	273 (4.7)	402 (2.4)	390 (1.9)	320 (2)	267 (1.8)	304 (2.4)	241 (3.1)	211 (5.3)	140 (6.7)	107 (5.6)

OSHR, non-16/18 high-risk HPV infection; OMHR, multiple non-16/18 high-risk HPV infection; SLR, low-risk HPV infection; MLR, multiple low-risk HPV infection.

25–49 years, increasing after age 50 to peak at 5.7% in the 60–64 year age group. Multiple low-risk (MLR) infections peaked at 4.7% in individuals <25 years, were 1.8–2.4% from 25–49 years, then increased markedly after age 50, reaching 6.7% in the 60–64 year age group.

These age-related variations suggest dynamic changes in HPV genotype distribution across different age groups. In younger individuals, particularly those <25 years old, there appears to be a higher prevalence of HPV 16/18 single infections and multiple HPV infections involving HPV 16/18. However, as age increases, there is a notable shift towards other high-risk HPV genotypes (OSHR), with a marked increase in prevalence after age 55, peaking in the 55–59 year age group. This transition may reflect changes in sexual behavior, immune response, or other factors influencing HPV acquisition, persistence, and clearance over the course of an individual's lifespan.

The trend depicted in Figure 3 illustrates varying HPV infection rates over time. Single HPV 16/18 infections peaked in 2013, gradually declining to 2.1% by 2022. Similarly, multiple HPV 16/18 infections peaked in 2013, decreasing to 1.8% by 2022. Other high-risk (OSHR) infections peaked in 2014, remaining relatively stable between 9.6–12.8%. Other multiple high-risk (OMHR) infections peaked in 2014, declining to 1.9% by 2022. Low-risk (SLR) infections peaked in 2012, decreasing to 2.7% by 2022. Multiple low-risk (MLR) infections had minor peaks in 2013 and 2016–2017, remaining stable at 2.2–2.8%. Overall, HPV infections peaked around 2013–2014 before declining, highlighting vaccine effectiveness. Persistent high-risk strains and age-related variations emphasize the need for ongoing surveillance and targeted interventions.

3.3 Characterizing cervical lesions in HPV-infected patients undergoing pathological examination

Table 2 illustrates the frequencies of non-16/18 high-risk HPV types and their distribution across different grades of cervical lesions. This large-scale analysis involved 11,666 HPV-positive patients with cervical pathology. The results revealed a significant association between age distribution and pathology type (*p* < 0.001). Patients with cervical cancer were older, with a mean age of 49 years, compared to those with other pathologies, who ranged from 38 to 42 years of age. The analysis reveals the prevalence of various non-16/18 high-risk HPV types among different cervical lesion groups. In the cancer group, HPV52 (8.2%) and HPV58 (7.4%) were the predominant types, followed by HPV33, HPV31, and HPV53. In the High-grade Squamous Intraepithelial Lesion (HSIL) group, HPV52 remained prevalent at 21.8%, along with significant proportions of HPV58, HPV33, HPV31, and HPV53. Similarly, in the Low-grade Squamous Intraepithelial Lesion (LSIL) group, HPV52 was the most common type at 29.3%, with HPV58, HPV33, HPV31, and HPV53 also exhibiting notable frequencies. The distribution of single and multiple infections by gene typing is illustrated in Figure 4. These findings underscore the importance of considering the distribution and potential contributions of non-16/18 high-risk HPV types in the development and progression of cervical lesions across different patient populations.

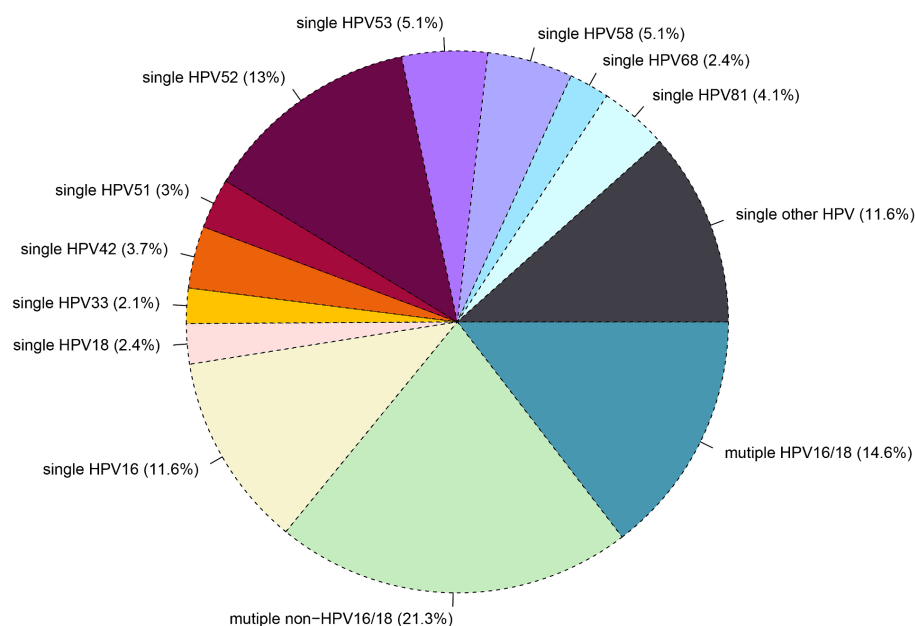


FIGURE 2
Distribution of single and multiple infections among different HR-HPV subtypes.

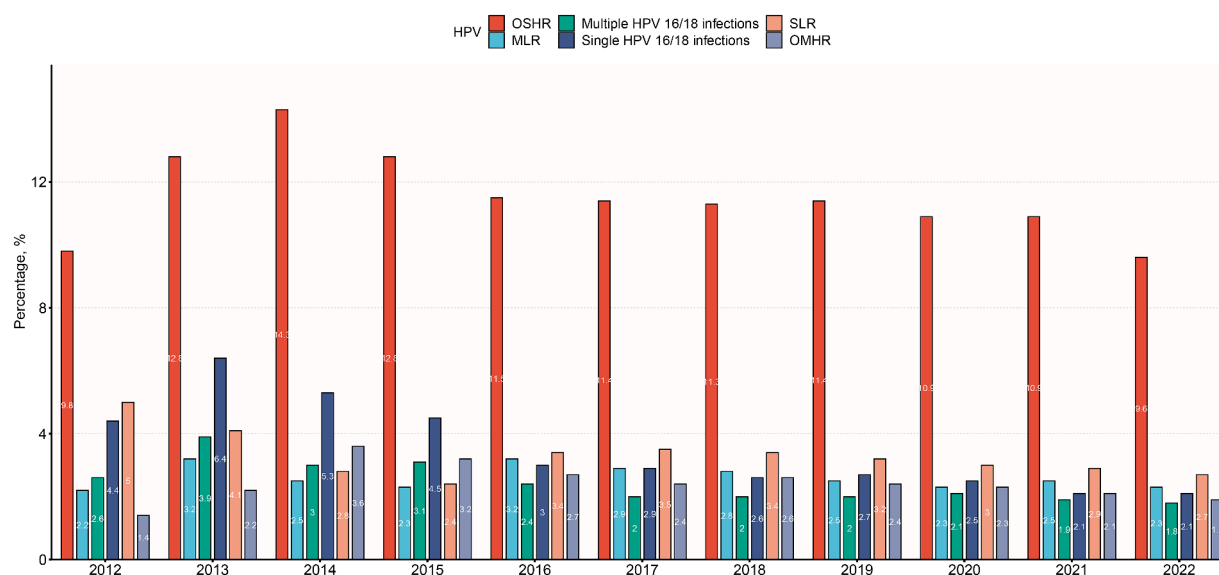


FIGURE 3
Distribution of HPV infection subtypes among different years. OSHR, non-16/18 high-risk HPV infection; OMHR, multiple non-16/18 high-risk HPV infection; SLR, low-risk HPV infection; MLR, multiple low-risk HPV infection.

3.4 Impact of HPV infection subtypes on cervical pathology

To gain further insights into the correlation between HPV types and the severity of cervical lesions, additional analyses were conducted by the researchers, adjusting for age and year (Table 3). Compared to single HPV16/18 infection, the following HPV types showed higher odds of association with LSIL: multiple HPV16/18 infections (OR 2.18, 95% CI 1.77–2.68), non-16/18 single high-risk HPV (OSHR)

(OR 1.71, 95% CI 1.44–2.04), non-16/18 multiple high-risk HPV (OMHR) (OR 2.53, 95% CI 2.05–3.12), single low-risk HPV (SLR) (OR 1.08, 95% CI 0.85–1.38), and multiple low-risk HPV (MLR) (OR 2.38, 95% CI 1.93–2.93). However, solitary HPV16/18 infections conferred higher odds of association with HSIL and cervical cancer compared to other HPV types. These findings suggest that while multiple infections and non-16/18 high-risk HPV types increase the risk of LSIL, HPV16 and HPV18 play a more prominent role in the progression to more severe cervical lesions and cervical cancer.

TABLE 2 Distribution of each human papillomavirus genotypes according to cervical pathology results among the 11,666 HPV infected patients, *n* (%).

Variables	Total (<i>n</i> = 11,666)	Cancer (<i>n</i> = 719)	HSIL (<i>n</i> = 1985)	LSIL (<i>n</i> = 2,272)	Normal or cervicitis (<i>n</i> = 6,690)	<i>p</i>
HPV age, Mean ± SD	41.9 ± 11.3	49.5 ± 10.0	42.5 ± 11.3	38.0 ± 10.7	42.2 ± 11.1	< 0.001
hpv16, <i>n</i> (%)	2,583 (22.1)	431 (59.9)	754 (38)	307 (13.5)	1,091 (16.3)	< 0.001
hpv18, <i>n</i> (%)	1,068 (9.2)	112 (15.6)	127 (6.4)	225 (9.9)	604 (9)	< 0.001
hpv31, <i>n</i> (%)	478 (4.1)	33 (4.6)	116 (5.8)	86 (3.8)	243 (3.6)	< 0.001
hpv33, <i>n</i> (%)	613 (5.3)	32 (4.5)	165 (8.3)	125 (5.5)	291 (4.3)	< 0.001
hpv35, <i>n</i> (%)	291 (2.5)	11 (1.5)	56 (2.8)	74 (3.3)	150 (2.2)	< 0.001
hpv39, <i>n</i> (%)	484 (4.1)	13 (1.8)	46 (2.3)	138 (6.1)	287 (4.3)	< 0.001
hpv45, <i>n</i> (%)	209 (1.8)	15 (2.1)	29 (1.5)	39 (1.7)	126 (1.9)	< 0.001
hpv51, <i>n</i> (%)	1,018 (8.7)	29 (4)	130 (6.5)	268 (11.8)	591 (8.8)	< 0.001
hpv52, <i>n</i> (%)	2,727 (23.4)	59 (8.2)	433 (21.8)	666 (29.3)	1,569 (23.5)	< 0.001
hpv53, <i>n</i> (%)	1,184 (10.1)	32 (4.5)	133 (6.7)	228 (10)	791 (11.8)	< 0.001
hpv56, <i>n</i> (%)	611 (5.2)	28 (3.9)	58 (2.9)	147 (6.5)	378 (5.7)	< 0.001
hpv58, <i>n</i> (%)	1,474 (12.6)	53 (7.4)	370 (18.6)	361 (15.9)	690 (10.3)	< 0.001
hpv59, <i>n</i> (%)	539 (4.6)	32 (4.5)	67 (3.4)	137 (6)	303 (4.5)	< 0.001
hpv66, <i>n</i> (%)	503 (4.3)	15 (2.1)	50 (2.5)	130 (5.7)	308 (4.6)	< 0.001
hpv68, <i>n</i> (%)	697 (6.0)	14 (1.9)	90 (4.5)	162 (7.1)	431 (6.4)	< 0.001
hpv73, <i>n</i> (%)	130 (1.1)	7 (1)	19 (1)	26 (1.1)	78 (1.2)	< 0.001
hpv82, <i>n</i> (%)	107 (0.9)	5 (0.7)	32 (1.6)	20 (0.9)	50 (0.7)	< 0.001
hpv42, <i>n</i> (%)	729 (6.2)	19 (2.6)	88 (4.4)	160 (7)	462 (6.9)	< 0.001
hpv43, <i>n</i> (%)	554 (4.7)	15 (2.1)	48 (2.4)	112 (4.9)	379 (5.7)	< 0.001
hpv44, <i>n</i> (%)	3 (0.0)	0 (0)	0 (0)	0 (0)	3 (0)	< 0.001
hpv11, <i>n</i> (%)	213 (1.8)	1 (0.1)	31 (1.6)	63 (2.8)	118 (1.8)	< 0.001
hpv6, <i>n</i> (%)	347 (3.0)	10 (1.4)	39 (2)	92 (4)	206 (3.1)	< 0.001
hpv81, <i>n</i> (%)	926 (7.9)	21 (2.9)	120 (6)	207 (9.1)	578 (8.6)	< 0.001
hpv83, <i>n</i> (%)	110 (0.9)	4 (0.6)	13 (0.7)	19 (0.8)	74 (1.1)	< 0.001

Understanding these associations informs targeted prevention strategies and underscores the importance of HPV vaccination and vigilant screening programs for cervical cancer prevention.

4 Discussion

Previous studies have found that HPV16 and 18 are responsible for approximately 70% of cervical cancers worldwide (11). The introduction of HPV vaccines holds promise in preventing HPV16/18-associated cancers, supported by the safety and efficacy of current vaccines (12). However, in the post-vaccine era, understanding HPV genotype distribution, non-16/18 epidemiology, and associated cancer risks is pivotal for optimizing vaccine development. This knowledge also guides screening and management of cervical lesions, particularly in less explored regions like Fujian Province, China.

Against this backdrop of limited vaccine coverage, assessing the oncogenicity of non-vaccine high-risk HPV types remains crucial, as they may still pose cancer risks in vaccinated groups. Our study findings reveal a widespread prevalence of non-16/18 HPV types, accounting for substantial proportions in cervical lesions across Fujian Province. This underscores the significance of these

oft-neglected genotypes in cervical carcinogenesis within this region. Specifically, our data highlight the prominent roles of HPV58, HPV33, and HPV52 among the high-risk non-16/18 types implicated in precancerous cervical intraepithelial neoplasia and invasive cervical cancer cases. These results underscore the need for comprehensive genotyping to delineate region-specific HPV profiles and cancer associations for informing tailored prevention and management strategies. Our findings revealed an HPV infection rate of 24.5%, surpassing the overall Asian rate (8.3%) (13) but falling below a prior estimate for China (47.3%) (14). The prevalent types, including HPV52, 16, 58, 51, and 53, mirrored China's dominant strains (14). Geographic variations in HPV prevalence indicate the influence of diverse factors, emphasizing the need for region-specific studies (15).

Building upon these insights into the regional HPV landscape, we identified 17.3% single HPV and 7.2% multiple HPV infections. Notably, multiple non-16/18 infections exceeded multiple 16/18 infections. While multiple HPV infection may not independently increase cervical cancer risk (15), some studies associate it with cancer-related genotypes and prolonged infections (16). Our findings therefore warrant further research on potential synergistic or competitive effects of multiple HPVs in cervical carcinogenesis.

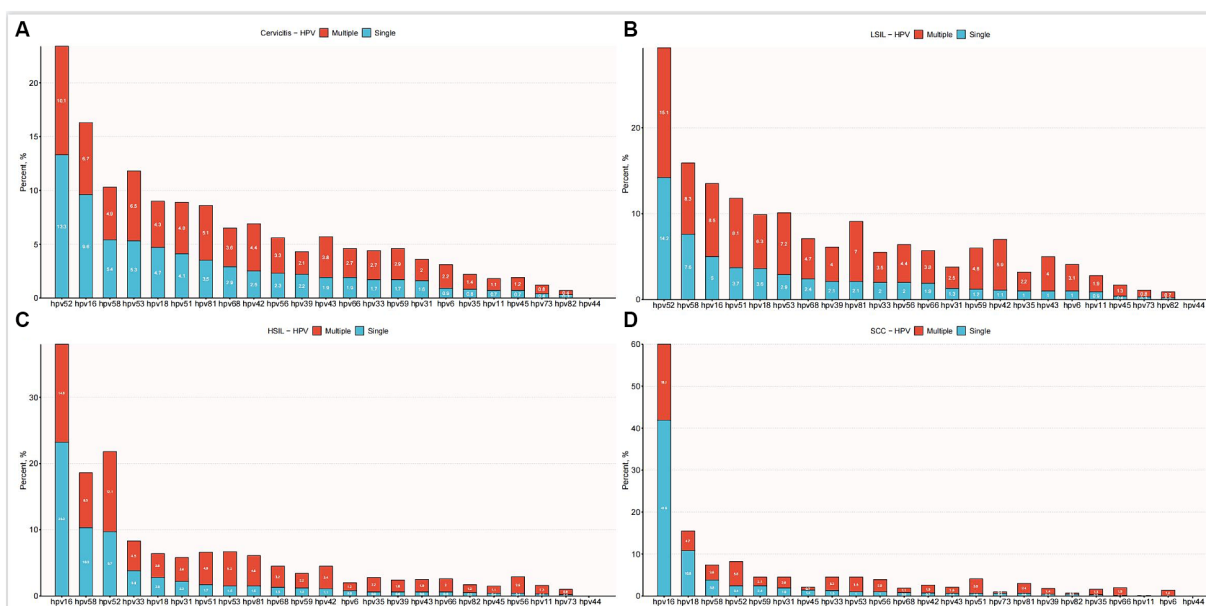


FIGURE 4

Distribution of single and multiple infections among different HPV subtypes. (A) Distribution of multiple and single HPV genotype infections in patients with cervicitis. (B) Distribution of multiple and single HPV genotype infections in patients with LSIL. (C) Distribution of multiple and single HPV genotype infections in patients with HSIL. (D) Distribution of multiple and single HPV genotype infections in patients with SCC.

Moreover, our investigation into age distribution uncovered a notable bimodal pattern in infection rates. This bimodal trend aligns with findings reported elsewhere (17). Proposed explanations posit that heightened sexual activity and engagement with new/multiple partners contribute to the peak in younger women, alongside relatively immature anti-HPV immunity. Conversely, the second peak in older women may be attributed to hormonal changes and potential reactivation in individuals seeking care for symptoms of prior infection (17, 18). Importantly, prior research suggests that this bimodal distribution may be influenced by lower levels of urbanization and education (19). Furthermore, understanding these trends can guide targeted interventions to mitigate HPV transmission risks. These age-specific infection rates lay the groundwork for our subsequent investigations, shedding light on the dynamic interplay between HPV prevalence and demographic factors.

Additionally, the infection rate of non-16/18 multiple types of HPV peaked in 2014 at 3.6%, gradually decreasing annually thereafter. By 2022, it had reached 1.9%, indicating potential improvements in detection methods accompanying economic development. However, despite this stabilization, the overall infection rate remains higher than the global average (20). Therefore, ongoing initiatives to enhance screening accessibility and vaccine coverage remain paramount. Moreover, the escalating proportion of non-16/18 HR-HPV and low-risk HPV underscores the importance of transmission prevention and asymptomatic infection management. Understanding these temporal trends in HPV prevalence highlights the significance of continued research into age-specific distribution, guiding more effective strategies for HPV control and prevention.

Furthermore, a deeper analysis of HPV genotype distribution's impact on pathological outcomes is essential. Persistent infection with high-risk HPV strains is recognized to increase the risk of developing precancerous and cancerous lesions (21–23). In benign infections, HPV typically remains in an episomal free form, but integration into the host

DNA can occur, resulting in the overexpression of viral oncogenes E6 and E7. This dysregulated gene expression promotes cellular proliferation, genomic instability, and lesion progression (24, 25). However, despite this understanding, the precise interactions between specific HPV types and their roles in lesion advancement remain unclear and necessitate further investigation (26). Elucidating these interactions is crucial for better understanding HPV-related disease pathogenesis and developing more targeted interventions for prevention and treatment.

Therefore, studying the distribution characteristics of HPV types in different cervical lesions is paramount. In a cohort of 11,666 HPV-positive patients, significant variations in HPV type distribution were noted across different pathological outcomes ($p < 0.001$). Specifically, non-16/18 single high-risk HPV (HR-HPV) types were prevalent in low-grade squamous intraepithelial lesions (LSIL) and high-grade squamous intraepithelial lesions (HSIL), respectively. In contrast, cancer patients exhibited the highest rate of solitary HPV16/18 infections. Moreover, certain HPV types were found to be more strongly associated with specific disease states, with other HPV types being more common in LSIL, while solitary HPV16/18 infections were correlated with HSIL and cancer. LSIL and HSIL showed non-16/18 single infections predominating, while solitary HPV16/18 was highest in cancer. An inverse association between multiple HPV and lesion severity has been reported (27). In summary, HPV16/18 predominates in cancer, while non-16/18 types prevail in LSIL and HSIL. Targeting non-16/18 genotypes like 52, 58, 53, 51, and 81 in preventative strategies can mitigate lesion severity and reduce LSIL risk. To address this, it's crucial to give adequate attention to non-16/18 genotypes in screening and vaccination strategies. This study reaffirms that HPV vaccination and cervical cancer screening collectively represent the most effective tools for reducing cervical cancer risks at both individual and population levels. Ongoing research into broader HPV protective vaccines and serotype-specific risks will further inform optimal prevention strategies.

TABLE 3 Multivariate logistic regression analysis of HPV infection types and final diagnoses.

Variable	No of total	normal or cervicitis, n (%)	LSIL, n (%)	HSIL, n (%)	Cancer, n (%)	LSIL vs. normal or cervicitis		HSIL vs. normal or cervicitis		Cancer vs. normal or cervicitis	
						OR (95%CI)	p value	OR (95%CI)	p value	OR (95%CI)	p value
Simple hpv16/18	2,047	956 (46.7)	195 (9.5)	517 (25.3)	379 (18.5)	1 (Ref)		1 (Ref)		1 (Ref)	
Multiple hpv 16/18	1,508	699 (46.4)	315 (20.9)	340 (22.5)	154 (10.2)	2.21 (1.8 ~ 2.71)	<0.001	0.9 (0.76 ~ 1.06)	0.216	0.56 (0.45 ~ 0.69)	<0.001
OSHR	4,785	2,981 (62.3)	981 (20.5)	692 (14.5)	131 (2.7)	1.61 (1.36 ~ 1.91)	<0.001	0.43 (0.37 ~ 0.49)	<0.001	0.11 (0.09 ~ 0.14)	<0.001
OMHR	1,235	674 (54.6)	322 (26.1)	213 (17.2)	26 (2.1)	2.34 (1.91 ~ 2.87)	<0.001	0.58 (0.48 ~ 0.7)	<0.001	0.1 (0.06 ~ 0.15)	<0.001
SLR	895	662 (74)	138 (15.4)	82 (9.2)	13 (1.5)	1.02 (0.8 ~ 1.3)	0.859	0.23 (0.18 ~ 0.3)	<0.001	0.05 (0.03 ~ 0.09)	<0.001
MLR	1,196	718 (60)	321 (26.8)	141 (11.8)	16 (1.3)	2.19 (1.79 ~ 2.68)	<0.001	0.36 (0.29 ~ 0.45)	<0.001	0.06 (0.03 ~ 0.09)	<0.001

Model adjusted age and years.
OSHR, non-16/18 high-risk HPV infection; SLR, low-risk HPV infection; OMHR, multiple non-16/18 high-risk HPV infection; MLR, multiple low-risk HPV infection.

While this study provides valuable insights into HPV prevalence and genotypes in women with cervical lesions in Fujian Province, it is essential to acknowledge certain limitations that may impact the generalizability of findings. The potential for patient selection bias is acknowledged, as the study primarily focused on symptomatic gynecology patients, possibly limiting its representativeness of the general population. Furthermore, financial constraints resulted in some patients declining testing, potentially introducing bias into the study population. The absence of data on relevant factors such as smoking, socioeconomics, and sexual history represents a notable limitation. These factors are known to influence HPV and cervical lesion risk and their exclusion may limit the comprehensive understanding of the study outcomes. Another limitation is the lack of specific analysis of patients' annual infection rates. The absence of serial HPV data may lead to an underestimation of persistent infections, restricting insights into the long-term dynamics of HPV infection and its impact on cervical lesions.

Despite these limitations, the study's large sample size contributes to robust data for analysis, mitigating some of the potential drawbacks. However, researchers and practitioners should exercise caution when interpreting the findings in light of these limitations. Future research in this area should strive to address these limitations by incorporating more diverse participant groups, considering relevant influencing factors, and conducting longitudinal analyses to capture the dynamic nature of HPV infection and its relationship with cervical lesions. This ongoing effort will contribute to a more comprehensive understanding of HPV epidemiology and improve the effectiveness of preventive strategies.

5 Conclusion

Our large-scale analysis in Fujian Province highlights HPV 52, 58, 53, 51, and 81 as predominant non-16/18 HR-HPV types. Multiple HPV poses increased LSIL risks, while solitary HPV16/18 elevates HSIL and cancer odds. These findings inform tailored cervical cancer prevention, emphasizing specific HPV impacts on lesion severity. The study underscores HR-HPV's role, emphasizing the need for region-specific prevention strategies, especially for prevalent non-16/18 types in Asia. It provides crucial insights into regional HPV epidemiology, guiding optimized screening. Ongoing surveillance is vital for adapting preventive strategies in the vaccination era.

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 Ethics Committee of Fujian Maternity and Child Health Hospital, Affiliated Hospital of Fujian Medical 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 in accordance with the national legislation and institutional requirements.

Author contributions

YZ: Formal analysis, Writing – original draft, Writing – review & editing. HL: Formal Analysis, Software, Writing – original draft, Writing – review & editing. QY: Data curation, Writing – original draft. YC: Investigation, Software, Writing – review & editing. ZZ: Visualization, Writing – review & editing. JC: Formal analysis, Writing – review & editing. YS: Writing – review & editing. XZ: Funding acquisition, Resources, Writing – original draft, Writing – review & editing. HY: Investigation, Supervision, Writing – original draft, Writing – review & editing. JS: 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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Protective effectiveness of previous infection against subsequent SARS-CoV-2 infection: systematic review and meta-analysis

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Background: The protective effectiveness provided by naturally acquired immunity against SARS-CoV-2 reinfection remain controversial.

Objective: To systematically evaluate the protective effect of natural immunity against subsequent SARS-CoV-2 infection with different variants.

Methods: We searched for related studies published in seven databases before March 5, 2023. Eligible studies included in the analysis reported the risk of subsequent infection for groups with or without a prior SARS-CoV-2 infection. The primary outcome was the overall pooled incidence rate ratio (IRR) of SARS-CoV-2 reinfection/infection between the two groups. We also focused on the protective effectiveness of natural immunity against reinfection/infection with different SARS-CoV-2 variants. We used a random-effects model to pool the data, and obtained the bias-adjusted results using the trim-and-fill method. Meta-regression and subgroup analyses were conducted to explore the sources of heterogeneity. Sensitivity analysis was performed by excluding included studies one by one to evaluate the stability of the results.

Results: We identified 40 eligible articles including more than 20 million individuals without the history of SARS-CoV-2 vaccination. The bias-adjusted efficacy of naturally acquired antibodies against reinfection was estimated at 65% (pooled IRR = 0.35, 95% CI = 0.26–0.47), with higher efficacy against symptomatic COVID-19 cases (pooled IRR = 0.15, 95% CI = 0.08–0.26) than asymptomatic infection (pooled IRR = 0.40, 95% CI = 0.29–0.54). Meta-regression revealed that SARS-CoV-2 variant was a statistically significant effect modifier, which explaining 46.40% of the variation in IRRs. For different SARS-CoV-2 variant, the pooled IRRs for the Alpha (pooled IRR = 0.11, 95% CI = 0.06–0.19), Delta (pooled IRR = 0.19, 95% CI = 0.15–0.24) and Omicron (pooled IRR = 0.61, 95% CI = 0.42–0.87) variant were higher and higher. In other subgroup analyses, the pooled IRRs of SARS-CoV-2 infection were statistically various in different countries, publication year and the inclusion end time of population, with a significant difference ($p = 0.02$, $p < 0.010$ and $p < 0.010$), respectively. The risk of subsequent infection in the seropositive population appeared to increase slowly over time. Despite the heterogeneity in included studies, sensitivity analyses showed stable results.

Conclusion: Previous SARS-CoV-2 infection provides protection against pre-omicron reinfection, but less against omicron. Ongoing viral mutation requires attention and prevention strategies, such as vaccine catch-up, in conjunction with multiple factors.

KEYWORDS

SARS-CoV-2, variant, naturally infection, reinfection, protective effectiveness

Highlights

- The efficacy of naturally immunity against reinfection was estimated at 65% ($IRR=0.35$, 95% confidence interval (CI)=0.26–0.47).
- For different SARS-CoV-2 variant, the pooled $IRRs$ for the Alpha ($IRR=0.11$), Delta ($IRR=0.19$) and Omicron ($IRR=0.61$) variant means a progressively lower protective effectiveness.

Introduction

SARS-CoV-2 has evolved into many variants since its initial outbreak in 2019, and the WHO has identified the Alpha, Beta, Gamma, Delta, and Omicron variants as variations of concern (VOCs). The Beta and Delta variants are distinguished by specific combinations of unique mutations, which can potentially lead to structural and functional abnormalities (1). Studies have demonstrated that these variants are associated with a higher risk compared to the Alpha and Gamma variants, as shown by a higher hospitalization rate, severity of illness, and mortality (2). Moreover, the Omicron variant emerged in late November 2021 and possesses a significantly higher number of mutations in the Spike protein compared to the aforementioned VOCs, surpassing them by 3–4 times (3). Consequently, the highly contagious Omicron variant quickly became the dominant strain and widespread around the world (4, 5). This, in conjunction with the gradual relaxation of strict COVID-19 control measures, led to a SARS-CoV-2 infection peak at the end of 2022 (6).

To date, the vast majority of the world's population has been infected with SARS-CoV-2 at least once, and the issue of reinfection has become a concern. Although most people have received a COVID-19 booster vaccination, the ability of vaccines to protect against infection of Omicron is still controversial due to its great number of mutations in the spike protein, which led to antigen escape (7). Besides, studies have shown that the neutralization titer induced by previous vaccination would drop significantly after 6 months of vaccination (8) and could not be detected after 1 year (9). In such cases, the immunity built up after natural infection may be a key aspect to fight against reinfection.

With the emergence of new variants of SARS-CoV-2, there has been a significant increase in reinfection rates. For example, a meta-analysis revealed an overall reinfection rate of 0.97% [95% confidence interval (CI)=0.71–1.27%]. However, studies providing specific data on the

Alpha wave showed a reinfection rate of 0.57% (95% CI: 0.28–0.94%), which rose to 1.25% (95% CI: 0.97–1.55%) with the Delta strain, and peaked to 3.31% (95% CI: 1.15–6.53%) during the first 3 months of the Omicron wave (10). These findings suggest that the Omicron variant has a strong ability to evade immunity from previous infections (11). Correspondingly, the protection of the immunity acquired by natural infection against reinfection gradually declined with the evolution of the variants. Studies have indicated an estimated protective effect of over 82% against Alpha, Beta, and Delta variants reinfection (12, 13), whereas the protection against reinfection of the Omicron variant from previous infection was significantly reduced to 45.3%. Moreover, it will continue to decline over time (12, 14), which would last for about 5–12 months (15).

The objective of this meta-analysis was to systematically evaluate the protective effect of natural immunity against SARS-CoV-2 reinfection (both symptomatic and asymptomatic) and its trend over time. We also conducted subgroup analysis to explore divergences of natural immunity in different variants, study population, and age groups. Compared with previous relevant studies, the present study included the most recent studies up to March 5, 2023, and in particular included more studies on Omicron; and evaluated evidence from cohort studies that included only unvaccinated populations to focus on the impact of natural immunity.

Methods

Study strategy

We systematically searched for the relevant literature published before 5 Mar 2023 in seven databases, including four peer-reviewed databases (PubMed, Embase, Web of Science and Scopus) and three preprint platforms (medRxiv, bioRxiv, and Europe PMC). Key search terms included the following: SARS-CoV-2, natural infection, protection and reinfection. The full search strategy was described in [Supplementary Table S1](#). A secondary reference search on all eligible studies and relevant review articles was also conducted (10, 13, 16–21). We used EndNote X8.2 (Thomson Research Soft, Stanford, CA, United States) to manage records, screen, and exclude duplicates. This study was followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA, [Supplementary Table S2](#)) (22), and had been registered at PROSPERO (Registration number: CRD42023405080).

Selection criteria

Inclusion and exclusion criteria were shown in [Table 1](#). All retrieved publications were independently assessed by two

Abbreviations: IRR, incidence rate ratio; 95% CI, 95% confidence interval; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; I^2 , I-squared.

TABLE 1 Inclusion and exclusion criteria for this systematic review and meta-analysis about protective effectiveness of previous infection against subsequent SARS-CoV-2 infection in the world from 2020 to 2022.

Characteristic	Inclusion criteria	Exclusion criteria
Study type	1. Cohort study	–
Participants	2. Population without a history of COVID-19 vaccination	–
Sample size	3. ≥ 10 participants in each group	–
SARS-CoV-2 serology testing at baseline	4. Done	–
Confirmation of COVID-19 cases during follow-up	5. Nucleic acid testing or antigenic rapid diagnostic tests	–
Data reported	6. The study must have compared the risk of SARS-CoV-2 reinfection/infection between baseline seropositive and seronegative groups	1. The study only used odds ratio as an effect size indicator and did not report original data

investigators according to the below criteria, and any inconsistencies were resolved by agreement in consultation with a third investigator.

Data extraction and quality assessment

A standardized electronic data collection form will be used to extract the following data from included studies: (1) literature information (i.e., study title, first author, title, publication or preprint date), (2) study details (e.g., study location, study population, demographic characteristics of the study population, SARS-CoV-2 variant, sample sizes, the date of study start and end, follow up time, effect measure, the type of target antibodies, the reinfection/infection cases in baseline seropositive or seronegative groups, the definition of reinfection, whether researchers attempted to adjust for any potential covariates, *IRRs* and 95% CI). We calculated the *IRR* by constructing a 2×2 contingency table for those study in which the *IRR* was not reported directly. We used the Newcastle–Ottawa quality assessment scale to evaluate the risk of bias of the included cohort studies. A score of 0–3 stars was considered a low-quality study, a score of 4–6 stars was considered a moderate-quality study, and a score of 7–9 stars was considered a high-quality study. Data extraction and quality assessment was conducted independently by two investigators and checked by a third investigator, and disagreements were resolved through discussion.

Statistical analysis

We performed a meta-analysis to estimate the pooled incidence rate ratio (*IRR*) and its 95% CI for estimating the risk of subsequent

infection between the baseline seropositive and seronegative groups. The primary outcome was the risk of SARS-CoV-2 reinfection/infection between the two groups, while the second outcome was the risk of symptomatic and asymptomatic SARS-CoV-2 reinfection/infection between the two groups. A suitable model (Fixed-effects or random-effects model) was used to pool the rates across studies separately, based on the heterogeneity between estimates which was evaluated by using the *I*-squared (I^2) (23). Fixed-effects models would be used if $I^2 \leq 50\%$, which represents low to moderate heterogeneity, and random-effects models would be used if $I^2 \geq 50\%$, representing substantial heterogeneity. We performed meta-regression to explore between-study heterogeneity.

Subgroup analyses of the primary outcome were performed in the following groups: SARS-CoV-2 variant (Alpha, Delta, and Omicron), definition of reinfection (two positive SARS-CoV-2 PCR test results at least 60 or 90 days apart), population (HCWs or general population), age (<60 years old or ≥ 60 years old, <55 years old or ≥ 55 years old), country, publication year (2020, 2021, or 2022), inclusion end time of population (every 6 months from 2020 to 2022), and study quality (moderate or high). The classification criteria for each subgroup are described in the [Supplementary Table S3](#). Bubble plots were used to explore trends in the immune protection acquired from natural infection with COVID-19. We used funnel plots and Begg's test to examine the potential for publication bias. If the results are suggestive of publication bias, we will further provide bias-adjusted results using trim-and-fill, a non-parametric method based on examining the funnel plot's asymmetry. We conducted sensitivity analysis with the one-study-at-a-time method adopted for assessing the reliability of the results. All statistical analyses were conducted using meta libraries in R 4.0.5.

Results

A total of 9,537 relevant records were identified, of which 1,119 duplicate records were removed. Eight thousand, four hundred eighteen article titles and abstracts were screened and 117 underwent full-text review. Finally, 40 unique articles reporting data for 52 studies were included in this meta-analysis ([Figure 1](#)). After a secondary reference search of all eligible studies and relevant review articles, no new studies were included. The 40 eligible articles included more than 20 million COVID-19 unvaccinated individuals without the history of COVID-19 vaccination. The sample sizes of the included studies ranged from 209 to 8,901,064 (median: 15075). Among the 40 unique articles, 11 studies were conducted in the United States, 9 in the United Kingdom, four in Switzerland, three in Qatar, two each in Sweden, Nicaragua, Italy and Israel, and one each in Austria, Bangladesh, Denmark, France and India. The mean/median ages of the enrolled participants were mostly less than 60 years old, with only two studies reporting median age over 60 years old. The study populations mainly included the general population, HCWs, care home residents and staffs, and hemodialysis patients. The included studies initiated between January 2020 and September 2021, and the length of the follow-up time ranged from 1.47 to 24.07 months. Different studies have used different window periods between positive PCR tests and baseline seropositive or previous RNA-positive results in defining reinfection. This is due to the fact that most studies were initiated in the early stages of the COVID-19 pandemic, when the

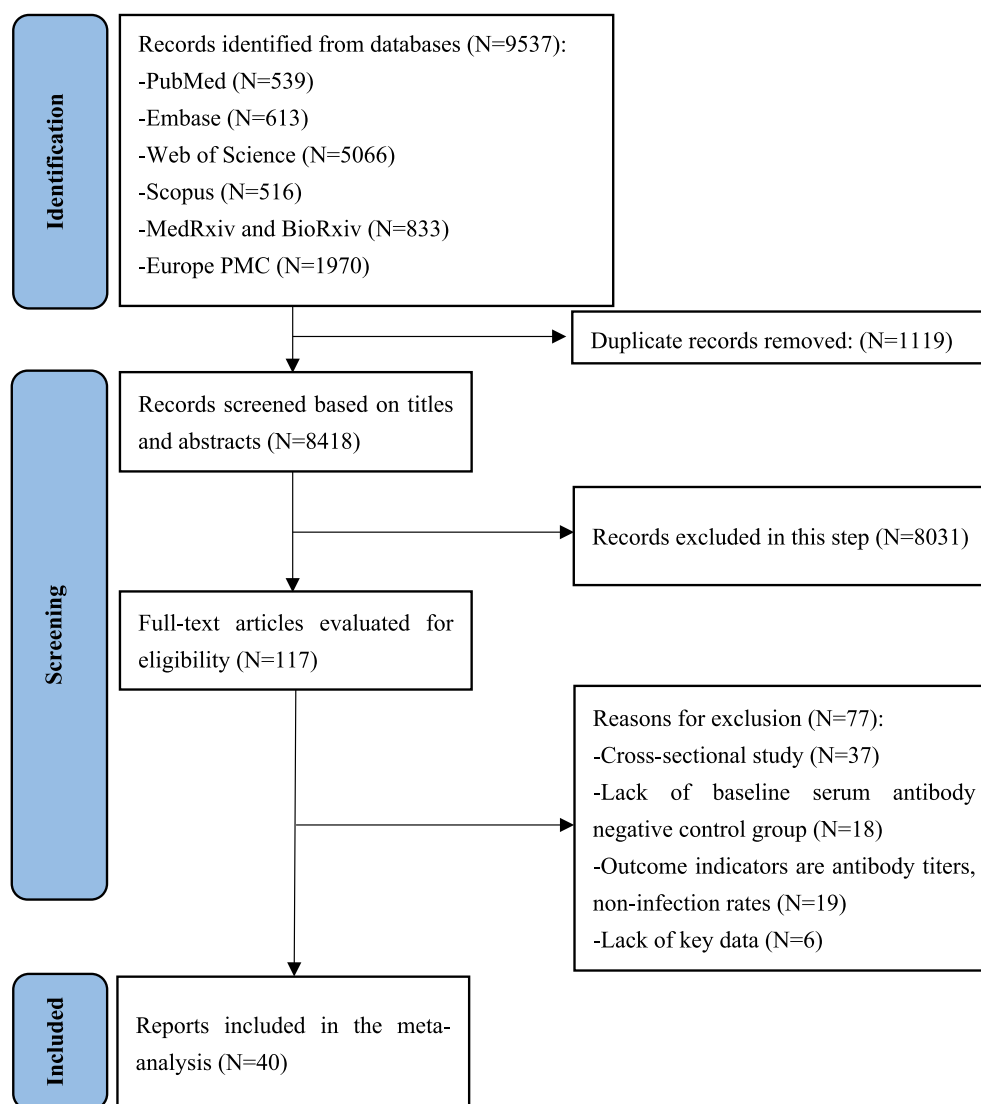


FIGURE 1
PRISMA flow diagram for this systematic review and meta-analysis about protective effectiveness of previous infection against subsequent SARS-CoV-2 infection in the world from 2020 to 2022.

persistence of SARS-CoV-2 RNA was not clearly understood. Of the included studies, 23 defined reinfection as two positive SARS-CoV-2 PCR test results at least 90 days apart, and 4 defined reinfection as two positive SARS-CoV-2 PCR test results at least 60 days apart, 1 study each defined reinfection as two positive SARS-CoV-2 PCR tests separated by a period of 270 or 28 days, and the remainder of the studies did not report a specific definition of reinfection. The quality score of study according to the NOS ranged from 4 to 9, with 14 studies of high quality, 26 studies of moderate quality, and none of low quality (Supplementary Table S4). The main characteristics of 40 eligible studies were summarized in Table 2.

The asymmetry in funnel plot and the result of Begg's test suggested a possible publication bias in the included studies ($p < 0.05$), so we adopted the trim-and-fill method. The funnel plot for publication bias before and after trimming and filling were shown in Supplementary Figure S3. The pooled results for the protection of naturally acquired antibodies against future SARS-CoV-2 infection

after using the trim-and-fill method were shown in Figure 2, while the original results without the trim-and-fill method were shown in Supplementary Figure S1. Adopting random effect meta-analysis models, we observed significant protection against SARS-CoV-2 reinfection in the seropositive population compared with seronegative individuals (pooled $IRR = 0.35$, 95% $CI = 0.26-0.47$). The original pooled IRR s without the trim-and-fill method was 0.19 (95% $CI = 0.15-0.23$). In the sensitivity analysis for the original result, the pooled IRR s of remaining studies ranges from 0.15–0.24 after removing any one of the studies, which suggested the good reliability of the pooled IRR (Supplementary Figure S2).

For secondary outcome, 12 studies reported the protection of the antibodies induced by a previous infection against future symptomatic between baseline seropositive and seronegative groups while there were 10 studies for asymptomatic reinfections. Natural infections of SARS-CoV-2 provided a lower level of protection against asymptomatic infection (pooled $IRR = 0.40$, 95% $CI = 0.29-0.54$) than

TABLE 2 Description of included studies in this systematic review and meta-analysis about protective effectiveness of previous infection against subsequent SARS-COV-2 infection in the world from 2020 to 2022.

ID	Authors, year	Location	Population	Sample size	Median/mean age	Variant	Study start time	Study end time	Length of follow-up (months)	Effect measure	Quality assessment
1	Maier et al. (24)	Nicaragua	General population	2,123	–	Gamma and Delta	2020-03-01	2021-10-14	4.10	Adjusted RR	6 (MQ)
2	Lumley et al. (25)	United Kingdom	HCWs	13,109	39	Alpha	2020-04-23	2021-02-28	4.10	Adjusted RR	5 (MQ)
3	Jeffery-Smith et al. (26)	United Kingdom	Care home residents and staffs	209	84	–	2020-05-01	2020-10-31	8.97	RR	5 (MQ)
4	Lumley et al. (27)	United Kingdom	HCWs	12,541	38	–	2020-04-23	2020-11-30	9.87	Adjusted RR	5 (MQ)
5	Hansen et al. (28)	Denmark	General population	525,339	–	–	2020-02-26	2020-12-31	9.90	Adjusted RR	7 (HQ)
6	Harvey et al. (29)	United States	General population	3,257,478	48	–	2020-01-08	2020-08-26	10.77	RR	6 (MQ)
7	Kim et al. (30)	United States	General population	325,157	48.8	Delta	2020-03-09	2021-09-09	11.50	RR	7 (HQ)
7	Kim et al. (30)	United States	General population	152,656	48.8	–	2020-03-09	2021-09-09	5.83	RR	7 (HQ)
8	Kohler et al. (31)	Switzerland	HCWs	4,812	38.9	–	2020-06-22	2021-03-09	6.13	RR	5 (MQ)
9	Krutikov et al. (32)	United Kingdom	Care home residents and staffs	682	86	–	2020-10-01	2021-02-01	21.37	Adjusted RR	6 (MQ)
9	Krutikov et al. (32)	United Kingdom	Care home residents and staffs	1,429	47	–	2020-10-01	2021-02-01	21.37	Adjusted RR	6 (MQ)
10	Leidi (33)	Switzerland	Essential workers	10,457	44	–	2020-05-01	2021-01-25	1.47	Adjusted HR	5 (MQ)
11	Jeffery-Smith et al. (34)	United Kingdom	Care home residents and staffs	1,377	Care home residents: 87, Staffs: 49	Alpha	2020-04-10	2021-01-31	4.20	Adjusted RR	6 (MQ)
12	Leidi et al. (35)	Switzerland	General population	8,344	47	–	2020-04-03	2021-01-25	6.07	HR	6 (MQ)
13	Havervall et al. (36)	Sweden	HCWs and patients	1935	46	–	2020-04-09	2021-02-26	8.63	RR	4 (MQ)
14	Hall et al. (37)	United Kingdom	HCWs	25,661	46	–	2020-02-01	2021-01-11	6.27	Adjusted RR	7 (HQ)
15	Letizia et al. (38)	United States	Marine recruits	3,249	19	–	2020-05-11	2020-11-02	6.03	Adjusted HR	6 (MQ)
16	Cohen et al. (39)	United States	Hemodialysis patients	2,337	59.5	–	2020-07-01	2021-01-01	13.17	Adjusted RR	7 (HQ)
17	Chemaitelly et al. (40)	Qatar	General population	581,276	32	–	2020-02-28	2021-11-30	16.63	Adjusted HR	9 (HQ)
17	Chemaitelly et al. (40)	Qatar	General population	240,966	27	Omicron	2020-02-28	2021-11-30	9.17	Adjusted HR	9 (HQ)
18	Abu-Raddad et al. (41)	Qatar	General population	291,309	34	Alpha	2021-01-18	2021-03-03	8.60	RR	7 (HQ)

(Continued)

TABLE 2 (Continued)

ID	Authors, year	Location	Population	Sample size	Median/mean age	Variant	Study start time	Study end time	Length of follow-up (months)	Effect measure	Quality assessment
19	Schuler et al. (42)	United States	HCWs or patients	338	41	–	–	–	5.50	RR	5 (MQ)
20	Dimeglio et al. (43)	France	HCWs	8,758	–	–	2020-06-10	2020-12-09	5.50	–	5 (MQ)
21	Abu-Raddad et al. (44)	Qatar	General population	192,984	35, 38	–	2020–04–16	2020-12-31	5.50	HR	8 (HQ)
22	Abo-Leyah et al. (45)	United Kingdom	HCWs	2063	46	–	2020-05-28	2020-12-02	5.50	Adjusted HR	6 (MQ)
23	Vitale et al. (46)	Italy	General population	15,075	59	–	2020-02-01	2020-07-31	5.50	Adjusted RR	7 (HQ)
24	Maier et al. (47)	Nicaragua	General population	2,338	24	–	2020-03-01	2021-03-31	5.50	RR	7 (HQ)
25	Rahman et al. (48)	Bangladesh	HCWs	1,644	38.4	–	2020-03-19	2021-07-31	7.60	RR	6 (MQ)
26	Shields et al. (49)	United Kingdom	HCWs	1,507	37	–	2020-05-01	2021-01-31	24.07	Adjusted RR	6 (MQ)
27	Mishra et al. (50)	India	General population	2,238	–	–	–	–	10.00	RR	5 (MQ)
28	Patalon et al. (51)	Israel	General population	458,959	–	Delta	2021-07-01	2021-12-13	18.77	Adjusted RR	7 (HQ)
28	Patalon et al. (51)	Israel	General population	458,959	–	Delta	2021-07-01	2021-12-13	3.27	Adjusted RR	7 (HQ)
28	Patalon et al. (51)	Israel	General population	458,959	–	Delta	2021-07-01	2021-12-13	9.03	Adjusted RR	7 (HQ)
28	Patalon et al. (51)	Israel	General population	458,959	–	Delta	2021-07-01	2021-12-13	10.10	Adjusted RR	7 (HQ)
28	Patalon et al. (51)	Israel	General population	458,959	–	Delta	2021-07-01	2021-12-13	7.57	Adjusted RR	7 (HQ)
28	Patalon et al. (51)	Israel	General population	458,959	–	Delta	2021-07-01	2021-12-13	4.10	Adjusted RR	7 (HQ)
29	Muir et al. (52)	United Kingdom	Hemodialysis patients	217	pos: 54.4, neg: 53.6	–	2020-05-30	2021-01-15	4.10	RR	6 (MQ)
30	Rothberg et al. (53)	United States	General population	635,341	47.3	Omicron	2020-03-09	2022-03-01	8.97	Adjusted RR	8 (HQ)
31	Spicer et al. (54)	United States	General population	360,314	–	–	2020-03-06	2020-12-31	9.87	Adjusted RR	6 (MQ)
32	Nordstrom et al. (55)	Sweden	General population	2,039,106	39.2	–	2020-03-20	2021-10-04	9.90	Adjusted RR	9 (HQ)
33	Rennert and McMahan (56)	United States	University student	16,101	20.3	–	2020-08-19	2020-11-25	10.77	Adjusted RR	5 (MQ)
34	Manica et al. (57)	Italy	General population	6,074	50	–	2020-05-05	2021-01-31	11.50	RR	8 (HQ)
35	Pilz et al. (58)	Austria	General population	8,901,064	–	–	2020-02-01	2020-11-30	5.83	RR	6 (MQ)
36	Wilkins et al. (59)	United States	HCWs	6,510	41	–	2020-05-26	2021-01-08	6.13	Adjusted RR	6 (MQ)

(Continued)

TABLE 2 (Continued)

ID	Authors, year	Location	Population	Sample size	Median/mean age	Variant	Study start time	Study end time	Length of follow-up (months)	Effect measure	Quality assessment
37	Babouee Flury et al. (60)	Switzerland	HCWs	330	36.8	Delta	2021-09-20	2022-03-06	5.5	Adjusted RR	6 (MQ)
37	Babouee Flury et al. (60)	Switzerland	HCWs	330	36.8	Omicron	2021-09-20	2022-03-06	5.5	Adjusted RR	6 (MQ)
38	Kim et al. (30)	United States	General population	325,157	50.1	Delta	2020-12-31	2021-09-09	8.3	RR	6 (MQ)
38	Kim et al. (30)	United States	General population	152,656	52.6	Delta	2020-08-30	2021-09-09	12.3	RR	6 (MQ)
39	Ptalon et al. (61)	Israel	Adolescents	458,959	66.3% 5-11 years	Delta	2021-07-01	2021-12-13	5.4	Adjusted RR	7 (HQ)
40	Rothberg et al. (53)	United States	General population	362,800	50.6	Omicron	2020-03-09	2022-03-01	23.7	RR	6 (MQ)
40	Rothberg et al. (53)	United States	General population	104,856	51.4	Omicron	2021-03-29	2022-03-01	11	RR	6 (MQ)
40	Rothberg et al. (53)	United States	General population	98,605	43.6	Omicron	2021-06-28	2022-03-01	8	RR	6 (MQ)

symptomatic COVID-19 cases (pooled $IRR=0.15$, 95% $CI=0.08-0.26$) (Figure 3).

Meta-regression revealed that SARS-CoV-2 variant was a statistically significant effect modifier, which explaining 46.40% of the variation in $IRRs$. The subgroup analysis for different SARS-CoV-2 variant showed that the pooled $IRRs$ for the Alpha (pooled $IRR=0.11$, 95% $CI=0.06-0.19$), Delta (pooled $IRR=0.19$, 95% $CI=0.15-0.24$) and Omicron (pooled $IRR=0.61$, 95% $CI=0.42-0.87$) variant were higher and higher, that is, the protection of natural infection for reinfection against these variants was progressively lower (Figure 4).

In other subgroup analyses, statistically significant differences were observed in the subgroup analysis of the country (the pooled $IRR=0.20$, 95% $CI=0.16-0.25$, $p=0.02$, Supplementary Figure S6), the publication year (the pooled $IRR=0.19$, 95% $CI=0.15-0.23$, $p<0.010$, Supplementary Figure S8-1) and the inclusion end time of population (the pooled $IRR=0.20$, 95% $CI=0.16-0.24$, $p<0.010$, Supplementary Figure S8-2). In different countries, Nicaragua was found a lower level of protection against reinfection (pooled $IRR=0.31$, 95% $CI=0.07-1.43$), while Italy was found a higher level of protection against reinfection (pooled $IRR=0.07$, 95% $CI=0.04-0.14$). For studies published from 2020 to 2023, the pooled IRR was on the rise. It is 0.09 (95% $CI=0.02-0.35$) for studies published in 2020, 0.15 (95% $CI=0.11-0.22$) in 2021, 0.19 (95% $CI=0.15-0.23$) in 2022 and 0.74 (95% $CI=0.57-0.97$) in 2023. However, no significant differences were observed in the subgroup analysis of the definition of reinfection (the pooled $IRR=0.21$, 95% $CI=0.17-0.27$, $p=0.06$, Supplementary Figure S10), the population type (the pooled $IRR=0.20$, 95% $CI=0.16-0.26$, $p=0.40$, Supplementary Figure S4) and the study quality score (the pooled $IRR=0.19$, 95% $CI=0.15-0.23$, $p=0.82$, Supplementary Figure S7). In addition, the pooled $IRRs$ of reinfection was higher in participants aged less than 60 years than those greater than 60 years (0.19, 95% $CI=0.15-0.25$ vs. 0.07, 95% $CI=0.03-0.18$), differences ($p<0.04$) between the two age groups were significant (Supplementary Figure S5-1). However, given that there were only two studies with a median age of over 60, the results may not be representative. Therefore, we also used the median age of 55 years as the basis of grouping for exploratory analysis. We found the difference of the pooled $IRRs$ in participants aged less than 55 years than those greater than 55 years (0.19, 95% $CI=0.14-0.25$ vs. 0.13, 95% $CI=0.04-0.42$) was not statistical (Supplementary Figure S5-2).

Most studies that reported the mean/median follow-up times were included in the bubble plot to explore the changing trends of the protection provided by naturally acquired antibodies after a prior COVID-19 infection, the protection appeared to decrease slowly over time (Supplementary Figure S9).

Discussion

This systematic review and meta-analysis, including 40 studies and over 20 million unvaccinated individuals, provides a synthesis of the evidence that natural immunity from primary infection can prevent SARS-CoV-2 reinfection ($IRR=0.35$), especially symptomatic reinfection ($IRR=0.15$). Meanwhile, the protective efficacy declined

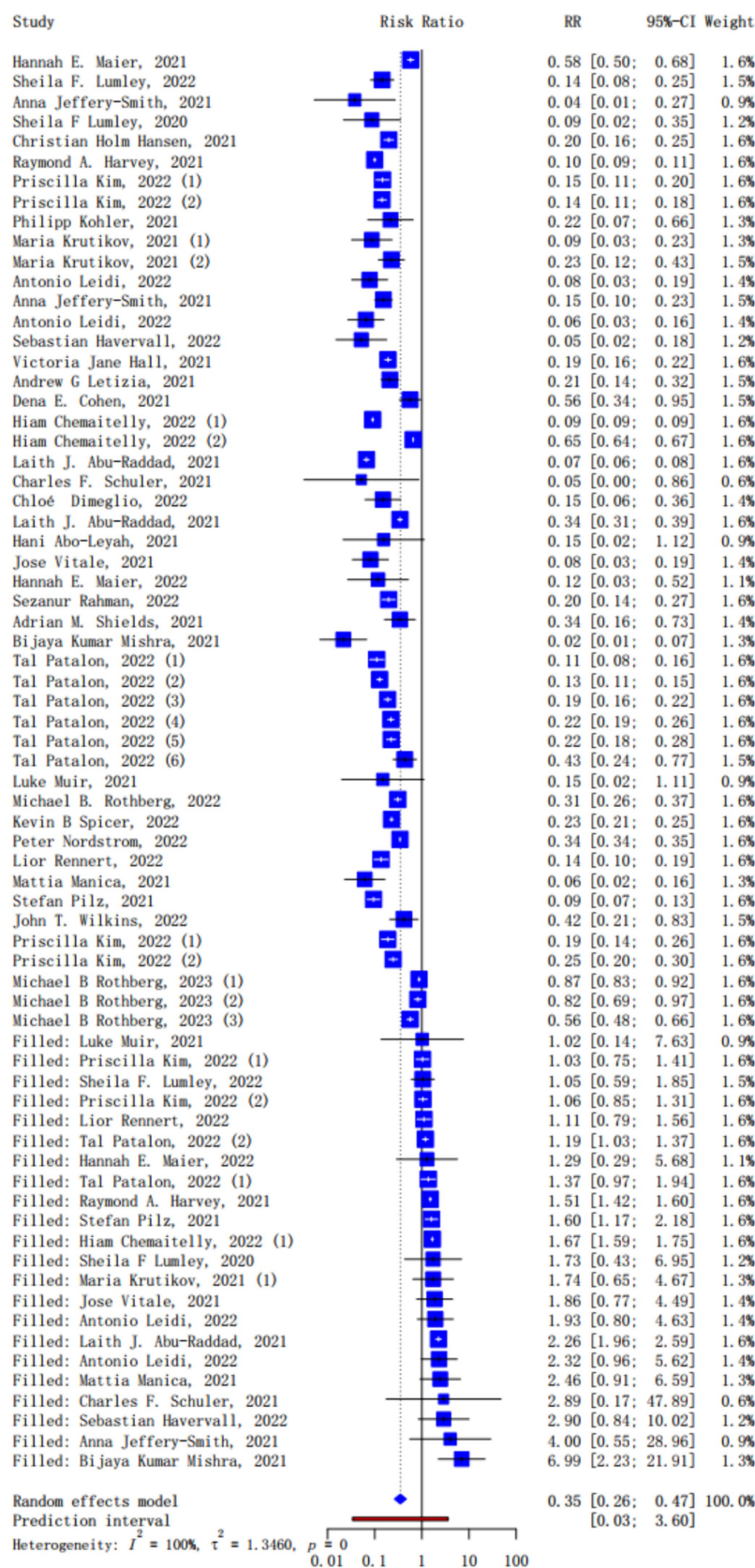
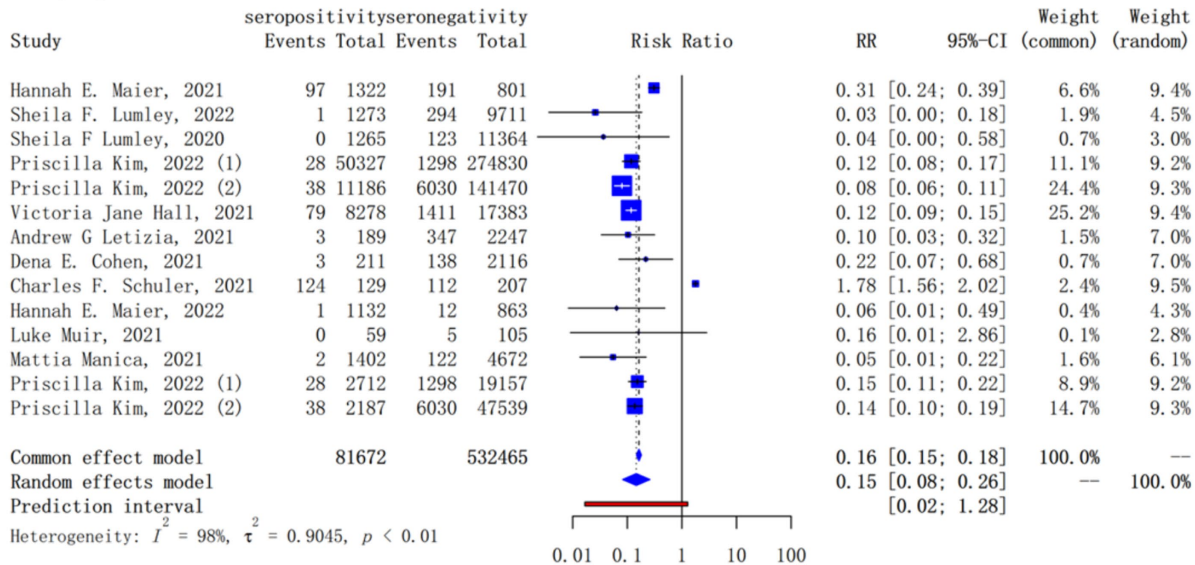


FIGURE 2 Forest plot of the pooled incidence rate ratio for SARS-CoV-2 infection comparing baseline seropositive and seronegative individuals (trim-and-fill method).

A

Symptomatic infection



B

Asymptomatic infection

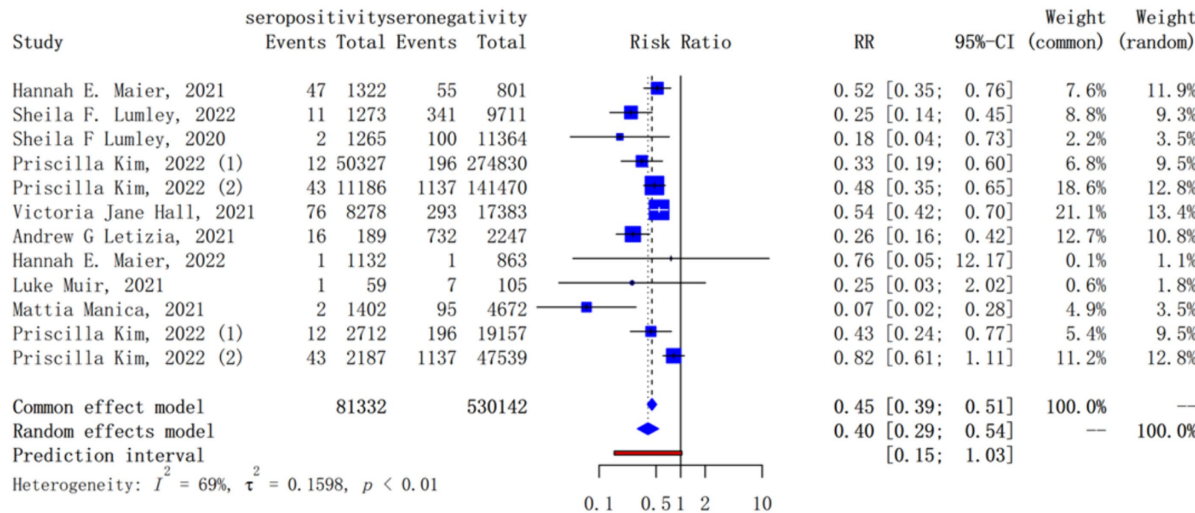


FIGURE 3 Forest plot of the protection provided by naturally acquired antibodies against future symptomatic (A) and asymptomatic (B) COVID-19 between baseline seropositive and seronegative individuals.

during Omicron wave and varied by study location and publication year. These findings suggests that people after primary infection should still be vaccinated and use personal protections to reduce the risk of reinfection.

A high protective efficacy of natural infection against SARS-CoV-2 reinfection has been reported in the available systematic reviews (10, 13, 62–64), but our estimate (65%) is much lower than others (>80%). On one side, the original estimated efficacy in our primary analysis was 81% (Supplementary Figure S2) and in line with the previous estimates, but the conservative estimate was obtained with a non-parametric “trim-and-fill” method to reduce publication bias (65). On the other side, evidence in South Africa suggests increased risk of SARS-CoV-2 reinfection associated with emergence of Omicron (66), and we included the most recent studies during Omicron epidemic which may lead to a lower protection effect due to

the omicron’s immune escape ability. Therefore, SARS-CoV-2 reinfection should be highlighted for the further prevention strategies over time.

In our study, protection against symptomatic reinfection is substantial with an estimate corresponding with the previous reviews (18, 64), while the effect on asymptomatic reinfection (60%) was weaker than on symptomatic reinfection (85%). The findings might be biased by the inadequate detection of all asymptomatic infections in those studies based on surveillance. Nevertheless, it is similar to the SIREN (SARS-CoV-2 Immunity and Reinfection Evaluation) study with the best methods, that the protective efficacy of primary infection was 93 and 52% against symptomatic and asymptomatic reinfection, respectively (37). Also, Deng et al. (16) found reinfection cases were more likely to present with mild symptoms than primary infection ones. In contrast, the meta-analysis performed by Bowe et al. (67)

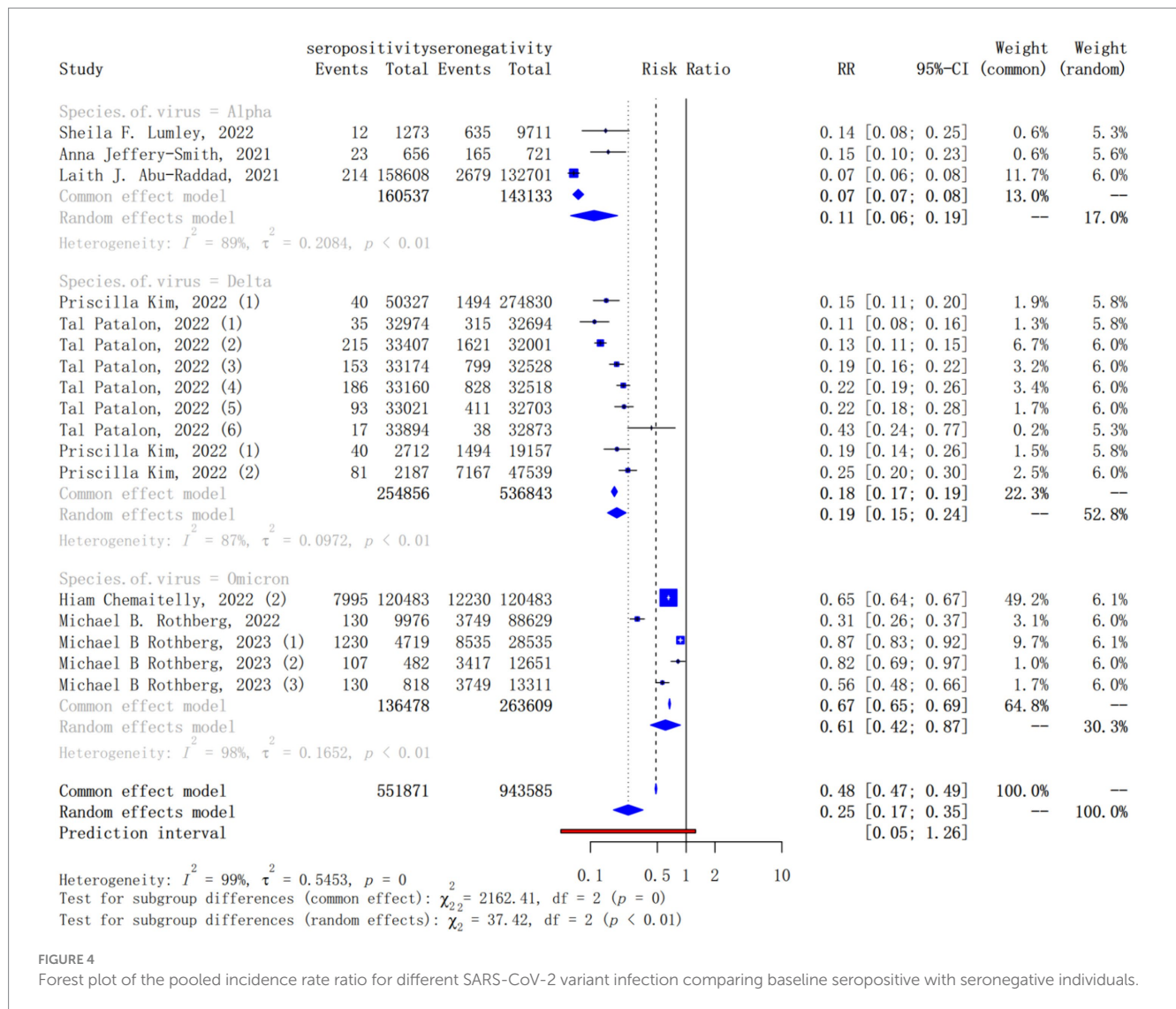


FIGURE 4

Forest plot of the pooled incidence rate ratio for different SARS-CoV-2 variant infection comparing baseline seropositive with seronegative individuals.

showed that reinfection can further increase risks of death, hospitalization, and sequelae in the acute and post-acute phase, regardless of vaccination status. Still, strategies for reinfection prevention remains to be carefully considered and evaluated.

Furthermore, the efficacy of natural infection against reinfection by the Alpha, Delta, and Omicron variants was estimated at 89, 81, and 49%, respectively. In spite of the limited number of variant-specific studies, similar pattern was observed in the sub-group analysis for the study publication year and the inclusion end time of population, that the efficacy of natural infection was lower during the period of omicron outbreak than during pre-omicron outbreak. Our findings are identical to a previous meta-analysis (10), suggesting an increase of reinfection risk as the omicron variant emerged. The low efficacy against the omicron variant might result from its unique mutations on pre-existing antibodies (68), as well as antibody neutralization (69). Accordingly, the risk of reinfection was lower among the vaccinated population than among the unvaccinated during the omicron wave, strengthening the need of multiple dose vaccination after primary infection (10). However, in addition to focusing on the rate of reinfection with a specific variant, it is equally

important to assess the prevalence of long-COVID and the overall health impact on individuals following reinfection. For instance, studies have indicated that the prevalence of long-COVID is significantly lower among individuals infected with the Omicron variant compared to those infected with previous variants such as Alpha and Delta (70). Moreover, among patients with long-COVID, it was not Omicron-infected but Alpha-infected patients who had a higher prevalence of central neurological symptoms (71). Hence, it is crucial to consider multiple factors comprehensively when developing a vaccination strategy.

Due to the unavailability of data and the complexity of the study, the present study was not focused on the protective effect of natural infection with a particular SARS-CoV-2 variant on reinfection with the same variant, but rather on the protective effect of a previously naturally infection on subsequent reinfections, and if there was a difference in its protective effect on reinfections with different variants. This review currently includes 40 relevant studies published up to March 2023 for extraction 52 study data (Table 2). Of the 17 study data that reported the type of reinfection variant, 3 data focused on the protective effect of natural infection on reinfection of Alpha variant

(17.65%), 9 data focused on the protective effect of natural infection on reinfection of Delta variant (52.94%), and 5 data focused on the protective effect of natural infection on reinfection of omicron variant (29.41%). The remaining 35 data were from studies that did not report a specific reinfection variant of interest, and it is highly likely that there is a mishmash of reinfection with multiple variants. Therefore, only these 17 data focusing on reinfection with a single variant were included in the subgroup analysis of viral variants in this paper. The virus has evolved over time, and the majority of the current population is infected with Omicron. However, there is a paucity of studies on the protective effect of previous infection with Omicron on reinfection with Omicron and its subsequent variants, which has not been considered at this time in this review study, and may therefore lead to an underestimation of the overall protective effect of previous infection on reinfection. In view of this, we will continue to follow up the study and plan to update the results at an appropriate time, such as in 6 months or a year later, depending on subsequent SARS-CoV-2 infections.

Here, we found poor protective effect of prior infection against SARS-CoV-2 reinfection in Nicaragua but a higher protective effect in Italy, which may be due to the lower Oxford policy stringency index in the former, that is, the looser prevention and control policy; and the higher index in the latter, meaning a stricter prevention and control policy. Distinctively, our study shows a low protective efficacy of natural infection among people over 60 years old, contrast to the previous findings (13, 55, 62). It may be because the median age of only 2 studies is greater than 60, the results obtained are not representative. However, there were four studies with a median age greater than 55 and we found there was no statistical difference in the protective effect of natural infection between people over and below 55 years old.

In China, the vaccine immunity of most people has been reduced to a very low level, and the current immunity to reinfection with SARS-CoV-2 mainly relies on the natural immunity generated during the Omicron epidemic at the end of last year. Therefore, this study is very in line with China's current national conditions and will help provide a scientific basis for preventing re-infection in the Chinese population.

However, this study was subject to limitations. Firstly, the I^2 value and Cochran's Q test suggests high heterogeneity between the studies in our analyses, due to the various regions, periods and populations (72). Under this circumstance, we had to accept the existence of the heterogeneity. Therefore, we used the random effects model instead of the fixed effects model to estimate the combined effect value in our meta-analysis. The greater uncertainty brought by heterogeneity to our estimate has been reflected in the method of estimation and calculation of the confidence interval under the random effects model. To explore the sources of heterogeneity and their impact on the results, we have conducted meta-regression and subgroup analyses. The meta-regression results of this study showed that the SARS-CoV-2 variant that the studies focused on and the year of publication of the studies were important sources of high heterogeneity. As the fact that the dominant strains of SARS-CoV-2 differed from year to year, we believe that the heterogeneity among studies due to different years of publication is essentially due to the different endemic strains of SARS-CoV-2 represented behind the different years, which explaining 46.40% of the variation in IRRs. Therefore, this review next focused on the protective effects of natural infection with SARS-CoV-2 against reinfection with different variants through subgroup analysis, which indicated the protective effects of

natural infection against reinfection Alpha to Omicron gradually decreases. Compared to the overall protective effect of natural infection against reinfection, we believe that the subgroup results of the sub-variant are of greater interest and are the highlight of this study. To evaluate the stability of the results of this review, we performed a sensitivity analysis by excluding the included literature one by one. The results showed that there was no significant change in the results of the meta-analysis of the remaining studies after excluding any of them. This suggests that the included studies had stable results despite their heterogeneity. Secondly, the estimated efficacy against asymptomatic reinfection might be underestimated, for the inadequate detection. Lastly, publication bias was detected in the included studies but we used trim-and-fill method to reduce its potential effect.

Conclusion

Our findings indicate that individuals who have previously been infected with SARS-CoV-2 possess significant protection against reinfection from pre-omicron variants. However, when it comes to the omicron variant, the level of protection against reinfection is notably diminished. This will require continued attention to viral mutation in the future and careful consideration of strategies to prevent reinfection, such as vaccine catch-up, in conjunction with other factors, such as the reinfection rate, the prevalence of long-COVID and the overall health impact on individuals following reinfection.

Author contributions

W-HH: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. H-LC: Writing – original draft, Data curation. H-CY: Writing – original draft, Data curation. HW: Writing – original draft, Data curation. H-MS: Writing – original draft, Data curation. Y-YW: Writing – review & editing, Methodology. Y-TH: Writing – review & editing, Supervision, Conceptualization.

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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.2024.1353415/full#supplementary-material>

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"Why would we?" A qualitative study on COVID-19 vaccination decision making among Ukrainian economic female migrants in Poland

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Background: Ukraine has one of the lowest COVID-19 vaccination rates in Europe. This may pose a significant epidemiological risk in the context of the refugee crisis and the fact that, since 2020, SARS-CoV-2 has been spreading and changing globally.

Objective: To evaluate determinants of vaccination decision making among Ukrainian female migrants (UFMs).

Methods: A qualitative study with 45 UFMs was conducted between December 2021 and January 2022. UFMs, from 2 Polish provinces, differing in age, education and length of stay were invited with the use of the snowball technique. Using a semi-structured topic guide, eight focus groups were conducted in person, recorded and transcribed. Thematic, qualitative analysis was made; key themes which emerged from the data (with the help of the Working Group Determinants of Vaccine Hesitancy Matrix), were related to contextual, individual/group and contextual vaccine/vaccination-specific influences.

Results: Mothers were found to be playing a crucial role in children and adolescent COVID-19 vaccine decision-making process. Universal trust in the Polish healthcare system and vaccination procedures, employer requirements and willingness to preserve jobs, desire to get back to normal and social influences were paramount prerequisites to let UFMs make a decision to get vaccinated. However, COVID-19 vaccines also faced backlash among UFMs. Negative experiences with vaccines provided in Ukraine, doubts about the rapid vaccine development, combined with lack of confidence in vaccine safety, specifically regarding child vaccination, might have a bearing on UFMs' decision about declining COVID-19 vaccine while on migration. Discrimination through HCWs during vaccination visits was also reported. Corrupted Ukrainian healthcare system, which facilitates proof forgery regarding vaccination certificates, could act as a negative influencer of UFMs' vaccine decision-making.

Conclusion: The results provide the novel information, expressed in economic UFMs' own words. Findings show that influencers of the decision-making

process regarding the COVID-19 vaccination are complex and polarized; elements of hesitancy may persist after migration. Any continuation of UFM's vaccination with COVID-19 vaccine should be subject to designing accessible information to address modifiable demotivators of the vaccine decision-making process identified in this study.

KEYWORDS

vaccine, Ukrainian migrants, COVID-19, females, Poland

1 Introduction

As of 10 January 2024, the COVID-19 pandemic has caused 773,448,535 cases and 6,991,829 confirmed deaths, making it one of the deadliest epidemics documented (1). While the acute phase of the COVID-19 pandemic has subsided, the virus continues to spread and to mutate into new variants (2). Safe and effective COVID-19 vaccines were widely deployed from December 2020. In 2021 alone, they saved an estimated 14.4 million lives worldwide (3, 4).

In Ukraine the COVID-19 immunization program started on 24 February 2021. One year after vaccines became available, the COVID-19 vaccination rate in Ukraine was 38% for the primary course and only 1.7% of the eligible population received a booster dose (5). There are several reasons behind low vaccination rates among Ukrainians, including healthcare-related factors such as delayed introduction of COVID-19 vaccines and shortages of supply (6, 7) and pre-existing dissatisfaction with the health-care system and services, and recognized corruption within the healthcare system fueling distrust for authorities and institutions (8, 9). Other factors, such as concerns about the safety of vaccines due to the fast development and deployment, as well as widespread misinformation regarding COVID-19, have also likely come into play (6, 10–12). Anti-vaccination movements have become increasingly active in Ukraine since the beginning of the 21st century (13, 14), and vaccine hesitancy and refusal by health care workers (HCWs) is common (8, 9, 13).

Immigration from Ukraine to Poland is a well-established migration route with economic, political and social consequences. As a result of the Russian aggression against Ukraine in 2014, unfavorable economic conditions and high un-employment in Ukraine, economy-driven migration flow from Ukraine into Poland, both permanent and seasonal, started to increase in the 2010s. In brief, an economic migrant is a person who leaves their home country to live in another country with better working or living conditions (15). In 2018 alone, Poland issued 1.6 million immigration documents to Ukrainians (16). Since the onset of the war between Russia and Ukraine, Ukrainian refugees have been fleeing from areas involved in the fighting or those at risk of conflict (17). Notably, refugees are in the EU countries under temporary protection. According to Ukrainian data (5), two thirds of the Ukrainian migrants and refugees were estimated to have not received any COVID-19 vaccination. In the context of ongoing SARS-CoV-2 transmission, vaccinating this vulnerable migrant population should be a high priority for Poland. Vaccinating this population has proved challenging, with low levels of uptake. Previous surveys highlighted hesitancy toward vaccines in general and COVID-19 vaccines specifically among Ukrainians

compared with other countries (18, 19). To the best of the authors' knowledge, no scientific study has been published to date regarding the factors that may influence the decision to be vaccinated against COVID-19 among economic Ukrainian female migrants (UFMs) living in Poland. We aimed to examine these factors in order to inform tailored intervention to improve vaccine uptake in this group.

2 Materials and methods

2.1 Study population and sampling

The study population was recruited as the Polish component of RIVER-EU (*Reducing Inequalities in Vaccine uptake in the European Region – Engaging Underserved communities*), a broader study aimed at improving child and adolescent MMR/HPV vaccination among underserved communities in Europe (20). The detailed project methodology is described elsewhere (21). In brief, this study was carried out between December 2021 and January 2022. Recruitment took place in the capital cities of two Polish regions: Lublin (Lubelskie province), located in the south-east of Poland and neighboring Ukraine; and Zielona Góra (Lubuskie province), in the western part of Poland, neighboring Germany. Ukrainian-born individuals aged 15 and over, residing in Poland for a minimum of 6 months and a maximum of 10 years (i.e., a recent migrant), were eligible. We focused the study on females, because they tend to be the decision-makers for the family with regards to vaccines, according to the literature (22). At the time the study was conducted, COVID-19 vaccines were available free of charge for those aged 12 and over. Eligible individuals were invited to participate into RIVER-EU study through social media (Facebook), through adverts at job agencies and institutions employing UFM's, and through an organization recruiting students willing to start education at Polish high schools.

Prior to consenting, adult participants received information sheets in Polish and Ukrainian that explained the study objectives, the voluntary nature of the study and the right to withdraw from the research at any time. For teenagers, a consent form together with project information was sent to their legal guardian; an invitation for the teenager was included. On the interview day, informed consent was confirmed, both from the teenager and their legal guardian in accordance with the Polish Act of the Medical Profession (UZL). For each participant, prior to interview, we collected socio-demographics details (age, sex, education, residency in Ukraine/Poland, number of children), length of stay in Poland, and number of trips between Ukraine and Poland per year. Each participant received a PLN 100,00 (about 22 EUR) compensation.

2.2 Data collection

Eight 60–90 min face-to-face focus group discussions were conducted with UFM. Discussions took place at local universities, and were facilitated by Polish/Ukrainian interpreters. UFM were asked about their attitudes toward the COVID-19 vaccine, factors influencing immunization decision making, and their previous vaccination experiences. Interviews were pseudonymized, audio recorded and transcribed verbatim by the researchers; a professional interpreter checked the content for clarification and amendment.

2.3 Data analysis

Thematic analysis was used. Interviews were analyzed thematically by the researchers using the steps outlined by Braun and Clarke (23): data familiarization, coding and theme identification, refinement. One researcher team member conducted a similar study among Ukrainian migrants in Poland (10) and brought her experience to this study.

The researchers managed the data using software program ATLAS.ti version 24; analyses were conducted separately for adults and teenagers. Two teams of authors reviewed the transcripts independently analyzing their content and assigning initial codes to text fragments. The constructs from the WHO's Determinants of Vaccine Hesitancy (24) were used to classify the prominent codes and elaborate on general themes related to factors influencing the COVID-19 vaccine decision-making process shared across all FGs transcripts. Intensive literature searches were performed, with the use of articles on qualitative research methods, textbooks chapters (25–27), and papers describing qualitative studies on vaccination beliefs and attitudes (28–33). Ongoing discussions via video-conferences and in person helped team members to critically review, discuss and refine initial coding and achieve a consensus regarding the final coding scheme. Codes were then arranged in sub-themes and themes. Deductive and inductive approaches were used to analyze which themes emerged from the qualitative data. In the end, illustrative excerpts from coded data were derived and classified within the appropriate thematic domain. Relevant quotes were collected and combined. Finally, by consensus among all research team members those UFM's statements which reflected themes the most were decided on to ensure adequate saturation, coherence, and reliability.

All researchers agreed on following key analysis themes presented in [Supplementary Table S1](#).

2.4 Ethics considerations

The study was approved by the Institutional Ethics Committee of the University of Zielona Góra (KB-UZ/20–9/2021; 27 September 2021). Informed consent was obtained from all subjects involved in the study.

3 Results

3.1 Participant demographics

Three focus group discussions (FGDs) were carried out with adult UMs in December 2021 in Zielona Góra (with 7, 3, and 6 participants

respectively) and another three FGDs — in January 2022 in Lublin (with 6 participants each); two other meetings with adolescent Ukrainian girls were conducted in January 2022 in Lublin (with 6 participants in each group). The mean age of the participants was 31.2 years. The mean duration of stay was 3.2 years: 40.0% of participants had resided in Poland for 2 years or less, 40.0% from 3 to 5 years, and 20.0% more than 5 years. Teenage girls, all high school students, represented 26.7% of all participants; adult UFM who were high school graduates represented 26.7% of participants, while 44.4% were bachelor's or master's degree holders; 51.1% participants originated from Ukrainian cities >150,000 inhabitants, 35.6% from smaller cities, and the rest from rural areas. All adult UFM had children. Two thirds of participants (66.7%) lived in the Polish city of Lublin and the rest in Zielona Góra.

3.2 Focus groups' discussions

Three main themes, adapted from the Vaccine Hesitancy Determinants Matrix (VHM) constructs (24), were set up: (1) contextual influences, (2) individual and group influences, (3) vaccine/vaccination specific issues ([Supplementary Table S2](#)). Results of the FGD discussions presented in this subsection were organized by describing main themes, sub-themes/categories and the most important quotations ([Supplementary Table S2](#)). The study findings were put together to systematize complex, inter-dependent factors influencing COVID-19 vaccine decision-making process among economic UFM in Poland. Factors were divided into two groups in terms to present this process from the Polish and Ukrainian perspective. Regarding some sub-themes, influencing factors overlapped and were presented as common for two countries.

3.2.1 Contextual influences

We identified subthemes and categories within the main theme as contextual factors influencing UFM's decision to get the COVID-19 vaccine as follows:

- Culture/religion

Ukrainian female migrants reported that their own culture influenced their decision-making process. Participants confirmed that mothers were the primary decision maker regarding vaccinations in the Ukrainian family. One mother explained “*when it comes to the decisions, it's all on me*” (female, age 35, FG7). Participating females were also asked about fathers' role in the COVID-19 vaccination decision-making process. According to participants, a father, rather than taking on a part of the responsibility from a mother, was eagerly relating on her and was not much involved with the process.

Notably, Ukrainian orthodox religious groups were commonly mentioned as having a negative impact on the migrants' COVID-19 vaccination decisions. “*People do not want to get vaccinated due to their religious beliefs...*” (female, age 42, FG 6).

- Communication and media environment

Ukrainian female migrants mentioned that mandatory vaccination-in place for routine childhood vaccines (but not COVID-19) made decision-making easier. “*Previously, there used to be a vaccination schedule with compulsory vaccines and we got our kids vaccinated according to the doctor's advice. That was obligatory and*

everyone followed, now we have too much information..." (female, age 33, FG 6). Some UFM's complained about the lack of consistency and confusion arising from multiple sources of information, from the internet or friends. Exposed to contradictory messages, some UFM's reported focusing on more authoritative resources, such as research papers. Some participants claimed to be "*reading into different experiences*" or "*resorting solemnly to medical resources*" (females, age 43, FG 3). Participants recognized the importance of objective, easily accessible data to make decisions about COVID-19 vaccines, and valued factual information, including statistical data, and trusted sources to make informed decisions.

- Policies – vaccine administration

Participants contrasted their experience of COVID-19 vaccination in Poland and Ukraine. Specifically, participants complained that in Ukraine "*there is no one who would run a proper health check or some tests*" (female, age 32, FG 1) before vaccination. UFM's saw such a health check as important, in particular in patients with comorbidities. Participants also voiced concerns about the lack of monitoring and reporting of adverse event following immunization in Ukraine. UFM's "*prefer to come to Poland to get vaccinated for COVID*" (female, age 47, FG 7), and negative experiences acquired in Ukraine in the past, may influence their decision process with regards to getting vaccinated against COVID-19 in Poland.

- Employment

Some UFM's complained that Polish employers sometimes directly or indirectly forced them to get vaccinated against COVID-19. As one participant explained "*they do not even provide one with choice*" (female, age 32, FG 6). Participants were also concerned that their autonomy around informed decision-making was not respected.

- Accessibility of the vaccine – language/product

Even for UFM's fluent in Polish, the technical language used when giving COVID-19 vaccines was a barrier. As one 42 years old female participant stated, they "*cannot recognize some of the medical terms*" (FG 1). Some UFM's asked relatives or friends fluent in Polish to accompany them when getting vaccinated. UFM's expressed preference for the "*proper*" vaccines (female, age 26, FG 1) made in the United States or in the Western Europe, as opposed to Chinese or Indian vaccines generally provided in Ukraine. Participants expressed doubt about the effectiveness of the latter ones. "*The only European one (available COVID-19 vaccine) is Pfizer. Otherwise, some Chinese and Indian ones are available. Even CureVac was ineffective*" (female, age 42, FG 1).

- Concern for differential treatment

UFM's complained about receiving discriminatory treatment, receiving an inferior service compared to their Polish. UFM's claimed that "*equal treatment is more important*" (female, age 42, FG 1) than other factors influencing decision-making.

3.2.2 Individual and group influences

In this section relevant subthemes and quotations within the main theme, i.e., influences on the individual and group level were organized as follows:

- Personal/altruistic motivations

Fear of infection was reported as a reason for vaccination among some UFM's. The belief in the vaccine's ability to protect against

SARS-CoV-2 was an enabler to vaccination as was the desire to protect themselves from the severe consequences of COVID-19 and to make "*the illness be lighter*" (female, age 40, FG 8). Some UFM's expressed altruistic vaccination motivations, including how vaccinating themselves contributed to the fight against SARS-CoV-2. UFM's mentioned the desire to "*suppress the amount of infection*" and "*return to pre-pandemic state*" (female, age 42, FG 5). It was also emphasized that besides combating the pandemic, ending to the broader accompanying social impact was equally important, and vaccination was seen as an important tool for this.

- Social influences

Multiple interviewees mentioned that decisions on COVID-19 vaccination were influenced by friends and relatives within their close social circles. UFM's reported that improved attitudes and increased intention to get vaccinated, was based on positive experiences of other family members. One UFM's stated that seeing some close friends getting vaccinated against COVID-19 increased her confidence in the vaccine and made her decide to vaccinate. Conversely, negative experiences of others worsened UFM's attitudes and motivation toward vaccination.

- Health system and providers – trust and personal experience

The UFM's reported higher levels of trust in the Polish healthcare system and providers compared to the Ukrainian system. Many participants mentioned preferring to come to Poland to get vaccinated for COVID-19, based on their personal experience with the Ukrainian system: "*I know that whatever they have in Ukraine will not work*" (female, age 37, FG 2).

- Return to routine

Beyond health concerns, most UFM's viewed vaccination pragmatically as a way to return to routine and to "*make their lives simpler*" (female, age 43, FG 6). The travel related issues, such as dealing with documentation at the border while traveling to school, work etc., were also very important factors in COVID-19 vaccination decision-making. A 40 year old female commented as follows: "*I got vaccinated for practical reasons, to travel in and out of the country*" (FG 8).

- Influence of other vaccines

UFM's expressed how negative experiences with COVID-19 vaccines reported in Ukraine impacted their decision regarding child vaccination, and *vice-versa*. A 35-year old Ukrainian female stated that in Ukraine, there were cases where "*after getting certain vaccines, children experienced serious side effects*" (FG 2), and she was concerned the same could happen after COVID-19 vaccination. Parents and grandparents often delayed or postponed COVID-19 vaccination in their children or grandchildren, citing a lack of concrete scientific evidence as their main concern.

3.2.3 Vaccine or vaccination – specific issues (directly related to vaccine or vaccination)

In the last section subthemes and quotations related to vaccine or vaccination were highlighted.

- Unnecessary/ineffective vaccine

The UFM's reported they did not see a compelling reason for getting vaccinated. A 45 year-old female migrant (FG 1) asked "*Why*

would we?." Another one claimed that COVID-19 vaccine "does not do anything good" (female, age 43, FG 3). Several participants mentioned pressure or compulsion to vaccinate as the main reason for going through with the vaccination procedure.

- Concerns about vaccine development

The UFM's questioned the rapid vaccine development process. A 37-year-old female (FG 1) asked, "How come they invented it within just a year?" The short time frame led to migrants questioning whether the available vaccines had been sufficiently researched.

- Vaccine safety and efficacy

A lot of Ukrainians did not want to be vaccinated because they doubted COVID vaccines were effective or even genuine. "They think it's just some kind of water or something..." (female student, age 16, FG 5). The perceived lack of efficacy led to participants querying their necessity. Some UFM's went as far as wondering whether the vaccines were harmful as a result of some of the ingredients they thought the vaccines contained, such as metals or formalin. Disinformation about COVID-19 vaccine side effects, including risk of death, negatively impacted migrants' decision-making process. According to participants, Ukrainian media relayed myths and misconceptions about COVID-19 vaccines. Conspiracy opinions, such as the existence of operations to cover-up vaccine related deaths, also existed: "if they were vaccinated and then die, it's never because of the vaccine obviously" (female, 40, FG 1).

- Vaccine storage

Participants expressed doubts adequate storage and handling in Ukraine. Pictures circulating on social media among Ukrainian groups showed that "COVID vaccines were kept in direct sunlight." (female, age 26, FG 8). Most Ukrainians did not want to get vaccinated with such "questionable products" (female, age 40, FG 7).

- Vaccine cost

The UFM's noted that while the availability of COVID-19 vaccines produced in the Western Europe or the US was scarce, it was still possible to purchase them outside the system. Traveling abroad to get vaccinated was mentioned as a common practice, with a particular preference for EU countries, where vaccines were believed to be safer and of better quality. A 43-year-old female explained: "We got vaccinated for COVID in Poland, yet with European vaccines, different to the ones widely available in Ukraine. I paid for them." (FG 1). Respondents also mentioned purchasing fake COVID-19 certificates (to avoid vaccination) as a common practice among their fellow Ukrainians. Prices for forged certificates seemed to widely fluctuate. While some of the interviewees claimed this practice was not as prevalent as it used to be, most said that it was still largely popular, especially among those who wanted to travel without constraints without getting vaccinated. A 35-year old female claimed "a lot of people, my own friends, purchased those certificates just to be able to travel abroad" (FG 2).

- Trust in practitioners' recommendations

Interviewees claimed that they placed a lot of trust in GPs' recommendations on COVID-19 vaccination. UFM's overwhelmingly described Polish GPs as a trusted source of information and stated that they "like research based advice, not one from a person who will make

something up." (female, age 42, FG 8). UFM's claimed GPs were especially influential in their decision-making process. While most participants reported the positive influence of Polish health professionals, others described lack of professionalism universally present in Ukrainian healthcare ("you can run into a doctor that knows less than you do"; female, age 37, FG 7), as well as bribery ("all those [doctors] over 40 were schooled to partake in the bribe scheme"; female, age 42, FG 7).

4 Discussion

To the authors knowledge this is the third qualitative study focusing on vaccination among Ukrainian migrants residing in Poland. Previously conducted studies examined the general attitudes toward the vaccines (8) and the structural barriers in access to the vaccines (21). This study looks specifically at UM's barriers and enablers toward COVID-19 vaccination and factors underlying the vaccination decision-making.

The study, based on FGDs with UFM's in Poland, was conducted just before the Russian aggression toward Ukraine. Therefore, it mainly reflects the views of Ukrainian economic migrants. Key analysis themes which emerged from the qualitative data, with the help of the Working Group Determinants of Vaccine Hesitancy Matrix, were related to contextual, individual/group and the COVID-19 vaccine and vaccination influences. In terms of contextual influences arising from cultural factors, matrilineal culture was found to be playing an important role in the vaccine decision-making process among UFM's. In this culture, older women are teachers and holders of traditional knowledge and they are entitled to and entrusted with creative roles, including adaptation to changing conditions, such as vaccination decisions and migration (25). Our study confirmed the influence of matrilineal decision makers regarding COVID-19 vaccination on child and adolescent immunization. Cultural norms influenced community members' decisions to get the COVID-19 vaccine after mothers had requested it. Thus the importance of getting females and mothers on board should be taken into consideration when planning vaccination strategies in context where such a matrilineal culture is important, as has been observed in other contexts (26). The influence of female on their partners (as opposed to their children) with regards to vaccination decision needs further investigation.

The UFM's reported differences in the perceived quality of healthcare services in Ukraine and Poland, with these experiences shaping their confidence in health interventions including vaccines. Participants blamed the Ukrainian state structures for not providing sufficient care to the citizens, including vaccines. The confidence in the Ukrainian government was low, as the population witnessed various political crises in the pre-war period (27). UFM's reported higher levels of trust in the Polish healthcare system, to the extent that in some instances Ukrainians came to Poland to get vaccinated against COVID-19. Some studies have highlighted the importance of rebuilding trust in state institutions in order to positively influence vaccination decision-making (28, 29).

In our study, as well as in the literature, compulsory vaccination or vaccination as a condition to employment was a strong enabler among participants wanting to preserve jobs (30, 31), but the perception was mixed. Notably, participants complained that through

pre-established, strict rules employers were forcing them to get the COVID-19 vaccine despite their hesitancy. Additionally, some studies report the dilemma between potentially losing jobs and getting vaccinated, in cases where vaccination was not done by personal choice (31). This observation suggests that unemployed Ukrainian migrant could have less incentives to vaccinate, creating inequalities within the migrant population.

Consistent with prior COVID-19 vaccine acceptability research (26, 32, 33), we found the desire to return to normal activities as another influential factor in UFM's decision-making. For many migrants, getting back to normal was synonym with being able to travel abroad. This finding was consistent with finding from another study that showed that avoidance of "travel ban" was one of the major predictors behind COVID-19 vaccination (32).

Personal factors, such as fear of infection or COVID-19 illness, and altruistic motivations, for instance contributing to eliminating COVID-19 or combating the virus together were also found as the motivators for getting vaccinated. Some UFM's described knowledge and awareness of negative COVID-19 outcomes among their family members and social network, as well as coworkers, as potential barriers to COVID-19 vaccination decision-making. A similar phenomenon was also observed in other studies (24, 33, 34). Unlike other studies (33, 35) family and social pressure to vaccinated was not mentioned. Our findings support that influences arising from the personal and immediate and wider social circles can influence the decision to get vaccinated. Additionally, we provide the important message that UFM's share decision-making with family, friends and coworkers.

Ukrainian female migrants expressed a high level of trust in the Polish healthcare system and healthcare providers; such trust if properly leveraged can improve willingness to vaccinate against COVID-19 (35–37). Indeed professional recommendations from healthcare providers can improve intention to vaccinate (8, 26, 28, 34–36, 38, 39). In our study, Polish healthcare providers, as well as those with Ukrainian background working in Poland, can play a crucial role in improving trust. Our study shows that while trust in the Ukrainian health system is low, trust in the healthcare system among migrants increases after migration from Ukraine to Poland. Such trust should be leveraged, especially as migrant populations are less likely to receive physician recommendations for vaccinations (28). Evidence also suggests that having had a negative previous experience with vaccines also decreases future intention to vaccinate (40). Thus potential pre-migration negative experiences around vaccines in Ukraine may influence vaccine attitudes and decision-making after arriving to Poland.

Consistent with published evidence (27, 36, 40, 41), we found concerns about the vaccine's rapid development and a lack of scientific evidence as barriers to immunization. Specifically, UFM's did not trust the short vaccine development process, expressing serious concerns that these vaccines might have unknown short and long-term adverse effects. Our results support previous reports (40, 42) that these concerns influence the decision to get vaccinated. Participants however distinguished between COVID-19 vaccines in Ukraine, seen to be ineffective and potentially dangerous, and vaccines provided in Poland, perceived as being of higher quality. This was similar to a previous paper on immunization among Ukrainian migrants (8), showing that compared to Ukraine, vaccines provided in Poland were seen as being manufactured by trusted, well recognized European or

American brands, and were appropriately stored and administered. UFM's believed that side effects observed in Poland were much less numerous than compared to Ukraine. To our knowledge, this is the first qualitative study to document the perceived difference in COVID-19 vaccine quality, safety and effectiveness between Poland and Ukraine, described in participants' own words.

4.1 Strengths and limitations

One strength of our study was a diverse sample that included UFM's of different demographic characteristics, residing in several different Polish regions. Despite the relatively low sample size, a limitation of qualitative studies (43, 44), the authors believe that data saturation was reached in this sample of migrants. However, Ukrainian migrants to Poland are diverse in terms of backgrounds and socio-demographic characteristics and the study may not representative of UFM's from other parts of the country. The inclusion of two geographically different regions of Poland might reduce this bias. Women are the key decision-maker for the family with regards to vaccine and for this reason we focused on this group. Findings may be different among men and holding focus groups with male UFM's may be of value. While the snowball sampling used in this study may limit generalizability to the larger UFM's population (8), our sample included a range of ages, literacy, areas of origin in Ukraine, and length of stay in Poland. As such, relatively heterogeneous opinions could be obtained. Finally, the vaccine hesitancy matrix may be not free from limitations when applied to a novel vaccine such as COVID-19. Earlier evaluation suggest the matrix is fit for evaluation of COVID-19 vaccines. Of note, COVID-19 vaccine awareness and knowledge has changed over the course of the pandemic (28). Since our interviews took place prior to the 2022 Russian attack on Ukraine, we cannot measure the impact of the War on vaccine perception; likewise we cannot generalize our finding to the war refugees, a more highly educated population than economic migrants.

5 Conclusion

Barriers to vaccination among UFM's were related to contextual influences, individual and group level influences and vaccine- or vaccination-specific issues. The results are consistent to existing evidence reported in the scientific literature (8, 26, 28, 31, 33, 39, 45). While some of the factors we identified had been previously identified, this study also brings new insights. First, most participants did not consider their personal and communal interests as major factors in decision-making. Second, the novelty of the vaccine and a consequent fear of poorly studied adverse effects and poor effectiveness were major factors. Third, the perceived need for immunization was not universal. Fourth, negative experiences with vaccines provided in Ukraine, specifically childhood vaccines, highlight possible links between experience of past vaccination and perceptions of risk from the COVID-19 vaccine, and elements of hesitancy formed in the country of origin may persist after migration: this might be another barrier to vaccination among migrants. This brings a new perspective not only applicable to COVID-19 immunization in Poland, but also generalizable to other countries hosting UFM's, as well as to other non-mandatory vaccines. By identifying factors enabling COVID-19

vaccine decision-making among the Ukrainian migrant community, the present study provides evidence that may inform the development of adequate tailored strategies to limit vaccine hesitancy.

Such strategies can include, beyond broad national COVID-19 vaccine campaigns, tailored communication campaigns and approaches, focused on the Ukrainian community in Poland; training Ukrainian healthcare providers working in Poland and Ukrainian community leaders, specifically females, could be crucial. Trained individuals could then act as vaccine ‘role models’ who can discuss vaccination and address misinformation. In addition, health care provider-Ukrainian patient interpersonal communication play a pivotal role especially when trust in Polish healthcare workers is high. Motivational, vaccine-oriented conversation could help Ukrainian migrants make the informed decision to vaccinate.

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 Ethics Committee of the University of Zielona Góra (KB-UZ/20–9/2021; 27 September 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

MG: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation. PK: Writing – review & editing, Validation, Investigation, Data curation. PT: Writing – original draft, Formal analysis, Data curation. DO: Writing – original draft, Formal analysis, Data curation. OP: Writing – original draft, Investigation, Data curation. ŁD-D: Writing – original draft, Investigation, Data curation. JV: Writing – review & editing, Supervision, Resources, Project administration, Methodology, Funding acquisition, Conceptualization. ME: Writing – review &

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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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Is it really better to “die” than “live”? Reflections on the practice of “death with dignity” in China

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Aim: To analyze the causes of the controversy caused by “death with dignity” in China, and to provide some useful thoughts for the practical exploration of “death with dignity.”

Subject and methods: By combing the periodical literature, legal texts and practice, we find that the Medical Regulations of Shenzhen Special Economic Zone, which was revised and passed by China in 2022, recognized the legal effect of “living will” for the first time in legislation, which triggered a wide-ranging social discussion on “death with dignity” and brought many controversies.

Results: Due to the influence of traditional culture, policies and laws, medical service supply capacity and other factors, death with dignity suffers from great practical resistance.

Conclusion: The exploration of “death with dignity” system needs to start with the problems encountered in practice, focusing on cultivating a good system implementation environment, strengthening the top-level design of “death with dignity” system, and improving the national social security system for hospice care.

KEYWORDS

death with dignity, living will, medical autonomy, hospice care, palliative care

1 Introduction

With the continuous improvement of people’s material and cultural life, ordinary citizens have begun to pay more and more attention to the right to die while attaching importance to the right to life. In the process of citizens’ struggle for the right to “die,” a right to die with dignity was put forward (hereinafter referred to as death with dignity). Although there are still controversies about the concept and connotation of death with dignity in academic circles at present, it is generally believed that death with dignity means that patients give up some unnecessary life-prolonging medical measures (such as intubation, dialysis, etc.) when they enter the end of their lives, so as to alleviate the physical and mental torture caused by diseases and let their lives inherit the simple view of nature and meet their death with dignity (1). In theory, people often equate death with dignity with euthanasia (2), but in fact, there is a big difference between them. “Euthanasia” generally refers to the act of taking certain measures to end the patient’s life in advance for the purpose of alleviating the patient’s pain when the patient is suffering from an incurable disease and is on the verge of death (3). However, death with dignity is different from euthanasia. Death with dignity gave up some unnecessary medical care measures to prolong life under the condition of respecting patients’ wishes. It is not like euthanasia, where the actor takes active measures to end patients’ lives ahead of

schedule (4). In addition, it should also be noted that the concept of death with dignity used in this paper should also be distinguished from the “ethnic cleansing” movements such as sterilization, euthanasia and mass slaughter forced by the Nazis during World War II. The death with dignity referred to in this paper was practiced on the basis of following the true feelings of patients, rather than being forced by outside powers. Moreover, the application premise of death with dignity in this paper is that the patients at the end of life have signed a legal and effective living will (5). The so-called living will was first seen in a paper published in the *Indiana Law Journal* in 1969 (6). The author believes that since the law has allowed people to make the entrustment about property distribution in advance when they are conscious, then people should also have the right to make and sign the entrustment about medical choice in advance. The living will can be regarded as an advance medical instruction of the patient, which specifically refers to a series of instructions and documents signed by the patient when the state of consciousness is clear and true, aiming at explaining what kind of medical care is “necessary” or “not” at the end of incurable life, such as whether to receive surgical chemotherapy and intubation medical services. A living will is similar to a legal document of a will or trust (7), but this “will” is special, and it deals not with personal property rights, but with personal life rights.

With the official promulgation of the revised Medical Regulations of Shenzhen Special Economic Zone in 2022, China has recognized the legal effect of living wills for the first time in legislation, and the social discussion about “death with dignity” in academic circles has gradually increased, which has also brought many debates (8). Therefore, after analyzing the reasons behind the controversy caused by death with dignity, this paper puts forward some suggestions based on the reality, so as to provide some useful thoughts for the system construction in death with dignity.

2 The controversy caused by death with dignity

Since the concept of death with dignity was put forward, it has attracted great attention from people from all walks of life, such as medicine, bioethics, law and so on, and it has also been debated in theory, among which two completely different academic viewpoints and positions have been formed around the legitimacy of death with dignity.

2.1 Position 1: “death with dignity” respect patients’ medical autonomy

The supporters believe that “death with dignity” is a manifestation of respecting patients’ “right to decide independently,” which is conducive to maintaining the personal dignity of patients at the end of their lives and a concentrated expression of respecting patients’ medical autonomy (9). In 1976, the California Natural Death Act was promulgated, which was the first draft legislation on death with dignity in the world. The bill allows citizens to sign an effective “living will” before their death to dispose of their core life rights and interests (10). Subsequently, Canada, France, Japan, South Korea, and Singapore have also promulgated special laws and regulations to promote domestic death with dignity legislation (11). In today’s

increasingly aging society, it has become a universal realistic demand for the development of the country and society to try to provide the older adult with high-quality and equal medical services to the greatest extent. In the process of promoting the development of hospice care for the older adult, it is particularly important to really pay attention to the physical and mental health needs of the older adult, respect their inner wishes and help them realize their inner demands. The starting point of “death with dignity” is to take patients at the end of life as the center, and to realize the protection, respect and guarantee at the end of life by responding to their inner demands.

2.2 Position 2: “death with dignity” challenges patients’ life rights and personal dignity

Another scholar believes that the patient’s “medical autonomy” is difficult to measure, and it is more difficult in clinical operation. Do patients have the ability of rational analysis, judgment and decision-making to give up their prudent life interests under the condition of patients’ lack of full and necessary understanding of their own life and health status and serious asymmetry of medical information (12)? If innocent patients are driven by the illegal purpose of a third party in this process, they will be easily used by others as “tools” to harm themselves. In addition, should the wishes of the patient’s family members and attending doctors be respected when the patient makes a decision on whether to accept or not to accept medical services? When there is a conflict between the two, how should we make an appropriate decision and plan (13)? Because of the above disputes, the clinical practice of death with dignity will also face severe challenges.

3 Dilemma in the practice of “death with dignity”

3.1 It seems to be in contradiction with the values of Chinese traditional culture

According to traditional culture of China, “Among all the virtues, filial piety comes first” and “Filial piety,” as a general term for respecting relatives and the older adult, is highly respected by the traditional China society. The *Analects of Confucius* says: “A disciple is filial when he enters, and a younger brother when he leaves.” “It’s very rare that filial and fraternal men would offend against their superiors. It’s unheard of that men who do not want to offend against their superiors would stir up trouble.” “Those who are filial are the foundation of benevolence.” For Confucianism, which advocates benevolence and morality, “filial piety” is placed in a higher position, which can be extended from consanguineous family ethics to general social relations and become the basic criterion for dealing with personal social relations. The *Book of Rites*, *The Doctrine of the Mean*, says, “A benevolent person is a human being, and a kiss is the greatest.” Confucius believes that “benevolence” is the highest criterion of individual behavior, and as a universal principle, it should be fundamentally followed in practice. To practice this principle, we must start from the people and things around us. This is “filial piety.” Mencius further improved the philosophical basis of “filial piety.” Mencius advocated the “five ethics” relationship criterion of

loyalty, filial piety, filial piety, forbearance and kindness, and regarded “filial piety” as the core of ethics and morality, ranking first in the “five ethics.” Mencius told the son said: “The way of Yao and Shun is just filial piety.” For Mencius, who admired Saint Wang Zhidao, “filial piety” was the highest expression of personal virtue.

Thus, in a society infiltrated by Confucian culture for a long time, “filial piety culture” does matter in decision-making scenarios. How to properly handle the relationship between parents and children and brothers and sisters has become an important pole in building a harmonious family relationship. Under the soil of China’s traditional culture, the “five ethics” relationship criterion with “filial piety” as the core has become the basic morality and behavior criterion for regulating social communication between people. As Fei Xiaotong wrote in *Earthbound China*, “Combination of etiquette and law” is an important feature of traditional society in China (14), Out of the “etiquette” into the “punishment.” From “Zhou Gong made rites” in the Western Zhou Dynasty to “The Five Degrees of Mourning Clothing System” in the Jin Dynasty and then to “ten evils” felony in the Sui and Tang Dynasties. The “etiquette” in the society was deeply embedded in the national legal system, which violated social conventions. “The Analects of Confucius” says: “That parents, when alive, be served according to propriety; that, when dead, they should be buried according to propriety; and that they should be sacrificed to according to propriety.” Whether parents are alive or dead, they should be filial in accordance with the “ritual” rules followed by society. Talking about his death before his parents died, and giving up or terminating the treatment of his the relatives’ physical illness when they have not completely lost vital life signs, is unacceptable and inappropriate in China’s traditional society, which values ceremony and filial piety. Therefore, considering the contradiction and conflict between the value concept behind “death with dignity” and Chinese traditional ethical culture, it will inevitably encounter great practical resistance when the system “falls to the ground.” Moreover, the implementation of the “death with dignity” system in China at this stage will also face challenges such as the absence of policies and regulations, insufficient material supply, deficit in revenue and expenditure, shortage of professionals, inadequate occupational management guarantee and low social support. This has also caused difficulties in the operation of death with dignity in practice.

3.2 The operational procedures of death with dignity have yet to be solved

On June 23, 2022, the newly revised Medical Regulations of Shenzhen Special Economic Zone was officially promulgated, and China recognized the legal effect of death with dignity (living will) for the first time in legislation. Among them, Article 78 of the Medical Regulations simply stipulates the content and form of death with dignity. [See Article 78 of the Medical Regulations of Shenzhen Special Economic Zone: If a patient or his close relatives provide a patient with the following conditions, the medical institution shall respect the intention of the patient’s living will when implementing medical measures at the end of the incurable injury or at the end of his life: (1) There is a clear intention of taking or not taking traumatic rescue measures such as intubation and cardiopulmonary resuscitation, using or not using a life support system, and continuing treatment of the primary disease; (2) notarized or witnessed by two or more witnesses,

and the witnesses shall not be medical and health personnel involved in the treatment of patients; (3) in writing or audio-visual recording, unless notarized, in writing, it shall be signed by the testator and witnesses and indicate the time; In the case of audio and video recording, the names or portraits of the testator and witnesses and the time shall be recorded].

Obviously, Article 78 of the Medical Regulations is only a principled provision for death with dignity, and the specific operating procedures are not complete. For example, how to judge whether the patient is in the “incurable injury terminal” or “dying” stage, and how to determine the clinical standard? Should death with dignity give due consideration to the opinions of his close relatives when signing? Can the patient entrust a third person to handle it beforehand? Wait a minute. All the above problems need to be further improved by legislation.

3.3 The supply of hospice care services is prominent

For patients who implement death with dignity, it is not to completely give up and stop all the clinical diagnosis and treatment measures, but to give up some unnecessary life-prolonging treatment measures and adopt a more “humanized” medical care plan for patients with full respect for their inner wishes, which is called hospice care in academic circles (15). “Hospice care” is a kind of more “warm-hearted” care, which requires hospitals to provide patients with general diagnosis and treatment services and pay more attention to the improvement of medical service quality, which also puts forward higher requirements for the hospital’s medical service level. In October, 2022, the state issued the 2022 National Bulletin on the Development of Aging (hereinafter referred to as the Bulletin), which showed that by the end of 2022, there were 280.04 million older adult people aged 60 and above in China, an increase of more than 10 million over the previous year, accounting for 19.8% of the total population. There are 387,000 institutions and facilities for the aged in China, with a total of 8.294 million beds for the aged (16). According to a little statistics, single institutions and facilities for the aged need to serve more than 700 older adult people, and single beds for the aged need to serve more than 30 older adult people. With the increase of the total number of older adult people in China year by year and the deepening of aging, the demand for hospice care services will also increase accordingly. However, compared with the huge older adult population in China, the supply capacity of hospice care services in China is insufficient, and the contradiction between supply and demand is gradually prominent.

4 The perfect path of death with dignity system

At present, death with dignity’s system exploration needs to start with the problems encountered in practice, focusing on cultivating a good system implementation environment, strengthening the top-level design of death with dignity system, and improving the national social security system for hospice care, so as to better safeguard and safeguard the basic rights and interests of patients at the end of their lives.

4.1 Cultivate a good environment for system implementation

At this stage, China is in the initial stage of death with dignity system exploration, and the landing of a new social system needs the support of a good social environment. Based on a survey on the knowledge, attitude and behavior of 260 older adult inpatients in a third-class first-class hospital in Wuhan, it shows that the knowledge, attitude and behavior of older adult patients about living wills are medium, and the level of knowledge dimension is the lowest (17). In order to change this situation, it is necessary for the administrative, educational, medical, news media and other departments to properly carry out bioethics publicity and education for the public, publicize the values of sacredness and quality of life, and advocate a brand-new view of life and death. Only when “top-down” institutional innovation and “bottom-up” interest drive interact with each other, and a two-way interaction and feedback mechanism is established, can the organic integration of system and reality be realized.

4.2 Strengthen the top-level design of death with dignity system

Although the Medical Regulations of Shenzhen Special Economic Zone recognizes the legal effect of death with dignity for the first time in legislation, there are some vague concepts and criteria for judging patients’ corresponding behavior ability in the existing regulations. The range of medical measures that patients can choose in their living wills is unclear; the subject of responsibility and the unclear legal liability provisions (18). In order to change this situation, the state needs to strengthen the top-level design of relevant policies and regulations in death with dignity and improve the specific operating procedures implemented in death with dignity. Specifically, considering that the rights and interests disposed by death with dignity are the core life rights and interests of individuals (19), reasonable restrictions should be made on the application subjects. The applicant must be a natural person with full capacity for civil conduct, and the applicable standards can refer to the provisions of Articles 17 and 18 of the Civil Code. (See Article 17 of the Civil Code: A natural person over the age of 18 is an adult. Natural persons under the age of eighteen are minors. Article 18: Adults are persons with full capacity for civil conduct and can independently carry out civil juristic acts. Minors over the age of 16 who take their own labor income as their main source of livelihood are regarded as persons with full capacity for civil conduct.)

When it is necessary by law (such as falling into consciousness disorder), a medical agent can be entrusted, but the patient’s written entrustment documents must be produced and the best interests of the patient should be followed as the basic principle. In the form of application, in order to show respect for the medical autonomy of patients at the end of life, but also to show a cautious attitude toward the disposition of life rights and interests, so that every patient at the end of life can be cautious when deciding on matters related to personal life and health. In principle, the application submitted by the applicant should be mainly in writing. In terms of witnesses, in comparative law, there is national legislation that requires at least two parties with full civil capacity to witness on the spot, and at least one of them is a doctor (20). China’s legislation can take it as a reference, and it is stipulated that the signing and application process of death with dignity should be witnessed by at

least two adult parties. At the same time, in order to prevent the related ethical and moral risks, the witness should not be the spouse, close relatives, heirs and other interested subjects of the patient. In terms of application content, death with dignity is a document of “want” or “do not want” medical care measures signed by patients at the end of their lives, and its content must reflect the true feelings of patients. If they go back on their word after applying for personnel, they can change or cancel their medical care instructions at any time, and they will not be treated unfairly because of the change or cancelation. In terms of filing and examination, in order to ensure the legitimate and reasonable exercise of death with dignity, the implementation of death with dignity needs to be filed and examined with a notary office. The state should set up a special death with dignity implementation supervision institution (or entrust relevant organs or social welfare organizations to supervise the implementation) as an independent third party with no interest to supervise the social implementation in death with dignity. In terms of the composition of the regulatory body, in order to ensure the scientific nature of the supervision decision, its members should accommodate experts and scholars from different disciplines such as medicine, ethics and law, and the regulatory body should improve its internal rules and regulations, regularly publish the list of members, and accept the supervision of the general public. In terms of relevant subject responsibilities, the enforcement applicant in death with dignity should be a patient at the end of his life. In order to avoid the risks between doctors and patients in the implementation, if the hospital legally and reasonably implements the death with dignity Agreement according to the contract, it does not need to bear the adverse legal consequences. On the other hand, if the hospital violates the contract or improperly performs the agreement and infringes on the personal or property rights of patients, it should bear corresponding legal responsibilities.

4.3 Improve the national social security system for hospice care

With the increasing aging population in China, it is necessary to improve the social security system of hospice care in China. At this stage, China should clarify the admission, care and operation standards of hospice care, strengthen the internal management of medical staff and improve the supply capacity of hospice care services. The government should increase the financial expenditure of medical services, strengthen the echelon and discipline construction of medical talents, and establish the norms of hospice care occupation, training and clinical practice. In discipline construction, medical curriculum should break the professional barriers between medicine and humanities and social sciences, and promote the deep cross-integration between medicine and other disciplines. In the distribution of medical resources, the management department should establish a fair and reasonable incentive mechanism, actively promote the fair distribution of medical resources between regions and between urban and rural areas, and realize the efficient allocation of medical human resources. In addition, hospice care service is an important social security measure. With the aging of our population, in order to improve the ability and security level of the whole society, enhance the sense of acquisition and happiness of the older adult, and better realize the protection of the rights and interests of the older adult, the state can try to bring hospice care into the social compulsory medical insurance to meet the increasing demand for hospice care (21).

5 Conclusion

Death with dignity is a brand-new outlook on life and death, full of humanitarianism and strong humanistic concern. Due to the influence of traditional culture, policies and laws, medical service supply and other factors, there is great practical resistance to social implementation in death with dignity. Therefore, focusing on cultivating a good system implementation environment, strengthening the top-level design of death with dignity system, and improving the national social security system for hospice care, so as to better promote the development of hospice care in China.

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

LC: Conceptualization, Writing – original draft, Writing – review & editing. MR: Supervision, Validation, Writing – original draft.

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The formation pattern, causes, and governance of network public opinion on university emergencies

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Background: University emergencies, garnering significant public attention and shaping network opinions, pose a crucial challenge to universities' management and societal stability. Hence, network public opinion on university emergencies is a vital issue. Nevertheless, the underlying mechanism has not been fully explored and cannot be efficiently controlled. This study aimed to explore the formation pattern of network public opinion on university emergencies, analyze its causes, and provide scientific governance strategies for coping with this issue.

Methods: Based on a sample set of 204 cases from the Zhiwei Data Sharing Platform, this study classifies network public opinion on university emergencies into six types and visually analyzes their characteristics: time distribution, subject, duration, and emotion. By integrating the theory of the network public opinion field, this study develops a network public opinion field model of university emergencies to reveal its formation pattern. Furthermore, it analyzes the causes of network public opinion on university emergencies from the perspective of the public opinion lifecycle and proposes corresponding governance strategies.

Results: The sample consisted of 304 cases of real-life public opinion, and the visualization results show that public opinion on mental health and teacher–student safety constitutes the predominant types, accounting for 83.3%. High-occurrence subjects are public universities (88.24%) and students (48%). The most frequent months are July and December. 90.20% of the public opinions have a lifespan of less than 19 days, with an impact index ranging from 40 to 80. The public's emotional response to different types of public opinion varies, with negative emotions dominating.

Conclusion: This study provides novel insights for understanding their formation and dissemination. It also provides practical implications for relevant departments to govern network public opinion on university emergencies.

KEYWORDS

university emergencies, network public opinion, network public opinion field theory, formation, cause, governance

1 Introduction

Amid higher education reform, new media proliferation, and university management shifts, university emergencies such as examinations, enrollment, and employment conflicts have been on the rise (1, 2). As an important part of public education, university emergencies are prone to attracting significant public attention (3), particularly driven by the online media,

leading to an enhanced tendency for public participation therein (4, 5). With the intensification of public opinion, network public opinion on university emergencies is increasingly characterized by diversified content, complex evolution, extreme emotions, and the proliferation of risks (6). The multifaceted risk characteristics of public opinion pose substantial threats to university management, ordered network environment, and education credibility (7). Thus, it is important and urgent to explore the formation and governance.

At present, the formation of network public opinion including the formation principle and process is mainly studied by social network analysis (8). This type of research traverses various academic domains, including information communication and social psychology, exploring significant topics such as the dynamics of opinion polarization (9), the impact of opinion leaders (10), and the evolution of public opinion (11). One of the centers of research related to the evolution of public opinion is the distinction between public and private opinions (12). Individuals may exhibit significant discrepancies between their private and expressed opinions due to a multitude of factors, including social normative pressures (13), misbehaving individuals (14), and sociocultural influences (15). Failing to acknowledge these discrepancies is likely to have significant ramifications, such as the Arab Spring movement, and the fall of the Soviet Union.

Network public opinion on university emergencies is a weathervane for all segments of the university system (6). It mainly refers to the collective attitude, opinions, and emotions held by Internet users toward hot topics triggered by university emergencies within a certain period. Consequently, this study must encompass both private and public opinions in a comprehensive manner.

As a sub-study of network public opinion on emergencies, research related to network public opinion on university emergencies can be traced back to the 1990s. The initial studies were few in number and limited to specific colleges and universities. With the widespread adoption of Internet technology and the expanding university student population, network public opinion on university emergencies has garnered increasing attention. Subsequently, research into the dissemination patterns, influencing factors, monitoring, and early warning mechanisms has made incremental progress. In recent years, social changes and shifts in information communication have heightened the complexity of public opinion formation and escalated public opinion risks. Therefore, existing researchers have initiated a re-examination of the formation and evolution of network public opinion on university emergencies, with a view to identifying effective governance strategies.

Drawing from the extant literature, the current research on network public opinion on university emergencies focuses on four categories. The first category has focused on the evolution mechanism of network public opinion on university emergencies. Related studies employ various modeling techniques to facilitate intelligent simulation (16, 17). For example, Qu simulated the evolution of network public opinion on university emergencies using an enhanced SNIDR model to illuminate the dynamic interaction mechanism (16). The second category has explored the factors influencing network public opinion on university emergencies. Different from other types of public opinions to prioritize objective factors (18, 19), network public opinion on university emergencies emphasizes greatly on subjective factors, such as social motivation and information source preference (20, 21). The third category has addressed monitoring network public opinion on university emergencies. In recent years, universities have

faced several worrisome trends related to student safety and wellbeing, including violent behavior, cyberbullying, and adolescent suicidality (22). To improve such situations, student social media monitoring programs and university dynamic monitoring systems are widely used to effectively identify and prevent potential problems (23–25). In addition, the fourth category is concerned with the governance of network public opinion on university emergencies (6, 20, 26).

Despite the fact that scholars have approached the issue from various perspectives, there are still gaps in the relevant studies. First, the research perspective covers a wide range of emergencies, while rarely paying attention to university emergencies. Universities play a crucial role in public health as a subsystem of the social system and the frontline of ideological dissemination. Existing research has mainly focused on network public opinion on emergencies, but it has failed to effectively incorporate the unique background of university emergencies. Consequently, the research insights cannot fully address network public opinion on university emergencies.

Second, research on the causes of network public opinion on university emergencies has not been sufficiently comprehensive. The formation and dissemination of public opinion is not a simple linear information transmission model, and the complexity of its evolutionary causes is increasing with the evolution of the new media landscape. Despite abundant research on public opinion formation, the existing literature often narrowly focuses on one aspect of its spread, neglecting a comprehensive view of its entire lifecycle (27). Furthermore, it is necessary to explore the interaction among the components of public opinion diffusion.

Third, an entry point and basic theories for exploring network public opinion on university emergencies are lacking. Most studies have considered network public opinion on university emergencies as a whole and have rarely explored its classification. In addition, many scholars have proposed governance strategies from the subject's perspective, ignoring the internal development characteristics of public opinion. These circumstances have led to a lack of focus on relevant public opinion governance strategies and further hindered in-depth exploration of the field.

To fill these gaps, this study aimed to construct and analyze the network public opinion model by combining data visualization and the theory of network public opinion field and to explore the causes and governance strategies of network public opinion on university emergencies. First of all, this study visually analyzed the network public opinion on university emergencies from the dimensions of type, time, subject, and emotion based on 204 real-life cases. Second, based on the results of the analysis, this study integrated the theory of the network public opinion field to develop a network public opinion field model of university emergencies. By exploring the dominant fields and interactions at different periods of the public opinion lifecycle, the causes of network public opinion on university emergencies were analyzed. Third, from the entire lifecycle perspective, this study proposes periodization governance strategies to enhance the efficiency of network public opinion governance.

The remainder of this paper is organized as follows: Section 2 describes the sample data collection process, including data source, data selection, and extraction. Section 3 reveals the analysis results based on the sample data set from various angles. Section 4 proposes a network public opinion field model of university emergencies to

present its formation mechanism and explores its causes and governance strategies. Section 5 concludes the theoretical and practical implications as well as the limitations.

2 Materials and methods

2.1 Data source and selection

2.1.1 Data source

This study employs microblogging data provided by the “Zhiwei Data Sharing Platform.”¹

Social media have emerged as a pivotal medium for the dissemination of public opinion, facilitating access to diverse essential information, including opinions and emotions (28). As the number of users and the influence of the platform have increased, Weibo has become the primary center for the dissemination of online public opinion in China (29). However, frequent upgrades have made it increasingly challenging to crawl their data, prompting some scholars to utilize third-party social media opinion aggregation platforms, such as the Zhiwei Data Sharing Platform (30). This platform provides an evaluation system for the influence of network public opinion based on big data technology, integrating social media data to effectively present current and trending topics. Furthermore, the platform employs rigorous and uniform criteria for incorporating public opinion events: (1) Achieving a high volume of dissemination within a brief period of time. (2) Maintaining a consistent volume of dissemination over an extended period. (3) Stimulating heated debates on online social media. These criteria effectively enhance the credibility and accuracy of the data. Therefore, it was deemed reasonable to use the Zhiwei Data Sharing Platform as the data source for this study.

2.1.2 Data selection

This study employed a keyword maximization search method to gather data. Considering the main subjects of public opinion on university emergencies, the following keywords were used for searching: “college,” “campus,” “university,” “student,” “postgraduate,” “teacher,” “professor,” and “faculty.” Furthermore, the search timeframe was set from 1 January 2015 to 31 December 2022.

The following inclusion criteria were formulated to ensure the validity of the sample data:

(1) The subject of the incident should be the university group or the university itself. Even if the site of the emergency is off campus, the entities involved are university-affiliated groups or the universities themselves.

(2) The incident occurred during the period of higher education. This criterion ensures that the research object is a university emergency.

(3) The incident was sudden. Suddenness, which is one of the main characteristics of university emergencies, is also a crucial aspect of network public opinion and a challenge in its governance (31).

(4) The negative impact of the incident was an imbalance in order (32). The incident had a certain impact on the university or community, disrupting the campus work or public opinion environment.

Following the above selection criteria and sample data selection process in Figure 1, 204 valid samples were obtained from the Zhiwei Data Sharing Platform.

2.2 Data extraction

Based on the obtained sample data, the following fields were extracted for subsequent analysis:

(1) Occurrence time of public opinion. The year of occurrence and the month of public opinion in the sample set were extracted. These data reveal the distribution of public opinion incidents in the time dimension.

(2) Type of university involved. The universities involved in the sample set were divided into public universities, private universities, and others according to their attributes. These data reveal the distribution of universities involved in public opinion incidents.

(3) Impact index of public opinion. The impact index within the Zhiwei Data Sharing Platform is calculated by summing the dissemination effects across self-media (Meibo and WeChat) and online media and then normalizing the resulting sum. The value of these data ranges from 0 to 100, indicating the dissemination intensity and spread of public opinion incidents on Internet platforms.

(4) Subjects of public opinion. The subjects involved in public opinion were divided into student, teacher, school, student–teacher, student–school, and others based on their relationships. These data can be used to analyze the subjects involved in public opinion incidents.

(5) Titles and abstracts of public opinion. The titles and news abstracts of each public opinion on the platform were preprocessed to obtain effective vocabulary. These data offer a rapid comprehension of the progression of public opinion incidents and the focal points of public interest.

(6) Public opinion commentary. Public opinion leaders are pivotal nodes in the dissemination of public opinion (10). These users are less susceptible to external influence when expressing their opinions, and their comments are primarily reflective of their private opinions. “Like” is a significant indicator for gauging social consensus (33). High “like” comments can be regarded as representatives of public opinion due to their extensive dissemination and acceptance. Therefore, this study comprehensively collected opinions from opinion leaders or highly popular comments on Weibo platforms, in order to ensure the comprehensiveness and accuracy of data analysis. These data can reveal the public’s views and attitudes toward public opinion incidents.

(7) Duration of public opinion. With days as the unit of time, the duration of public opinion on the platform was extracted. These data reveal the durations of active public opinion incidents on Weibo.

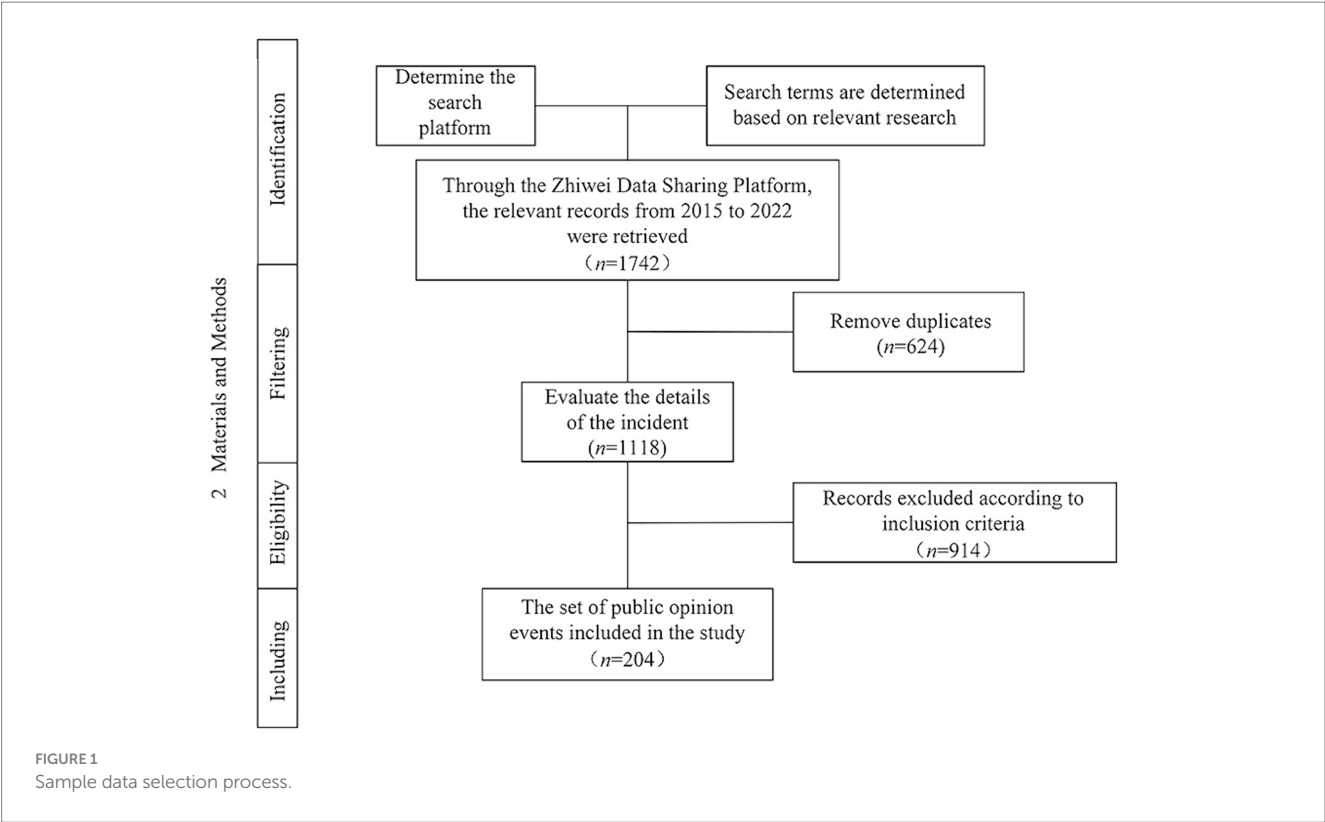
3 Results

3.1 Classification and characteristics of network public opinion on universities emergencies

3.1.1 Classification of network public opinion on universities emergencies

Classifying the types of network public opinion on university emergencies is a prerequisite for studying their evolution and

¹ <http://university.zhiweidata.com/>



governance. This is conducive to clarifying evolutionary patterns and providing rapid and targeted responses and governance.

A semantic analysis of the themes in the sample data revealed that the optimal number of clusters—and thus the optimal classification of the types of network public opinion regarding university emergencies—was four (Figure 2).

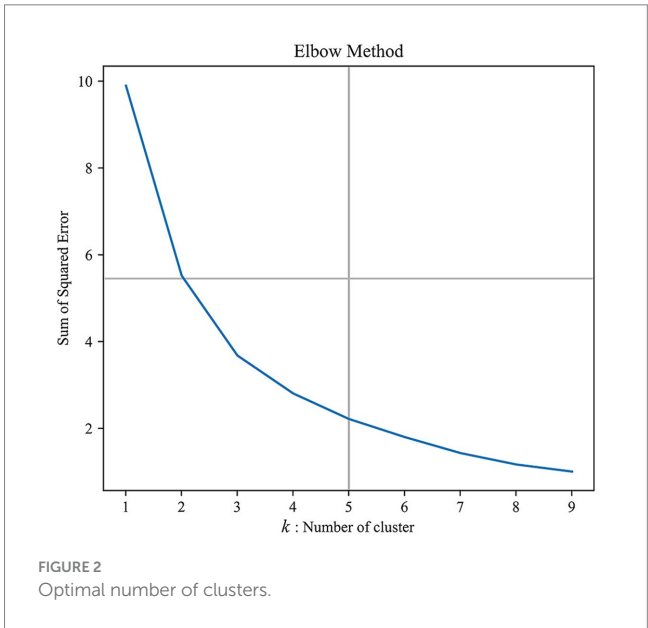
In addition, the sample data included a small number of public opinions on natural disasters and social and political issues. Hence, this study developed six categories of network public opinion on university emergencies, as shown in Table 1.

(1) Network public opinion on natural disaster emergencies. It refers to the university network public opinion triggered by natural disasters such as earthquakes, floods, typhoons, and blizzards. It is characterized by suddenness and unpredictability.

(2) Network public opinion on sociopolitical emergencies. It refers to the university network public opinion triggered by university groups in the fields of international situations, religious beliefs, and national sentiments. The incidence of such network public opinion on university emergencies is low but politically charged. It is characterized by high cohesion among opinion subjects, extensive diffusion of public opinion, and substantial social influence.

(3) Network public opinion on public service emergencies. It refers to a university network public opinion triggered by improper campus management, including public health, network information security, management systems, and decision-making. The incidence of such network public opinion on university emergencies is high; however, the nature and impact indices vary widely. It is characterized by diversity and high incidence.

(4) Network public opinion on teacher–student safety emergencies. It refers to the university network public opinion



triggered by campus accidents and students’ and teachers’ personal safety. As university teachers and students are mostly young people with low awareness and ability to cope with danger, these public opinions have typical age characteristics.

(5) Network public opinion on academic security emergencies. It refers to the university network public opinion triggered by teaching accidents and academic fraud by students and teachers. This particular type not only endangers the university’s development in the academic

TABLE 1 Types of network public opinion on university emergencies.

Category	Type	Segmentation
A	Natural disasters	A Earthquakes, floods, etc.
B	Sociopolitics	B Ideology, ethnic issues, etc.
C	Public services	C1 Public health: canteen hygiene.
		C2 Network information security: campus network failures and network attacks.
		C3 Management system: charges, administrative disposal.
D	Teacher–student safety	D1 Laboratory accidents, dormitory fires, campus public facilities.
		D2 Personal health: sudden death, loss of contact.
E	Academic safety	E1 Teaching accidents: examination accidents, improper study style.
		E2 Academic fraud.
F	Mental health	F1 Students' inappropriate words and behaviors.
		F2 Teachers' moral corruption.

world but also leads to a credibility crisis for the entire education system.

(6) Network public opinion on mental health emergencies. It refers to the university network public opinion triggered by students' inappropriate behavior and teachers' moral transgressions. This particular type is mainly caused by human factors. The subject's behavior, which is somewhat hidden, is induced by some opportunities.

The above six types cover all the current network public opinion on university emergencies. In reality, however, different types of network public opinion on university emergencies are not clearly defined and completely independent; under certain scenarios, they may overlap or even transform into each other. Therefore, it is necessary to comprehensively govern public opinion in line with its actual development.

3.1.2 Characteristics of network public opinion on university emergencies

Understanding the characteristics of different types of network public opinion on university emergencies can help establish or improve public opinion response mechanisms. Hence, this study analyzed the occurrence volume and impact index of different types of public opinion incidents to identify their characteristics, as shown in Figure 3.

In terms of the number of occurrences, mental health network public opinion and teacher–student safety public opinion have the highest occurrence, with both types of public opinion accounting for 83.30% of the total sample size, followed by public service, academic ethics, sociopolitics, and natural disasters. In terms of the impact index,

network public opinion on teacher–student safety was the highest, followed by mental health, public service, sociopolitics, natural disasters, and academic safety. Hence, mental health and teacher–student safety were the two commonly occurring types of network public opinion with a high impact index, and they should be considered priorities in the governance of network public opinion on university emergencies.

3.2 Time distribution of network public opinion on university emergencies

Network public opinion on university emergencies is characterized by substantial dynamic evolution. Exploring its evolution process helps to understand the relevant elements affecting public opinion (34) and provides a reference for public opinion governance. Hence, this study analyzes the time distribution of network public opinion on university emergencies.

First, this study examined the annual occurrence changes of different types of network public opinion on university emergencies, as shown in Figure 4.

The total number of network public opinion on university emergencies showed an overall “inverted U-shape.” The growth was slow from 2015 to 2018. It peaked between 2019 and 2020 and showed a downward trend from 2021 to 2022. Moreover, the overall fluctuation of network public opinion on natural disasters and sociopolitics was relatively small, indicating that the attention to such incidents was stable. Network public opinion on public services, teacher–student safety, and academic safety varied sharply by year. In recent years, public opinion on mental health has increased, quickly becoming the most common type of network. This indicates that network public opinion on mental health is becoming increasingly prominent.

The growth from 2019 to 2020 is closely related to the COVID-19 pandemic. Universities are considered as one of the “main battlefields” of epidemic prevention and control (35). During the COVID-19 pandemic, universities implemented a series of stringent lockdown measures, necessitating an abrupt adaptation of existing education systems to a new online teaching environment (36). Due to the disruption of teaching order, internal conflicts within universities intensified, leading to a comprehensive increase in occurrences from 2019 to 2020. As the pandemic waned and university management was optimized, the occurrences declined. Beyond physiological harm, the COVID-19 pandemic has also triggered widespread psychological crises (37, 38). The university population, particularly freshmen, exhibits heightened vulnerability in terms of mental health, with notable elevations in stress levels, anxiety, and depressive thoughts during the pandemic (39, 40). As stress levels escalate, individuals inevitably project their burdens onto social media (41), creating a vicious cycle where the overwhelming influx of information exacerbates mental health problems (42, 43). Consequently, public opinion on mental health still remains high after the COVID-19 pandemic (44), and it has gradually become the mainstream public opinion on university emergencies.

Second, this study analyzed the monthly occurrence changes of different types of network public opinion on university emergencies, as shown in Figure 5.

The monthly average occurrence of 17 cases as the basis shows that the occurrence of network public opinion on university emergencies varied greatly by month (Figure 5A). It mainly occurred in the second

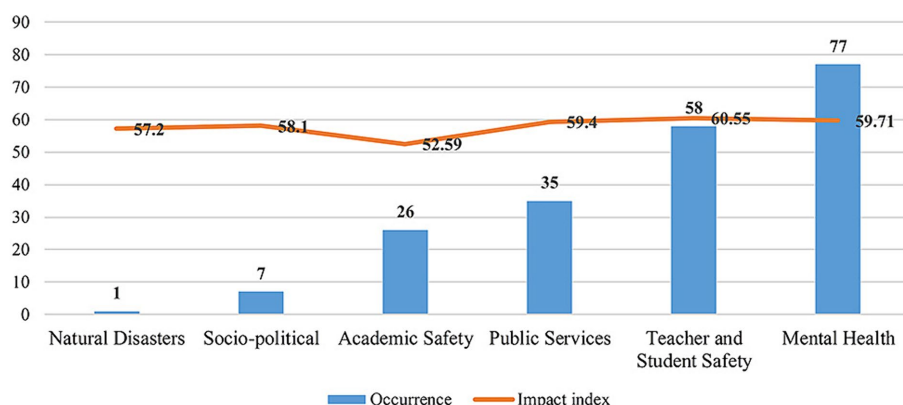


FIGURE 3

Occurrence volume and impact index of network public opinion on university emergencies.

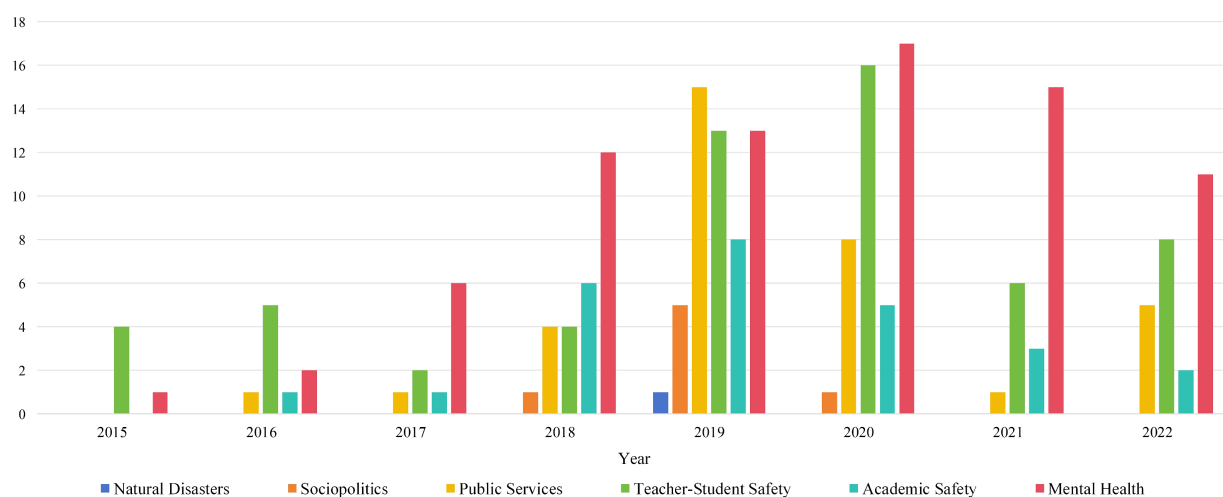


FIGURE 4

Annual distribution of network public opinion on university emergencies.

half of the year and had a double-peak distribution in July and December. Furthermore, the emergence of network public opinion on university emergencies is intricately linked to the university's management cycle (Figure 5B). Public opinion is usually accompanied by various university activities with high mobility and pressure, including festivals and holidays, awards and assessments, major examinations, and campus recruitment. These activities are prone to attracting public attention and discussion, thereby generating relevant network public opinion.

3.3 Subject of network public opinion on university emergencies

Network public opinion dissemination is the outcome of a subject's behavioral choices in a specific cyberspace (45). Students, teachers, and universities participate in university education, and they are also the subjects of network public opinion on university emergencies. Hence, this study analyzed subject characteristics to understand the

behavior and role of different subjects in the development of network public opinion on university emergencies, as shown in Figure 6.

The occurrence rate of network public opinion on university emergencies in public universities stands at 88.24%, significantly exceeding that in private universities (Figure 6A). The reasons for this finding are two. First, China's higher education system is dominated by public universities and supplemented by private universities. The number of public universities significantly exceeds that of private universities. Second, public universities place more emphasis on cultivating student information quality, leading to higher levels of online participation and dominance among students at public universities. This results in a high degree of social concern for public universities, which makes it easier for public opinion to form.

The occurrence of network public opinion on university emergencies was the highest among students, accounting for 48% of the total, followed by school, student-teacher, and student-school (Figure 6B). In addition, different subjects are often associated with specific types of public opinion, which is related to the subject activities and group characteristics. Students, being inclined toward having an active mind

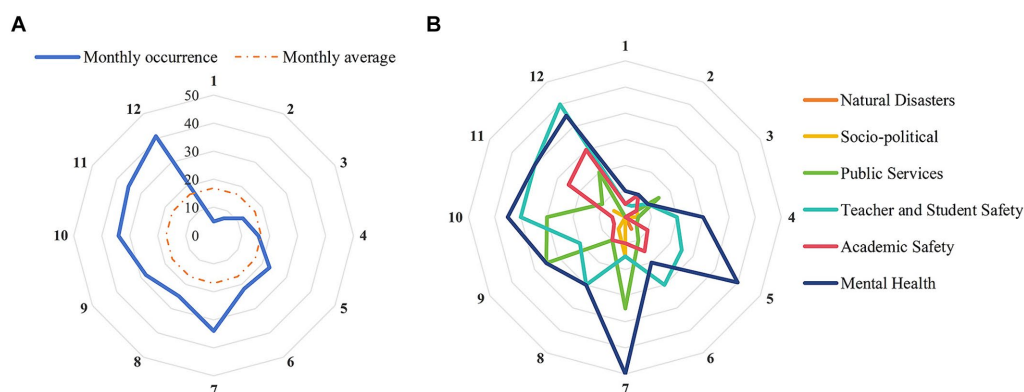


FIGURE 5
Monthly distribution of network public opinion on university emergencies. (A) Overall distribution. (B) Distribution of each type.

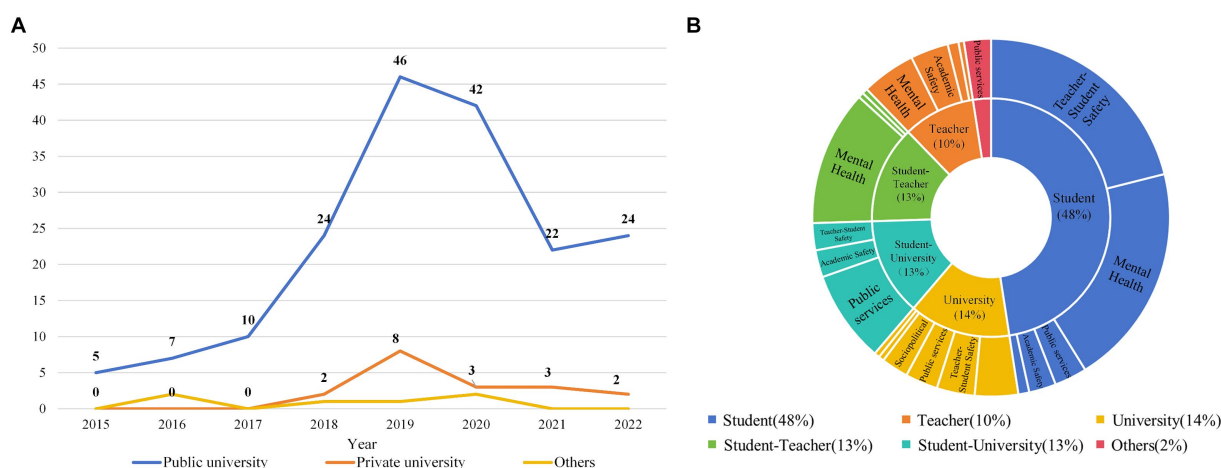


FIGURE 6
Subject distribution of network public opinion on university emergencies. (A) Proportion of different types of universities. (B) Proportion of different public opinion subjects.

and being open to novelty, often lack social practical experience and are prone to the influence of harmful information (46). Consequently, they frequently become ensnared in public opinion, regarding issues such as teacher–student safety and mental health. University teachers, often facing substantial professional pressure (47), have experienced a gradual decline in their mental wellbeing in recent years (48, 49). Consequently, public opinion involving teachers has primarily focused on mental health. Universities are social and cultural centers with talent training, scientific research, and innovation as their main activities. Therefore, public opinion related to public services and academic safety at universities is more likely to evoke widespread social discussion.

3.4 Duration of network public opinion on university emergencies

Duration is an important variable in the study of public opinion (50). Hence, this study analyzed the duration distribution to understand social attention toward different types of public opinion, as shown in Figure 7.

The duration of the six types of network public opinion on university emergencies was centrally distributed over 4–9 days, with medians of 6.25, 6, 6, 6, 8, and 7.79 (Figure 7A). This indicates that most network public opinion on university emergencies tends to last for approximately 1 week.

The distribution of network public opinion on university emergencies in terms of duration and impact index conformed to a normal distribution (Figure 7B). It was found that 90.20% of public opinion samples remained stable at 0–19 days, and their impact index remained within the range of 40–80. Furthermore, the correlation coefficient between duration and impact index was 0.211, with a significance value of $0.002 < 0.001$ (Table 2). Therefore, a significant weak positive correlation was observed between the duration and impact index of network public opinion on university emergencies.

This study further explored the factors that affect the duration of public opinion. Duration is a quantitative indicator and measure of the public opinion lifecycle that includes multiple periods of public opinion development. It can be divided into three periods (51), four periods (52), five periods (53), and six periods (54) based on different

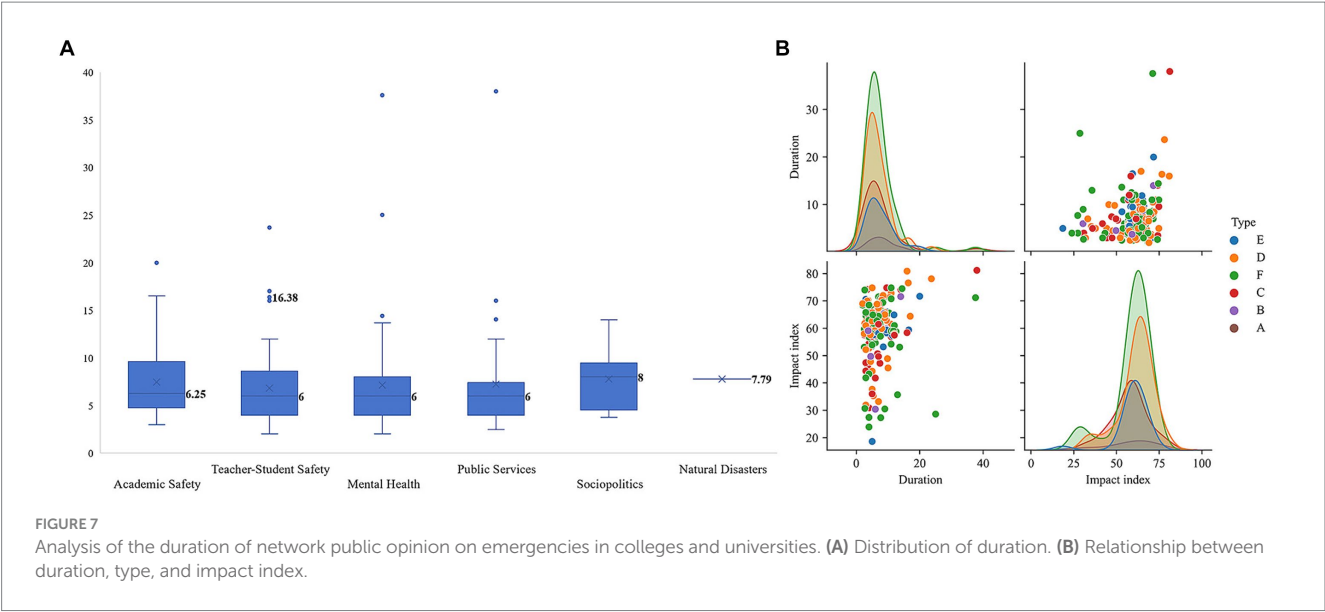


TABLE 2 Correlation analysis of duration with impact index.

		Impact index	Duration
Impact Index	Pearson's correlation	1	0.211
	Sig. (2-tailed)		0.002
	N	204	204
Duration	Pearson's correlation	0.211	1
	Sig. (2-tailed)	0.002	
	N	204	204

segmentation methods. Employing a public opinion lifecycle framework can facilitate the analysis of changes in the duration of public opinion. This study selected the longest-lasting cases under different types and investigated the corresponding trend in public opinion evolution, as shown in Figure 8.

In summary, this study divided the network public opinion on university emergencies into five periods: brewing, diffusion, outbreak, dissipation, and calming. During the diffusion period, the curves of public opinion on natural disasters, social politics, and academic safety steadily declined, whereas those pertaining to public services, mental health, and teacher–student safety resurged. The first three types of public opinion had a relatively short duration, whereas the last three types had a longer duration. Therefore, it can be inferred that the dissipation period is crucial in influencing the duration of network public opinion on university emergencies.

3.5 Emotion analysis of network public opinion on university emergencies

The dissemination of public opinion is also a process of transforming public emotions (55). Understanding the emotions of

network public opinion on university emergencies aids in exploring the evolution mechanism (56). Hence, this study extracted keywords expressing obvious emotional tendencies in microblog comments to construct emotional word clouds, as shown in Figure 9.

Emotions toward different types of network public opinion on university emergencies varied, basically dominated by negative emotions. The keywords in the word cloud of public opinion on natural disasters (Figure 9A) include “earthquake,” “student,” “safe,” “panicky,” and “worry,” reflecting the public’s concern for student safety and fear of disasters. The keywords in the word cloud of sociopolitical public opinion (Figure 9B) include “foreign,” “discrimination,” “patriotic,” “China,” “fawning,” “insulting,” and “shameful,” reflecting the public’s patriotic feelings and anger toward the trend of worshipping foreign countries. The keywords in the word cloud of public service opinion (Figure 9C) include “canteen,” “dormitory,” “notice,” “dissatisfied,” “stipulated,” and “grumble,” reflecting the public’s dissatisfaction with campus management. The keywords in the word cloud of public opinion on teacher–student safety (Figure 9D) include “safe,” “wish,” “kill,” “depression,” “pressure,” and “death,” reflecting the public’s grief over the accident casualties and prayers for the deceased. The keywords in the word cloud of academic safety opinion (Figure 9E) include “suspect,” “satirize,” “plagiarize,” “academic,” and “dishonorable,” reflecting the irony and helplessness of the public toward academic misconduct. The keywords in the word cloud of public opinion on mental health (Figure 9F) include “afraid,” “molestation,” “lewd,” “harass,” and “notification,” reflecting the public’s fear of sexual harassment and molestation.

The reason for this is that the public’s expression of emotions in network public opinion depends on their own risk perception (57). Individuals generate corresponding emotional feedback based on the risk characteristics brought by different types of network public opinion. Among them, risk perception is most likely to elicit negative emotions (58).

This study further explored the relationship between emotions and the public opinion lifecycle. The network public opinion of “cholera cases in Wuhan University” was taken as the research case. In this case, the impact index was as high as 74.8. However, the duration

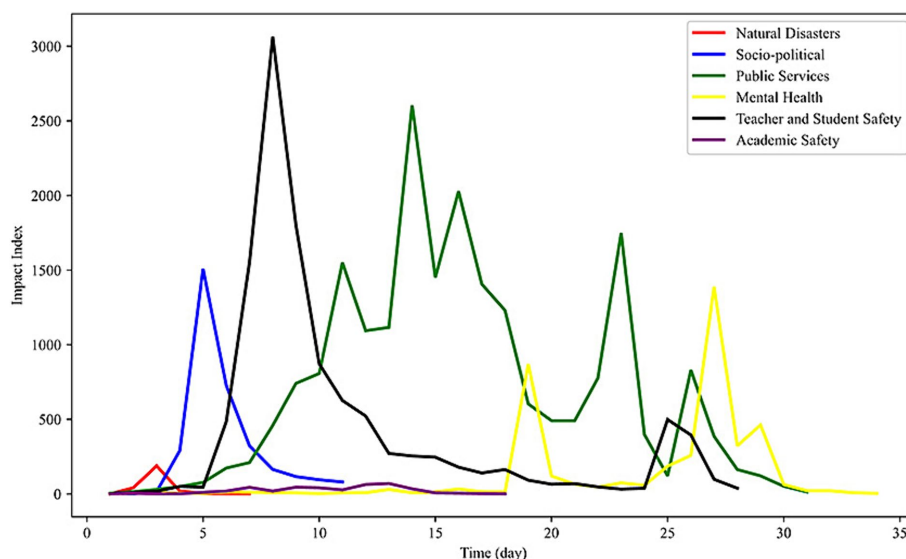


FIGURE 8
Evolution trend of network public opinion on university emergencies.

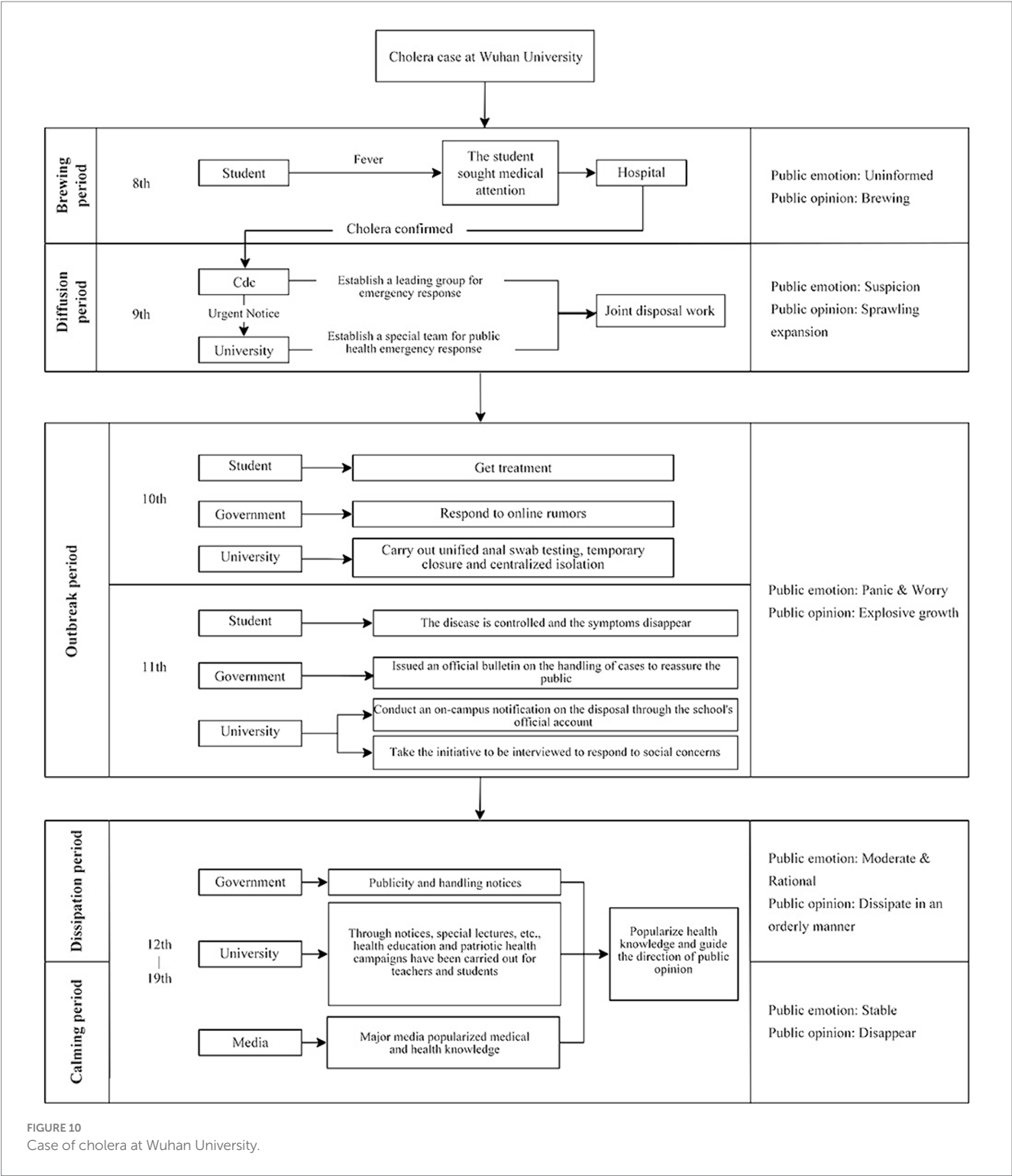


FIGURE 9
Word cloud of network public opinion on university emergencies. (A) Natural disasters. (B) Socio-political. (C) Public service. (D) Teacher and student safety. (E) Academic safety. (F) Mental health.

was only 9.5 days. Therefore, the correlation between impact index and duration may not have interfered with the analysis to a certain extent. Hence, this study reviewed the entire case to analyze the changes in emotions and the evolution trend of public opinion, as shown in Figure 10.

Public opinion expressed different emotional tendencies in different periods. On 8 July, most of the public was uninformed,

and public opinion was in the brewing period. On 9 July, public opinion diffused amid public suspicion of cholera. From 10 to 11 July, a case of cholera was identified, which led to a rapid outbreak of public opinion. From 12 to 19 July, with various management departments demonstrating efficient joint governance capabilities, the public panic was alleviated, and public opinion dissipated accordingly. The general public's emotional changes drive the



cyclic evolution of network public opinion on university emergencies. This is because the development process of network public opinion on university emergencies involves public information demand and information feedback. Emotional demand is also a part of information demand (59). To satisfy their emotional needs, netizens take the initiative to contact the public and express their emotions; therefore, their emotional demand is crucial in influencing the impact index of public opinion.

4 Discussion

The results above indicate that network public opinion on university emergencies has certain regularities in terms of characteristics, time distribution, subject, duration, and emotion. These regularities form a relatively independent network space called the network public opinion field. Based on the theory of the network public opinion field, this study constructs a network public opinion

field model of university emergencies. By analyzing the interactions between different fields, this study further examines the underlying causes from a lifecycle perspective. Moreover, related governance strategies are proposed to provide insights into network public opinion on university emergencies.

4.1 Network public opinion field model of university emergencies

The popularity of the Internet and new media has shifted public opinion from print media to online, resulting in a network field dominated by social media platforms (60). As a branch of field theory, the network public opinion field refers to a spatial and temporal environment containing several interacting factors that enable public opinion (61). The theory emphasizes how different viewpoints, emotions, and attitudes intersect and collide in a particular public opinion environment. This theoretical framework is highly compatible with the specific social opinion phenomenon of network public opinion on university emergencies.

Network public opinion on university emergencies can be considered the result of the combined influence of multiple factors (62). In the process of formation and dissemination, the influencing factors of network public opinion on university emergencies are interrelated, attracting the voices of students, faculty, administrators, and external stakeholders. These voices intertwine and collide in cyberspace, forming a network public opinion field of university emergencies containing multiple subfields. An evident correspondence exists between the subfields and influencing factors, and the different subfields share an interaction and constraint relationship. The network public opinion field presents the characteristics of plurality, interactivity, and dynamics with the development of network public opinion on university emergencies. By emphasizing these characteristics, the theory of the network public opinion field provides a powerful theoretical tool and analytical framework for understanding, analyzing, and responding to network public opinion on university emergencies.

Drawing from the theory of the network public opinion field, this study identifies key factors shaping network opinion on university emergencies and establishes a corresponding model (Figure 11). The model divides the whole network public opinion field of university emergencies into three subfields: psychological field, social field, and new media field. This reveals the interaction within and between each subfield from the perspective of the public opinion lifecycle.

With respect to each field, the relationship with its elements is as follows:

(1) Psychological field—subjects of public opinion. The psychological field of network public opinion on university emergencies refers to the density of people and frequency of communication in the same space. The higher the crowd density and interaction frequency, the stronger the subject's dissemination effect in the psychological field. Universities, teachers, and students are key subjects in the evolution of network public opinion on university emergencies. They converge in their cultural communication, living space, and interests and tend to have the same opinion, which makes it easy for them to resonate with each other's emotions and cooperate. This characteristic enables them to easily accumulate public opinion both online and offline, which spreads further due to other influencing

factors. Therefore, the subject of public opinion is the key factor in the psychological field.

(2) Social field—public opinion emotion. The social field of network public opinion on university emergencies refers to the rendering objects and atmosphere of the public opinion environment. The greater the number of rendering objects and the stronger the rendering atmosphere, the stronger the emotion in the social field. The rendering atmosphere consists of various figurative rendering objects such as opinion labels and online slogans. They enhance the communication of a point of view or emotion by stimulating the senses and attracting a high level of public attention. The network public opinion on university emergencies contains rich emotional expressions, and the tendency and intensity of these emotions have a significant impact on the evolution of public opinion (63). Thus, public opinion emotion is a key factor in the social field.

(3) New media field—duration of public opinion. The new media field of network public opinion on university emergencies refers to the openness of the public opinion environment. The higher the openness of public opinion, the longer the duration of public emotion in the new media field. The network public opinion field and society are in a relationship of part and whole. In the early development of network public opinion on university emergencies, small-scale public opinion is connected to the overall social environment through the new media field; as a result, a smooth information channel is established. The openness of the information channel affects the intensity of public information expression in the public opinion environment. High-intensity information expression often awakens other similar issues under public opinion, generating derivative public opinion and lengthening its duration. Therefore, the duration of public opinion is a key factor in the new media field.

Moreover, an interactive relationship exists among all fields. First, network public opinion on university emergencies is noticed and disseminated by subjects of public opinion in the psychological field. Through actions such as liking, commenting, and sharing on social media, public opinion subjects gradually open up the new media field and induce emotion in the social field. Second, under the influence of emotional motivation, the social field creates an atmosphere of emotional attributes, which, in turn, shapes the psychological field and expands the dissemination of the new media field. Third, the new media field interfaces with the psychological and social fields through the information channel. Expanding the information channel means that the new media field is more likely to strengthen the subject's communication and emotional expression. Conversely, when the information channel narrows, the power generated by the psychological and social fields diminishes. Public attention then shifts to other events, thus shortening the duration of public opinion.

In summary, network public opinion on university emergencies forms and evolves under the interaction within and among subfields. The evolutionary cycle includes five periods: brewing, diffusion, outbreak, dissipation, and calming.

4.2 Causes of network public opinion on university emergencies

The evolution of network public opinion on university emergencies is closely related to the interactions between the psychological, social, and new media fields. Based on the constructed

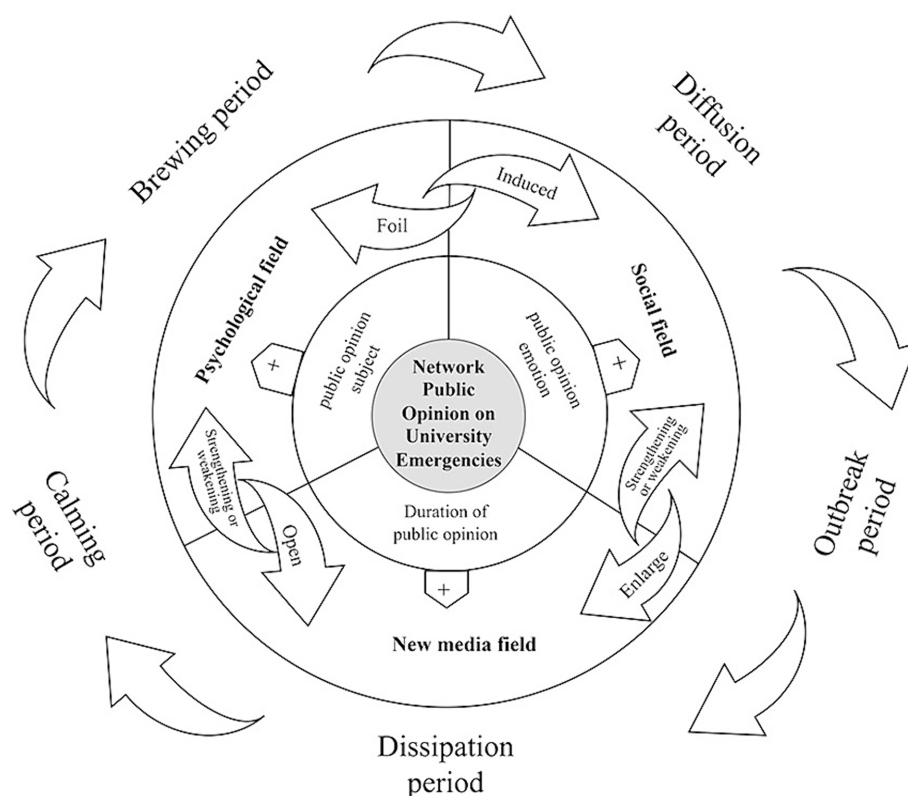


FIGURE 11
Network public opinion field model of university emergencies.

network public opinion field model of university emergencies, this study clarifies the underlying causes from the perspective of the public opinion lifecycle. The different periods of network public opinion on university emergencies are dominated by specific fields, as shown in Figure 12.

The brewing period is dominated by the psychological field when public opinion has a certain degree of concealment and inducement. The diffusion period is dominated by the social field when the interaction and risk diffusion of public opinion intensify. The outbreak period is dominated by the psychological, social, and new media fields, and the impact index of public opinion reaches its peak at this time. The dissipation period is dominated by the new media field when the direction of the force of the new media field determines the duration of public opinion. The calming period is not dominated by any field, and the whole network public opinion field gradually withdraws from the network environment.

The causes of network public opinion on university emergencies at various periods are explained below.

(1) Brewing period

During the brewing period, network public opinion on university emergencies is mainly concentrated within the university. The analysis results of subjects' public opinion (Figure 6) show that students are the main group triggering network public opinion on university emergencies. As network public opinion on university emergencies always resonates with university students, it spreads more easily within the university network circles. Therefore, brewing the psychological field is an important basis for transferring

network public opinion from university communication to social communication.

(2) Diffusion period

With the increase in impact index, network public opinion on university emergencies enters the diffusion period and is no longer limited to the university; an increasing number of social netizens begin to pay attention to the progress of public opinion, forming a large-scale "network spectatorship." At this time, communication among netizens begins to show the characteristics of emotional transmission (64). Netizens exhibit distinct emotional tendencies toward different types of network public opinion on university emergencies (Figure 9). These emotions form a specific rendering atmosphere, which, in turn, affects the psychological and new media fields. Therefore, the diffusion of the social field is the accumulation of network public opinion on university emergencies into the outbreak period.

(3) Outbreak period

After the brewing and diffusion periods, network public opinion on university emergencies enters the outbreak period. The psychological and social fields are jointly involved in public opinion through the new media field, and the influx of public opinion and emotion in a short period of time creates a huge "storm of public opinion" (65). It can be argued that the outbreak is the result of all three fields working together.

(4) Dissipation period

When the network public opinion on university emergencies enters the dissipation period, the new media field dominates. The

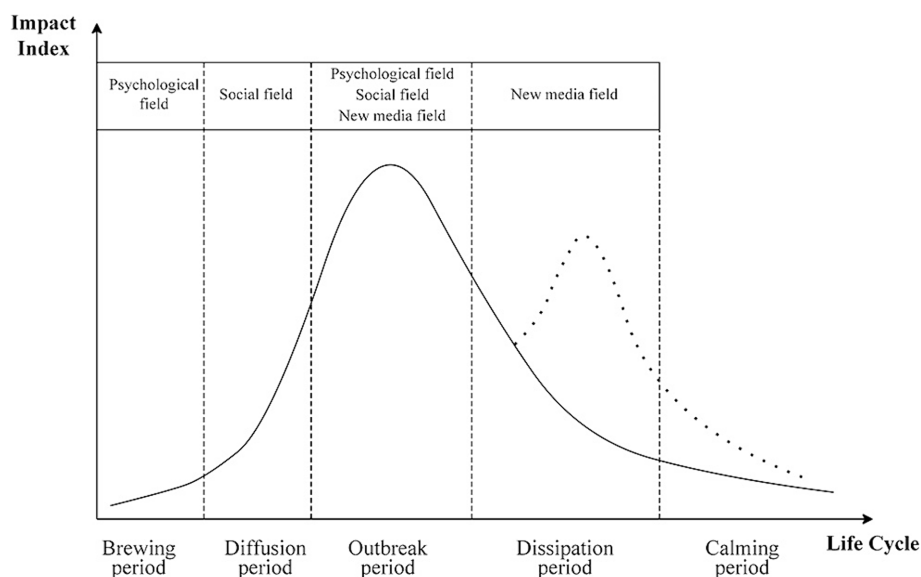


FIGURE 12
Dominant fields at different periods of network public opinion on university emergencies.

management department employs stringent measures to regulate and steer network public opinion on university emergencies and constrain the participants' communication behavior in the psychological field. This leads to a gradual return of rationality in the emotional landscape of the social field, resulting in a sustained decline in the impact index of public opinion. Figure 9 shows the rapid quelling of public emotion during the dissipation period due to the positive public response and joint governance efforts of various departments. Conversely, if management fails to provide appropriate guidance, the decline in public opinion influence index will turn upward. This will induce a wider range of public opinion risks, produce a secondary public opinion crisis, and prolong the duration of public opinion. As shown in Figure 8, the impact index of public opinion on public services, mental health, and teacher–student safety peaked during the dissipation period. This implies that these three types of public opinion have a secondary public opinion in the dissipation period, which lengthens the duration of public opinion. Therefore, the dissipation period is critical for the governance of network public opinion on university emergencies.

(5) Calming period

In the calming period, public opinion is rarely mentioned. The psychological, social, and new media fields gradually return to an independent state, and the entire public opinion field withdraws from public view.

4.3 Governance strategies of network public opinion on university emergencies

Through an analysis of the causes, this study combines the evolution cycle of network public opinion on university emergencies to formulate governance strategies at three levels: public opinion

prevention and management, in-process public opinion detection and control, and post-public opinion monitoring and evaluation.

(1) Public opinion prevention and management

Based on the results of the data analysis, this study formulates prevention and governance strategies for network public opinion on university emergencies from the aspects of subject, type, and time. First, the subjects of network public opinion on university emergencies include students, teachers, and universities. The ability to respond to public opinion should be improved according to the characteristics of the different subjects. For example, students have active minds but lack social experience; therefore, it is necessary to strengthen the ideological construction of this group (66). Teachers are under pressure and easily exhausted; therefore, it is necessary to strengthen psychological interventions for this group (67). As administrators, universities should actively enhance their sense of responsibility to realize the safe dissemination of network public opinion on university emergencies (68). Second, the analysis and early warning should be strengthened for network public opinion on the high-incidence categories (mental health and teacher–student safety) during high-incidence periods (July and December). Moreover, university management strategies should be optimized to prevent the emergence of network public opinion on university emergencies.

(2) In-process public opinion detection and control

During the brewing period, network public opinion on university emergencies is dominated by the psychological field, which is the best period for public opinion governance. At this time, public opinion governance should be centered on the university. The subject of governance should grasp the public opinion situation and guide the positive development of public opinion from two aspects. First, identifying the source of alarm and quickly judging the type of network public opinion on university emergencies. Second, analyzing the warning signs. The university community's degree of attention to

network public opinion on university emergencies can be determined using the degree of public opinion topics, degree of dissemination, and interaction rate as main indicators.

During the diffusion period, the network public opinion on university emergencies is dominated by the social field, which is the last period to prevent the outbreak of public opinion. At this time, the governance of public opinion should be conducted mainly by universities and supplemented by social opinion leaders. The governance subject should take hold of the power of public opinion discourse and control its spread in two ways. First, universities should take the initiative to establish a collaborative information dissemination system that encompasses their official website and opinion leaders. This system aims to respond to concerns regarding different types of network public opinion on university emergencies. Second, the governance subject should actively appease public emotions and prevent the large-scale contagion of negative emotions (69).

During the outbreak period, network public opinion on university emergencies is jointly influenced by psychological, social, and new media fields. Hence, multiple subjects should collaborate to conduct public opinion governance, which should control the risk of public opinion and reduce its negative impacts. First, a mechanism for leading public opinion ought to be established. Government-centralized leadership and unified deployment of risk governance for network public opinion on university emergencies are recommended. Furthermore, collaborative governance alliances should be broadened, coordination among key players strengthened, and the responsibilities of all parties involved refined. Second, an online–offline linkage mechanism ought to be built. Online and offline synergistic governance can be realized through the good interaction of multiple governance subjects.

During the dissipation period, network public opinion on university emergencies is dominated by the new media field with a declining impact index. This is a critical period for public opinion governance, when mainstream official media should be considered the center of public opinion governance. The governance subject should consolidate the results of the battle and prevent the occurrence of secondary public opinion crises. First, the implementation of public opinion governance should be emphasized. It is imperative to conduct real-time supervision to ensure the effective implementation of governance results pertaining to network public opinion on university emergencies and, second, emphasize positive opinion guidance, expand applications of communication tools, enhance public engagement, and steer network discourse on university emergencies positively.

(3) Post-public opinion monitoring and evaluation

During the calming period, the impact index of network public opinion on university emergencies tends to approach zero. At this time, the aftermath of public opinion should have universities at the center (70). First, post-evaluation work should be strengthened. Universities should organize the post-evaluation work of public opinion in a timely manner to learn from the experience. This is conducive to checking and mending the emergency response mechanism for network public opinion on university emergencies. Second, the positive publicity of universities should be strengthened. Universities should prioritize the establishment of ideological

fortifications, cultivating a favorable image of themselves through the meticulous development of campus culture.

5 Method comparison

5.1 Comparative analysis of research methods

This study used three core methods to analyze the causes and governance strategies of network public opinion on university emergencies: data analysis, quantitative analysis, and theoretical inference. To gain a deeper understanding of the application value of these methods, this study compares them with the methods used in recent relevant studies.

(1) Data analysis versus empirical analysis. In the realm of social sciences, the majority of extant research predominantly employs empirical analysis to verify or reveal the correlations among social phenomena. For example, Ren utilizes the COVID-19 epidemic as an empirical case to validate hypotheses by observing public opinion evolution and analyzing interactions among communication elements (27). However, empirical analysis methods face challenges in excluding all confounding variables and factors, hindering causal relationship confirmation. Hence, this study adopts statistical, comparative, clustering, intersection, correlation, and other data analytical methods to systematically analyze the relevant public opinion data collected and processed from the Zhiwei Data Sharing Platform. Based on these data-driven methods, this study was able to further subdivide the types of network public opinion on university emergencies and discover the patterns in terms of time, subject, and emotion. Compared with the prior studies, this study can better grasp the interaction relationship between variables of public opinion elements.

(2) Quantitative analysis versus qualitative analysis. Most existing studies of network public opinion mainly use qualitative analysis to identify key factors and construct conceptual models. For example, Yang constructs a framework of factors for the emergence of network public opinion by qualitatively categorizing the comments (18). However, the results of qualitative analysis are inevitably limited by a series of assumptions and subjective emotions in practice, and different researchers may have different interpretations of the same phenomenon. Hence, this study uses visual quantitative analysis methods such as mathematics and statistics to visualize the data results through graphs and other means. These quantitative analysis methods further verified the existence of a distinct correlation among various elements of network public opinion, thereby providing a data basis for the subsequent construction of the network public opinion field of university emergencies. Compared with qualitative research, this study emphasizes numerical data and the results of the analysis are more objective and generalizable.

(3) Integration of multiple methods versus a single research method. In existing research on network public opinion on university emergencies, the application of a single research method is prevalent. For example, Ye only studied the influencing factors of college students' willingness to spread network public opinion through quantitative analysis methods such as questionnaires (3). However, a single research method is insufficient to meet the increasingly convergent and interdisciplinary demands, limiting researchers' ability to fully

understand and address complex issues. Hence, this study adopts a research paradigm that combines data-driven with theoretically oriented. Data from the Zhiwei Data Sharing Platform are quantitatively analyzed to extract public opinion trends, which are then interpreted using the theory of network public opinion field to deduce causes. Compared to a single research method, the integration of multiple methods enhances the scientific, innovative, and comprehensive nature of research results.

5.2 Advantages of the proposed methods

Through the comparative analysis above, the characteristics and advantages of the method utilized by this study can be summarized to highlight the academic contributions of this study.

First, the application of the Zhiwei Data Sharing Platform makes it possible to analyze the data in a more in-depth way to explore the potential value of the data. The Zhiwei Data Sharing Platform uses big data analysis technology, offering real-time, high-accuracy data. This study collects network public opinion data on university emergencies from the Zhiwei Data Sharing Platform, which helps to better explore the patterns and correlations among the types of public opinion, subjects, and time and space. This lays the foundation for subsequent analysis of public opinion evolution laws and trends.

Second, accurately quantify the relationship between public opinion data and make the research results easy to understand through intuitive graphics. Throughout the various stages of data collection, processing, and analysis, quantitative analysis methods are employed to ensure the accuracy and objectivity of our findings. Additionally, this study visualizes public opinion analysis through charts and images, simplifying complex data for intuitive understanding and enabling deeper research.

Third, the combination of data-driven and theoretically oriented makes the research results more comprehensive and systematic. This study is data-driven by visualizing and analyzing the network public opinion data of 204 cases of university emergencies. It is also theoretically-oriented, using the theory of the network public opinion field to facilitate the construction of the network public opinion field of university emergencies. The combined method of data-driven and theory-oriented analysis integrates theory and practice, facilitating the explanation, prediction, and analysis of the causes of network public opinion on university emergencies.

6 Conclusion and implications

This study constructs a network public opinion field model of university emergencies based on visual analysis and the theory of the network public opinion field. Using the model as a foundation, it explores the causes of network public opinion on university emergencies and proposes corresponding governance.

6.1 Theoretical implications

First, this study further subdivided network public opinion on university emergencies. Few studies have classified network public opinion on university emergencies. Based on real cases and related studies, this study classified network public opinion on university

emergencies into six types. It further confirmed that different types of network public opinion on university emergencies differ in terms of the occurrence, time of dissemination, impact index, and emotion of public opinion dissemination. The visualization results show that mental health and teacher–student safety are the most common types of network public opinion on university emergencies (83.3%). The emotional tendency expressed by the public is influenced by the type of public opinion and generally tends to be negative; 90.20% of the public opinions last for less than 19 days, and their influence ranges from 40 to 80.

Second, this study developed a network public opinion field model of university emergencies to elaborate the interactive relationship between the public opinion elements in the network field. From the perspective of the theory of the network public opinion field, the proposed network public opinion field model of university emergencies consists of subfields with different characteristics and operating rules. For the psychological field, public universities (88.24%) and students (48%) are important subjects of network public opinion on university emergencies, implicitly mirroring the underlying social structure and relationships shaping public opinion. In the social field, different kinds of university emergencies form a consensus of network public opinion within a certain social scope, leading to the spread of certain emotional tendencies (Figure 9). For the new media field, media technology, and communication channels affect the fluidity of public opinion information, with greater fluidity correlating to longer opinion durations.

Third, from the perspective of the entire lifecycle, this study comprehensively analyzed the causes and governance strategies of network public opinion on university emergencies. This study finds that the development of network public opinion on university emergencies conforms to the lifecycle theory, which contains five periods: brewing, diffusion, outbreak, dissipation, and calming. Most of the existing literature has focused on the impact of individual factors on the evolution of network public opinion on university emergencies. In contrast, this study provided a comprehensive analysis of the causes and trends in each period of public opinion development, enabling the development of tailored public opinion governance strategies for each period.

6.2 Practical implications

First, the university is the key subject in the governance of network public opinion on university emergencies. The network public opinion on university emergencies exhibits certain regularity. Therefore, universities should accurately grasp the key elements in the formation of university emergency network public opinion. In light of the high-incidence types and periods of network public opinion on university emergencies, it is imperative to establish an effective emergency response system. In addition, university administrators should uphold the principle of people-oriented public opinion guidance and emphasize students' subjectivity. Therefore, ideological education activities should be conducted regularly to improve students' fundamental network literacy.

Second, period-based governance helps improve the governance efficiency of network public opinion on university emergencies. The results of this study show that network public opinion on university emergencies presents different characteristics in each period. During the

brewing period, the scope of public opinion is limited to within the university, and this is an important node for effectively containing its spread. During the diffusion period, potential secondary public opinion is a significant factor influencing the duration of public opinion. Preventing the occurrence of such phenomena is crucial for governance at this period. The calming period signifies a marked decrease or complete cessation of public opinion activities, serving as a symbolic node of the disappearance of public opinion. Formulating reasonable governance strategies based on period characteristics is conducive to prescribing the right remedy and controlling the spread of public opinion risks.

Third, building a pattern of collaborative governance by multiple subjects is necessary for governing network public opinion on university emergencies. Synthesizing this study reveals that the formation of network public opinion on university emergencies involves university groups, social netizens, social media, and other subjects. Different subjects play a corresponding role in promoting the evolution of public opinion. Therefore, it is necessary to not only highlight the joint participation of multiple subjects but also strengthen the subjects' collaborative governance ability.

6.3 Limitations and future directions

In this study, only the Zhiwei Data Sharing Platform was used as the data source, which resulted in insufficient sample diversity. Further evidence is required to support the interaction between fields within the network public opinion field of university emergencies. In the future, different regions and levels of network public opinion on university emergencies will be selected to conduct extended research and realize the deep integration of theory and practice.

Data availability statement

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

Author contributions

XG: Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Supervision,

Writing – original draft, Writing – review & editing. ZL: Data curation, Formal analysis, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. KZ: Data curation, Methodology, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. CB: Data curation, Methodology, 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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A novel application of lemmatize and thematic analysis to understand protective measures perspectives of patients with chronic respiratory disease during the first outbreak of COVID-19 pandemic: a qualitative study

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Objective: To describe the perspectives of a group of COPD patients during the first outbreak of the COVID-19 pandemic and narrate the emotions and polarity (acceptance-rejection) regarding living with COPD during the pandemic.

Design/methods: We used a novel application of lemmatization and thematic analysis of participants' narratives. A study was carried out with eight patients with moderate–severe–very severe COPD during the first outbreak of COVID-19 using purposive sampling. In-depth interviews and field notes from the researchers were used to collect data. A statistical content analysis (lemmatization) of the patients' narratives was performed. Additionally, inductive thematic analysis was used to identify emerging themes. This study was conducted following the guidelines of Consolidated Criteria/Standards for Reporting Qualitative Research. The study was conducted in accordance with the principles articulated in the WMA Declaration of Helsinki. Participants provided verbal informed consent prior to their inclusion as previously described.

Results: The average age of our sample was 65 years, and 75% of the patients suffered from moderate COPD, 12.5% from severe COPD, and 12.5% from very severe COPD according to GOLD criteria. The lemmatized and sentiment analysis showed a predominance of positive emotions, and the polarity of the interviews

indicated a very slight positive trend towards acceptance of the experience lived during the pandemic. Additionally, three main themes were identified: (1) Confinement and restriction measures, (2) COVID-19 and protective measures, and (3) Clinical care during the first outbreak of the pandemic.

Conclusion: Patients experienced confinement with a feeling of security and protection. They strictly respect social distancing. They used masks, but these caused them to feel short of breath and fatigue, especially FFP2 masks. Half of the patients rejected the possibility of being vaccinated. Finally, they were very satisfied with the clinical care they received in the COPD unit of their hospital. Our results show that COPD patients have not experienced a negative impact of the COVID-19 pandemic.

KEYWORDS

chronic obstructive pulmonary disease, COVID-19, SARS-CoV-2, life change events, life course perspective, qualitative research

1 Introduction

To date, patients with chronic obstructive pulmonary disease (COPD) have a fourfold increased risk of developing severe forms (1) and are more likely to be affected by COVID-19 (2). Patients with COPD are known to be more susceptible to respiratory viral infection and virus-induced exacerbations caused by influenza, rhinovirus, and seasonal coronaviruses (3, 4). The incidence of hospitalization and severity of illness in patients with COPD are much higher in patients with COVID-19 than in those with seasonal influenza (5). Awatade et al. (3) in their systematic review show that people with COPD do not have a higher prevalence of hospital admission. Therefore, this could indicate that there is no increased susceptibility to SARS-CoV-2 infection or it may reflect a change in community behavior – which benefits from social isolation. Also the implementation of infection control measures during the COVID-19 pandemic has reduced the number of respiratory infections, which is the most common cause of COPD exacerbations (6).

Despite this, studies show that the number of COPD patients admitted at hospital for SARS-CoV-2 infection ranges from 2 to 7.7% and in intensive care units, this prevalence does not exceed 5% (7, 8). These results may be due to the protective effect of inhaled drugs, due to the underdiagnosis of COPD, which reaches 74.7% in Spain (9), and the strict compliance with isolation measures (10). The “lockdown” that the worldwide population has been forced to endure during the first COVID-19 outbreak has led to the emergence of a situation of psychosocial instability that may have worsened due to the mass quarantine (11). These aspects have several consequences in the natural history of the patient’s disease, with high psychiatric morbidities such as depression and anxiety.

Therefore, efforts should be made to maintain a situation of low clinical impact over time in individuals with COPD, since clinical management in COPD is an integrative, dynamic and useful tool (12) where the patient’s perception is key to their treatment. In Italy, feelings of terror, fear and/or apprehension were reported in 58.22% of COPD patients during the first months of the pandemic (13). The result of COPD patients suffering from COVID-19 is that the patient reports increased shortness of breath and worse quality of life and

sleep, combined with mood disturbances. However, previous studies had shown how the “lockdown” and confinement had a low impact on COPD patients, albeit many clinical consultations and tests were cancelled, patients were very satisfied with the telephonic care provided (14).

During the COVID-19 pandemic it has been shown how COPD patients experienced an increase in their feeling of fragility (15) and, faced with the fear of becoming infected and dying (6), patients adopted restrictive protective measures (16, 17), by changing their perception of risk (17). As a consequence, there was an increase in protective measures against contagion, but also a decrease in social contact and isolation in their homes (10, 16, 17). New technologies and virtual platforms and chats helped to maintain contact with professionals and continue with COPD treatment (18, 19).

Therefore, the aims of this study were: (a) to describe the perspectives of a group of Spanish patients with COPD during the first outbreak of Covid-19 pandemic regarding confinement, restrictive measures, protective strategies adopted, and clinical care during the pandemic, and (b) to narrate the emotions and polarity (acceptance-rejection) of their perspectives regarding living with COPD during the pandemic applying a novel lemmatized and thematic analysis of participants’ narratives.

2 Materials and methods

2.1 Design

A qualitative descriptive case study was conducted (20) based on constructivist paradigm (21). Case study is a research proposal that explores or describes a single case bounded in time and place (e.g., individuals in pandemic period). Also, case studies are suitable for answering how and why research questions or can be used to describe patient perspectives or experiences regarding care (22, 23). The Consolidated Criteria for Reporting Qualitative Research (24) (Supplementary Table S1) and the Standards for Reporting Qualitative Research guidelines (25) (Supplementary Table S2) were used. Qualitative studies have been used to research the barriers and

facilitators to COPD rehabilitation, the expectations before and after COPD treatment and the use of technology to follow-up COPD treatment (26–28).

Seven researchers (two women), including one pulmonary and lung specialist doctor, three nurses, two physical therapists and one occupational therapist participated in this study, three of whom (DPC, CGB, CFP) had experience in qualitative study designs. Three researchers (DDP, CCM, and DPO) had clinical experience in COPD. Prior to the study, the positioning of the researchers was established according to their previous experience and their motivation.

2.2 Participants and sampling strategies

In this study, a non-probabilistic, purposeful sampling strategy was used based on relevance to the research question rather than representativeness (29). Participants were recruited from the high complexity COPD unit of the Complejo Hospitalario Universitario de Canarias belonging to the CHAIN (COPD History Assessment in Spain) cohort (30).

The inclusion criteria were: (a) Patients >18 years of age, (b) diagnosed with COPD of at least 12 months of evolution according to the GesEPOC criteria (31), presenting a moderate (GOLD 2)—severe (GOLD 3) -very severe (GOLD 4) stage according to the Global Initiative for Chronic Obstructive Lung Disease (GOLD) criteria (32); an FEV1/FVC ratio of less than 0.7 after bronchodilator testing and who also have an airflow obstruction of less than 80% of the theoretical FEV1, and (c) with internet connection and owning a device capable of making video calls. The exclusion criteria were: (a) patients with cognitive impairment, and/or with verbal communication disorders, (b) presenting auditory or verbal sensory disorders preventing proper communication with the interviewer.

In qualitative research, a wide variety of proposals exist for justifying and determining sample size (33, 34). Furthermore, there

is no formula for the prior calculation of the sample size (33, 34). Due to the unavailability of many cases (lockdown), the sample size was determined following Pragmatic Considerations (34), and the Information Power criteria proposed by Malterud et al. (35). In the present study, all available cases were included in order to obtain a greater richness of the data. In such scene, information power indicates that the more information relevant for the current study the sample holds, the lower number of participants is needed (35). The sample size with enough information power (and fewer number of participants) depends on: (a) a specific project objective aimed at the analysis of a phenomenon to be studied (narrow study); (b) the specificity of the sample, with a homogeneous and defined profile of the participants (dense sample); and (c) the application of a specific analysis strategy to specific and defined cases (participants), using different analysis strategies (35). The present study meets the above criteria by having objectives focused on the perspectives of patients with a specific type of disease (COPD), with a certain degree of severity (moderate–severe–very severe), under specific conditions (first outbreak of the COVID-19 pandemic) and using various analysis systems (lemmatization and thematic analysis of the interviews) (36).

2.3 Data collection

Semi-structured interviews including open questions were used to obtain information regarding the issues of interest (29). After collecting professional and personal data from each participant, the broad opening question was: “Please, can you share with me your personal experience during the COVID-19 pandemic?” Open-ended follow-up questions were used to obtain detailed descriptions (Table 1). Additionally, “Please tell me more about that,” was also used to enhance the depth of the discussion of a specific topic. Thereafter, the researchers noted the key words and topics identified in the

TABLE 1 Question guide used for the semi-structured interviews.

Areas of research	Questions
Disease	What is it like to live with moderate/severe COPD? What is more relevant to you? What are your expectations about the disease and its evolution? What was it like living with COPD during the first wave of the COVID-19 pandemic?
Treatment during the COVID-19 pandemic	What is more relevant to you about COPD treatment during the pandemic? Have you made any changes to adapt to the preventive measures against COVID-19?
The COVID-19 pandemic and expectations concerning the patient's health status	How had the pandemic influenced your health status and the evolution of your disease? What has been the most relevant for you? How did you experience the risk of infection with COVID-19? What strategies do you use to avoid infection? How did you experience confinement during the first wave of the pandemic in Spain?
The COVID-19 pandemic and its relationship with health professionals and/or professional help-seeking	How would you describe your relationship with healthcare professionals? How had the COVID-19 pandemic influenced your relationship with healthcare professionals?
The COVID-19 pandemic and barriers and facilitators to professional help-seeking in healthcare facilities	What barriers or facilitators had you perceived during the COVID-19 pandemic to seeking professional help and/or accessing a healthcare facility? What is the most relevant to you?
Confinement during the pandemic	How did you experience the confinement during the pandemic? What was the most relevant for you? How do you think the confinement had influenced your health? Could you describe what your emotions and feelings were during the outbreak?
Family relations	How did the pandemic affect your family life and your relationships with each other?
Vaccine	How do you feel about the vaccine? What barriers or facilitators have you encountered in getting the vaccine?

TABLE 2 Interview procedure using Microsoft Teams (<https://www.microsoft.com/es-ww/microsoft-teams/log-in>).

At the prearranged date and time, the participant and researcher both clicked on the Microsoft Teams link and entered into the private video chat room.
The interview involved the researcher first sharing the screen with the participant and reviewing an informed consent form together, reading and ensuring participant comprehension.
After verbal consent to participate was provided, all participants were offered an email copy of the consent form.
The researcher asked for participants' permissions for recording the interview in both video and audio, and after confirming the participant's consent, the researcher turned on the recording. If a participant declined to record the video, only audio was recorded.
The researcher opened the semi-structured interview guide (in Microsoft Word document) on his/her computer and started the interview.
The researcher asked participants to describe their experiences, perspectives and feelings during the COVID-19 outbreak, to obtain a better understanding of how their unique situation may affect their comprehension or interpretation of its interview.
During the interview, the researcher took notes on the participant's responses. At the end of the interview, and when the patient's considered it suitable, the audio/video recording was stopped.

patients' responses and used their answers to ask further questions and to clarify the content (29).

Due to the lockdown situation for flattening the COVID-19 curve established by the Spanish Government on 14th March 2020 interviews were conducted in a private video chat room using the Microsoft Teams videoconference platform¹ (37). Each participant received a private/personalized email with an invitation. Table 2 shows the specific procedure followed for the interviews using zoom platform.

All interviews were audio- and video-recorded after oral permission was granted by the participants, in order to access non-verbal cues such as eye contact, facial expressions or body motions, which are unique data resources for qualitative studies. Videorecording enabled the collection as much non-verbal information as possible, which could enrich the descriptions of participants' experiences. All interviews were transcribed verbatim, recording a total of 427 min of interviews over-all (average of 53.37, SD 10 min). The interviews were managed by CGB, DPO, and JNCZ.

Furthermore, field notes were collected by the researchers during the semi-structured interviews since they provide a rich source of information as participants describe their personal experiences, their behaviors during data collection, and enable researchers to note their reflections concerning methodological aspects of the data collection (36).

Sociodemographic data were collected from the participants (age, sex, whether they were an active smoker, marital status, job, and who they lived with) and data from the Chronic Obstructive Pulmonary Disease Assessment Test-CAT scale (38), and the BODE index (39). The COPD Assessment Test o CAT, assessing the impact of COPD on health status, is a short and simple instrument consisting of eight items covering disease symptoms and restricted activity (38). Also, the BODE Index is a multidimensional scoring system that has been developed as a prognostic marker for COPD patients and integrates the respiratory and the systemic expressions of COPD. It is composed of body mass (B), degree of airflow obstruction (O), level of functional dyspnea (D) and exercise capacity (E) (40). Confidentiality was assured by consecutively numbering each interview and removing identifying information from the transcripts. All audio recordings and

transcripts were saved on a password-protected computer with restricted access only by the researchers.

2.4 Analysis

The interviews were analyzed by means of a lemmatize textual content analysis of the participants' words and narratives (41), and an inductive thematic analysis for the identification of the relevant themes obtained from the interviews (29, 36).

From the lemmatize textual content analysis we obtained: (a) a cloud of the most used words, and (b) an identification of the feelings of the participants and the polarity (acceptance or rejection) of their narratives. The use of lemmatize textual content analysis in interviews and written texts through statistical techniques is used in discourse analysis and qualitative studies as a method of deepening and triangulating the analysis (36). Also, the statistical analysis of narratives and transcribed interview texts in qualitative studies has been previously used in studies on understanding COPD disease through patient narratives (42), analysis of electronic health records (43), and death in intensive care unit (44).

2.4.1 Lemmatize textual content analysis

For the lemmatize textual statistical analysis of the qualitative content (36), the software R version 3.5.1 (R Foundation for Statistical Computing, Institute for Statistics and Mathematics, Welthandelsplatz 1, 1020 Vienna, Austria) was used. The text of the interviews was lemmatised for analysis. A word frequency analysis was carried out using the tf-idf algorithm (term frequency—inverse document frequency), and a word-cloud, representing the most frequent use of words within the participants' interviews, was obtained. Emotion analysis was performed using Bing (45), Afinn (46) and National Research Council Canada (NRC) dictionaries (41, 47). Text polarity was analyzed, using the SODictionaries V1.11Spa dictionary as amplifiers and decrementators, the Bing dictionary (45), and as deniers, those proposed by Vilares et al. (48). For the analysis of polarity (acceptance-rejection) four stages were used. In the first stage, a file was created with the text from the interviews, broken down by sentences for textual analysis. In the second stage, polarity was calculated using the Bing Sentiment Dictionary, amplifiers and de-amplifiers of SODictionar-iesV1.11Spa (41, 47) and the deniers proposed by Vilares et al. (48) (Supplementary Table S3). In the third stage, the scatter diagram of the sentences in the text in relation to

1 <https://www.microsoft.com/es-ww/microsoft-teams/group-chat-software>

neutrality was calculated to identify positive or negative tendencies. Finally, the evolution of emotional valence (positive–negative) was shown throughout the interviews. Fourier transformation was applied to confirm the polarity trend.

2.4.2 Thematic analysis

Full transcripts were made of each semi-structured interview and of the researchers' field notes. Inductive analysis (36) consisted of identifying text fragments with relevant information to answer the research question. From these narratives, the most descriptive contents (codes) were identified. Subsequently, these units were grouped by their common meaning (categories) and/or similar content. Thematic analysis was applied separately to interviews and field notes by DPC, CGB, and CFP. Joint team meetings were held to combine the results of the analysis and discuss data collection and analysis procedures. In these team meetings, the final themes were displayed, combined, integrated and identified. In case of divergence of opinions, the identification of the theme was based on consensus among the members of the research team. Finally, three themes were identified (Figure 1).

2.5 Rigor and trustworthiness

We used criteria by Guba and Lincoln for establishing trustworthiness of the data (29). Table 3 summarizes the procedures used to enhance trustworthiness.

2.6 Ethical considerations

This study was approved by the Clinical Research Ethics Committee of the Complejo Hospitalario Universitario de Canarias (Canary Islands

Health Service, Spain; code: CHUNSC_2020_79-October 15, 2020). The study was conducted in accordance with the principles articulated in the WMA Declaration of Helsinki. Participants provided verbal informed consent prior to their inclusion as previously described.

3 Results

The sample of the present study consisted of eight patients with COPD (five women) with a mean age of 65.12 years (SD 6.87). Six patients had moderate COPD, one had severe COPD, and one had very severe COPD. Two participants continued to smoke (P1 and P7), the number of packs of tobacco per year that they continued to consume were 45, and 35, respectively for P1 and P7. The characteristics of the participants are shown in Table 4.

3.1 Results of lemmatized textual content analysis

The word cloud showed how cough, school and phlegm are the most repeated followed by to eat, blow, breathe, and blood (Figure 2). The sentiment analysis showed a predominance of positive emotions (Figure 3) from NRC (Figure 3A), and Bing (Figure 3B) dictionaries sentiment scores. In the case of the AFINN dictionary there is a predominance of negative emotions, especially scores -1 and -2 against positive scores of 1 (Figure 3C). The associated emotions are those of fear and sadness, followed by trust and emotions of anticipation (Figure 3A).

The polarity of the interviews is 0.01 ± 0.421 which indicates a very slight positive trend towards positive emotions due to the presence of some more extreme positive values (Figure 4).

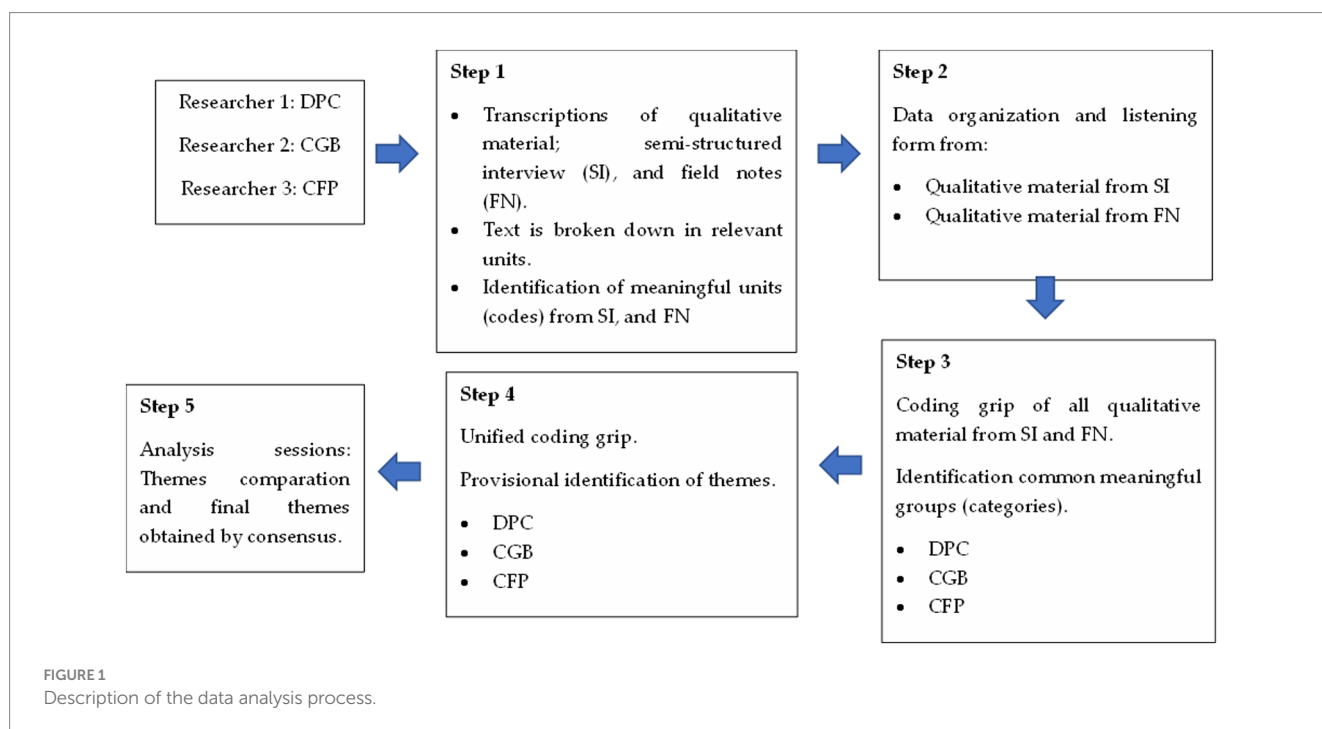


TABLE 3 Trustworthiness techniques.

Criteria	Techniques performed and application procedures
Credibility ¹	Investigator triangulation: each interview was analyzed by three researchers. Thereafter, team meetings were performed in which the analyses were compared, and themes were identified.
	Triangulation of data collection methods: semi-structured interviews were conducted and researcher field notes were kept.
	Triangulation of analysis methods: inductive thematic analysis and content analysis of narratives were used.
	Member checking: this consisted of asking the participants to confirm the data obtained during the data collection.
Transferability ²	In-depth descriptions of the study were performed, providing details of the characteristics of researchers, participants, contexts, sampling strategies, and the data collection and analysis procedures.
Dependability ³	Audit by an external researcher: an external researcher assessed the study research protocol, focusing on aspects concerning the methods applied and study design.
Confirmability ⁴	Investigator triangulation, data collection and analysis triangulation.
	Researcher reflexivity was encouraged via the completion of reflexive reports and by describing the rationale for the study.

¹Credibility confidence in the truth of the findings.
²Transferability reporting that the findings have applicability in other contexts.
³Dependability reporting that the findings are consistent and could be repeated.
⁴Confirmability the degree to which findings are determined by the respondents and not by the biases, motivations, and interests of researchers (29).

TABLE 4 Sociodemographic and clinical features of patients.

Patients	Age	Sex	CAT scale ¹	BODE index	Active smoker	Civil status	Work status	Living with
P1	71	Female	13	1	Yes	Divorced	Permanent incapacity for work	Lives with relatives
P2	67	Female	13	6	No	Married	House wife	Lives with partner
P3	74	Male	9	0	No	Married	Retired	Lives with partner
P4	71	Male	1	0	No	Married	Retired	Lives with partner
P5	62	Male	4	0	No	Divorced	Retired	Lives with partner
P6	55	Female	8	2	No	Divorced	Actively working	Lives with partner
P7	64	Female	11	1	Yes	Divorced	Actively working	Lives alone
P8	57	Female	15	7	No	Divorced	Sick leave. Inability to work/ study	Lives alone

¹CAT: COPD (chronic obstructive pulmonary disease) assessment test.

3.2 Results of the thematic analysis

Three main themes were identified: (1) Confinement and restrictive measures, (2) COVID-19 and protective measures, and (3) Clinical care during first pandemic out-break. Participants’ narratives, extracted directly from interviews, described each identified theme.

3.2.1 Theme 1: confinement and restrictive measures

All participants reported that the confinement did not affect their daily life or their disease. Most participants reported that before the pandemic, COPD already caused symptoms (fatigue, shortness of breath) that limited their activity, and they had to modify their habits to a greater or lesser degree. They adapted their lives to remain at home most of the day. Thus, the confinement did not entail a substantial change in their life routine:

“Throughout all the pandemic, I was at home, I was doing my business and I have not noticed any change. I have a bed,

I have a fridge, I have a computer and I spend the day there” (P2).

All the participants reported that during the pandemic they limited their trips out of the house and the time they spent outdoors. They were more wary of going out and when they did, they complied with all the protective measures, masks, hand hygiene, and social distancing.

In addition, most participants described how they endured the confinement with positive feelings, perceiving it as a protective measure, as they were more at-risk, they felt more protected and safer:

“I saw it as protection for me. I had no bad feelings. It’s true that there were moments of anguish for not being able to go out at any time, but I did not have bad feelings. My feelings were more positive than negative. At the end, confinement, for people with my disease, was a protective measure. That was how I experienced it” (P6).

Indeed, some participants described that the pandemic has heightened their awareness and concern about the evolution of COPD, and the need to follow clinical recommendations. In the case of participant 8, the confinement even helped her COPD:

“During the confinement I improved. I was able to train and exercise gently and progressively every day. Before the pandemic I had 24% lung capacity, and I finished the confinement with 37.7% lung capacity” (P8).

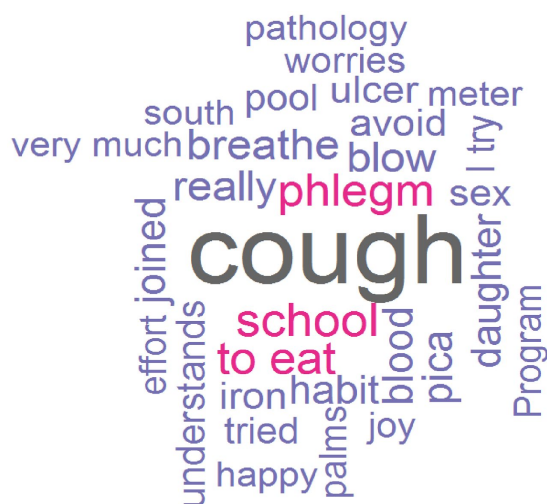


FIGURE 2
Word cloud.

The participants reported that the pandemic did not trigger conflicts in their relationships with their families and partners. On the contrary, it made the family more protective, more vigilant and closer. This resulted in them carrying out all those tasks that could be a risk of contagion for the patient (going shopping, going to the pharmacy, etc.). Moreover, the family decreased the frequency of visits, and the number of people visiting the patients:

“I’ll give you an example of how some things have changed. On Christmas Eve we used to gather up to 50 people at my house for dinner and now my wife and I have dinner alone. The whole family agrees, they all protect us...” (P3).

The participants referred that their social relationships have changed. They have become more distant. One participant recounted how she perceives more distance and feels lonely, even when going to the doctor:

“Above all, the change has been the feeling of loneliness. Before COVID-19, when you went to the doctor, you were always talking to people, everyone was sitting around talking to someone. Now no one talks to anyone, you go into the health center and wait, you are really on your own, with your illness” (P2).

Some participants described how the pandemic has changed their relationship with the society, with people, but has not changed their life or way of living with COPD.

“With the pandemic, what has changed the most in me is my relationship with other people. My way of living my life remains

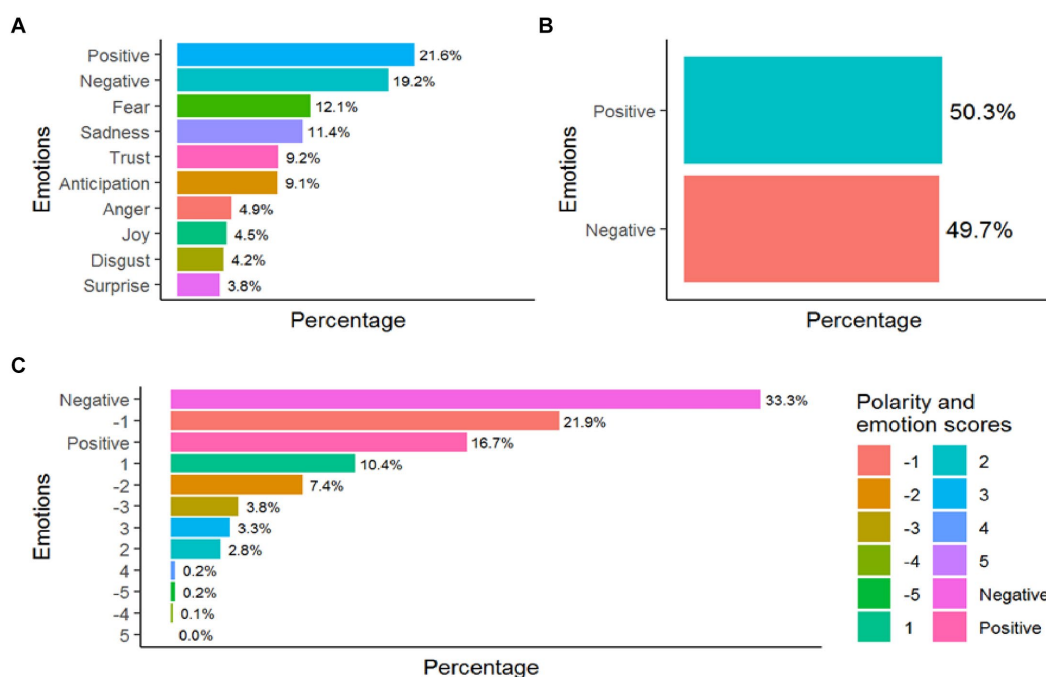


FIGURE 3
Sentiment analysis (A) from NRC dictionary, (B) from Bing dictionary, and (C) from Afinn dictionary.

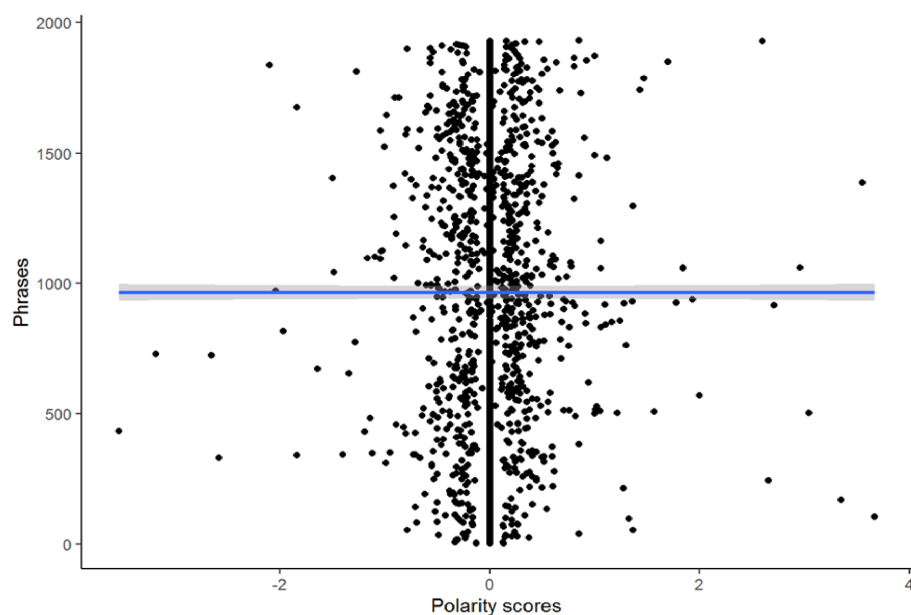


FIGURE 4
Polarity analysis.

the same, with my illness. But with people it is different, more distant, socially distant" (P4).

3.2.2 Theme 2: COVID-19 and protective measures

Some participants reported feeling like a target, as they are more vulnerable to COVID-19 and being considered at risk. This feeling was continuous and was generated from different sources, i.e., the media, family, health professionals, etc.

All participants except one (P4) reported being afraid. Fear of contagion, fear of being vulnerable, fear of their COPD and/or their lungs getting worse because COVID-19, fear of getting sick and not having the opportunity to say goodbye to their family, fear of intubation and being admitted into the ICU. Some patients reported that their fear was due to having COPD. If they were not at so much risk of dying because of their COPD they would not be afraid:

"If I did not have COPD, I would not be so afraid, I would, but it would not be like it is now. Having COPD is one more thing that means that if I get COVID-19, it will harm me more and I would have a higher risk of die. I have an affected lung and if I get COVID-19 I have a greater risk of dying. That's what I fear" (P3).

Participants described how they avoided seeking clinical help and going to the primary care center, because despite the online appointment-based care systems, at the health center there were many people together, without social distancing, waiting to be seen in the same room. Another measure they adopted was to stay at home, avoid going out, if they went for a walk, they would cross to a side of the

street that was empty, avoid crowds, and above all avoid approaching and encountering people. They recounted how the use of gloves, hydroalcoholic gel, and face masks intensified as the pandemic progressed.

"I came to avoid going to the medical center when I felt bad or that I was breathing worse. There you were with many people who did not follow the rules and the feeling of risk of contagion was very strong. "I even changed sidewalk on the street, trying to be alone, with no one around" (P3).

In relation to masks, only one participant reported that they adapted without difficulty (P4). The rest of the participants confirmed that the use of face masks made them more tired, experiencing greater fatigue when walking, feelings of breathlessness and shortness of breath:

"I am uncomfortable. It's a mask, which prevents me from breathing, because of my COPD, I breathe even worse, and I feel even more breathless. So, I must take it off" (P2).

They had the feeling that they are in a prison, they noticed that the air they breathe is not "pure," experiencing feelings of choking and suffocating. One of the participants even described how, due to the use of the face mask, their COPD can worsen due to the fact that they are continuously breathing air that was high in CO₂:

"I left my house without a face mask. I hate it, it's something that's harming me. If I have COPD, I'm swallowing the same air that I'm expelling. I think that hurts me, because the air is not purified, all the carbon dioxide goes inside. And so that is suffocating me a lot" (P3).

Participants noted that the face mask that most accentuates these sensations is the FFP2 mask (equivalent to other international standards known as N95, KN95 and P2 masks). They were aware that it is the face mask that protects them the most, yet, it is the one that makes them feel the most distressed when they go out. Conversely, they explained that this sensation of suffocation and fatigue decreases with the surgical mask:

“When I go to a closed place and I must put on the FFP2, I get anxious, I have a terrible time, I have to stop every three steps to breathe and lower the face mask. With the surgical mask, it's more bearable, at least you can breathe better, you don't get tired so much, it filters the air more” (P2).

Most participants reported that they usually need to lower or remove the mask to continue walking. They end up with accelerated breathing and pulsations due to the effort:

“I can wear the mask, but with enormous effort and I arrive with my breathing totally accelerated and my heart beating at full speed [makes the sound and gesture of beating]” (P6).

Regarding the use of vaccines, half of the participants were in favor of their use, but the other half rejected them. The reasons they gave for not wishing to be vaccinated were distrust of their rapid development, distrust of the pharmaceutical industry, and lack of experience. They pointed out that the use of information about the vaccine and the organization of vaccination programs by politicians has not helped. Among the participants who did not accept the vaccine, some were likely to change their minds once time has passed and the vaccine has been tested first in other people, and it is confirmed that there are no significant risks or negative effects. The theory used to justify their refusal to vaccination is based on beliefs of how COVID-19 affects the lung, if the vaccine contains part of the virus, people with COPD should not get the vaccine as there would be more risk of that part of the vaccine virus attacking their already damaged lungs:

“The vaccine can affect my lung, just like COPD. If I am going to treat a lung disease and the virus attacks the lung, and they are going to give me a vaccine to make it easier for the virus to go to the lung... Then, farewell... I wouldn't get vaccinated even with a gun to my head” (P3).

All participants, those who were likely to accept or refuse vaccination against COVID-19, justified their decision using the flu vaccine as a comparison. Thus, those who accepted the vaccine stated that the COVID-19 vaccine is much like the flu vaccine, considering that it is safe and should be given periodically in people at higher risk of complications, such as COPD patients. Meanwhile, those who rejected it argued that the COVID-19 vaccine is unlike the flu vaccine, stating (from their perspective) that the vaccine introduces the virus and goes straight to the lung, whereas the flu vaccine does not attack the lung and is safer. Both groups of participants accepted the flu vaccine.

“The flu vaccine is different. It has been tested for a long time, and it is safe. In addition, the virus does not get inside you to attack your lungs. “The flu vaccine protects your entire body” (P4).

3.2.3 Theme 3: clinical care during the first outbreak of the pandemic

Participants described how the main changes they experienced have been in primary care, where access to clinical consultations has become more difficult, due to the suspension of face-to-face care, the delay of appointments, and the implementation of an online appointment request system, and telephone care, which limited participants' face-to-face access to the doctor:

“The first barrier is getting an appointment, everything online, when you get it, it's over the phone, no contact, and in the end if they decide you don't need to be seen you don't get anyone in person to assess you. You assume that what they tell you over the phone will work” (P4).

Subsequently, the physician assesses whether the participants require face-to-face care. However, even when a face-to-face consultation is carried out, the professional distance is maintained. For some of the participants who need to see a primary care physician and wish to be evaluated by a professional, it is a difficult decision because they perceived it as a risk of contagion:

“You want to go to the doctor like before, to have contact, to be touched, to be examined, but on the other hand you are afraid, because of the risk of contagion, it is a closed place, a lot of people waiting, all together” (P1).

In contrast, participants reported that the specialized care provided by the hospital's COPD unit remained the same, with face-to-face consultations, scheduled appointments, and periodic follow-up and monitoring of treatment and the disease as if there were no pandemic:

“As for my COPD, I have not noticed any change in the monitoring they do. Throughout the pandemic they have continued to keep an eye on my tests, on when I have to do the next one, on the control of my disease, on everything. Everything has remained the same with or without a pandemic” (P1).

The participants reported that it makes them feel safe and protected, because there is a group of professionals who, despite the pandemic, are in charge of monitoring the disease and controlling its progress:

“I feel fortunate, because they are taking care of me, whether there is a pandemic or not, they have continued to be there, monitoring me so that my COPD does not continue. I feel very much safeguarded with them, I was afraid that they would stop monitoring COPD patients” (P5).

All concurred that they have a very close relationship with the professionals in the unit, and that their experience has been very positive. The reasons reported by participants are having close contact with the same staff for a long time, face-to-face care, maintenance of the follow-up and surveillance protocol during the pandemic and resolving doubts and incidents regarding COPD and COVID-19.

3.3 Integration of thematic analysis and results for emotions and polarity

In the thematic analysis, patients with COPD described how confinement did not affect their level of activity and showed how it helped protecting them, but fear of contagion increased the adoption of protective measures (wearing masks and avoiding close contact with people). Content analysis of emotions and polarity showed fear as the main emotion identified, along with a negative trend in the narrative of the participant's speech. On the other hand, the results of the thematic analysis showed important negative aspects (fears of contagion, dissatisfaction with medical care, etc.). However, when determining the polarity (acceptance/rejection) of the discourse about the pandemic and the impact on their lives, the final result was positive. The identified words focused on describing the COPD clinic but were not related to the COVID-19 pandemic.

4 Discussion

Our thematic results showed that patients with COPD did not have a major negative experience of confinement during the first wave of COVID-19 outbreak, following the recommendations to avoid the infection. They had many difficulties with face masks, particularly FFP2 type, and half of them refused the vaccine. Ultimately, they feel safe and protected by the health care professionals in the COPD unit of their hospital.

Upon triangulation of the thematic results with textual content analysis, participants showed a positive polarity of their discourse regarding the first wave of the COVID-19 pandemic. Our results coincided with the work of Pleguezuelos et al. (14) on the experience of patients with COPD during their confinement in the COVID-19 pandemic, where they described how most of the patients stated that their feeling regarding lung disease and their general health was similar or even better during confinement, and how it had little impact on their life. This contrasts with previous studies of COPD patients during the pandemic, which described negative feelings, along with anxiety, and stress (10, 16, 49). The psychological and emotional impact described in previous studies due to the pandemic were a consequence of the fear of dying, fear of becoming infected, feeling abandoned by the health system, difficulty of access to health professionals, and lack of support and care, despite being vulnerable patients (10, 15, 16, 49). The positive polarity of our participants' perspective, identified in their narratives, can be explained by the fact that the patients belong to a specialized COPD cohort/unit of a regional hospital, where specific treatment and follow-up protocols were in place, where the Referring professionals (physicians and nurses) have not changed, and where care protocols have continued to be applied in the same way as before the pandemic. Previous studies have shown how the involvement and proactivity of professionals minimized the adverse effects of the COVID-19 pandemic on patients with COPD (10, 18, 19).

Regarding home confinement, our participants did not experience it in a negative or distressing way. On the contrary, they recounted how these measures were particularly beneficial to vulnerable patients with chronic conditions. These results agree

with an observational study (14) conducted in Spain, where 100 COPD patients were interviewed by telephone. The Hospital Anxiety and Depression, the COPD Assessment Test, and the 5-Dimension Euro Quality-of-Life questionnaire were administered. The interviews also included questions about the lockdown, missed clinical appointments, and fears of the disease. In this study, Pleguezuelos et al. (14) showed that, in general, the worldwide lockdown had a low impact on COPD patients. In contrast, in Italy, during the confinement, COPD patients described feeling terror, anguish, and apprehension (13). This difference compared to our results could be explained by the fact that the restrictive measures were applied to all people, decreasing the exposure of COPD patients to other non-vulnerable people, and therefore decreasing the risk of contagion. Moreover, prior to the pandemic, patients had adapted their habits and lifestyle to the restrictions caused by COPD symptoms. Whereas Philip et al. (49) described the concerns and difficulties of patients with COPD regarding obtaining food, money, supplements, and medication, keeping their distance from their social and family environment, and in those living alone, in our results these difficulties were not reported because they were performed by the partner, or the family (in the case of those who lived alone).

Our results showed how patients with COPD felt more vulnerable, and they strictly adopted protective measures (avoiding going to the doctor, using masks and gloves, hydroalcoholic gel, etc.) due to fear (of contagion, of COPD progressing and worsening, of intubation). Moreover, agreed with previous studies (10, 16) that reported how patients with COPD during the pandemic, due to the fear of becoming infected, have implemented strict measures of social distancing, self-isolation, and distancing from family and friends. Measures such as wearing face masks, social distancing, washing or sanitizing hands, and avoiding public or crowded places, were largely followed and applied and in a higher proportion by patients with chronic diseases compared to the healthy population (50). However, Kusk et al. (16) described how patients with COPD, by applying strict precautionary measures, experienced a feeling of loneliness and an alteration of the life-illness balance, since they were protecting a life while losing another. Conversely, previous studies (51, 52) showed how the application of these measures reduced the number of severe COPD exacerbations during the COVID-19 Pandemic. On the other hand, our results showed that as a consequence of using the mask, patients with COPD felt suffocated, with shortness of breath as if they were in a prison. The increased feeling of shortness of breath could be damaging for COPD patients, easing protective measures and increasing the risk of contagion. Tomán et al. (15) showed how for patients with COPD, dyspnea was the most terrifying symptom of progressive lung disease, and how patients tried to minimize it at all costs.

Previous studies described how patients experience denial of care, discrimination, or inequity in health care (49), and even oblivion by health authorities and health professionals (10). Our results did not show that patients with COPD have experienced lack of clinical care or inequity in access to health care. They described difficulties in accessing clinical consultations in primary care; however, similar to the rest of the people in their environment. In addition, they feel protected and safe by their healthcare

professionals and by the measures taken by the health authorities to protect the population (including the most vulnerable) such as the strict confinement during the first wave of the COVID-19 outbreak for a period of 3 months (14).

Regarding vaccination, our results showed the experience of a small group of patients. However, it is paradoxical that despite the high risk of death of COPD patients in the event of contracting the SARS-CoV-2 virus and the vaccination recommendations (53), half of the participants did not wish to be vaccinated. We find these results surprising, as all the participants reported having been informed of the vaccination by their physicians and feeling very satisfied with the clinical care, trusting the professionals of the COPD unit, and confirmed having a very good professional-patient relationship. Previous studies (54, 55) reported evidence of a COVID-19 vaccine hesitancy among chronic patients. This hesitancy or distrust towards COVID-19 vaccination is not a local phenomenon but rather is widespread throughout the world (54). Factors that facilitate refusal include possible side effects, fears that the vaccine may not be safe, fear of injections, belief in natural or traditional remedies, need for more information, anti-vaccine attitudes or beliefs, believing that the vaccine will serve to those who produce this virus, i.e., conspiracy beliefs of the vaccine (55).

The qualitative design allowed us to explore and describe in depth the perspectives of patients with COPD during the COVID-19 pandemic (10, 15–19, 49). Compared to previous studies (10, 15–19), our study added these new findings: (a) The confinement measures did not cause limitation of their daily activities since they were previously limited by the illness; (b) confinement was perceived as a measure that protected them since they were more vulnerable; (c) they strictly adopted personal protection measures (masks, gloves, etc.) but they had problems adapting to the masks since they felt suffocated as if they were in a prison; (d) when walking and moving outside they tended to remove the mask to minimize the feeling of suffocation; (e) the COVID-19 vaccine was not accepted, the reasons included fear that it would further damage their lungs, the fact that the information provided by politicians was confusing and they preferred to wait getting vaccinated; (f) the professionals and the care from their reference hospital made them feel safe (unlike primary care) as they continued to monitor COPD by maintaining the in-person visit, regardless of the pandemic.

Regarding the integration of the results, the use of two analytical proposals (thematic and content) allowed us to obtain and understand the perspective of patients with COPD, as well as deepening the emotions and the tendency of polarity (acceptance/rejection) of their discourses. This did not mean that the results of both analyses coincided, but rather that they showed nuances of perspective, which only one type of analysis could not identify. Thus, in the present work, using thematic analysis, patients with COPD described important negative aspects of experiencing the first wave of the pandemic from their perspective. However, in the content analysis of his speech, through lemmatization, the polarity of his speech had a positive final result.

An important novelty of this work was the use of lemmatization as a complementary analysis proposal to other qualitative tools (such as thematic analysis), and in this way increased the credibility of the results and also the depth of the perspective analysis of the participants.

5 Limitations

First, regarding sample size sufficiency, previous studies (33, 34) reported that the sample size justification in qualitative health research was limited and defining sample size *a priori* is inherently problematic. Also, Sebele-Mpofu (56) describes how the definition of the concept of saturation can vary, depending on the qualitative design chosen, sampling strategy and the data collection instrument used. Due to this great variability of criteria, the authors opted for a proposal to establish the sample size based on pragmatic considerations (difficulty of access to participants due to confinement and social isolation measures) and on the information power to achieve sample size saturation (35). The inclusion of a small sample with 8 participants was in line with existing research: (a) on the sample size in qualitative studies (qualitative sample size), which described how the sample could be reached by saturation between 5–12 interviews (56–63); and (b) on qualitative studies conducted in patients with COPD during the COVID-19 pandemic, using samples of eight (15) and 10 participants (19). However, as a result of using this pragmatic consideration, along with the qualitative nature of this study, gathering the perspective of a group of COPD patients concerning a certain phenomenon and the small number of patients with COPD, this study has limitations in terms of generalizability. Finally, data collection was carried out in December 2020, time after the first wave of the COVID-19 pandemic in Spain (March 14, 2020 to June 21, 2020) (64). This could have influenced the narratives and results obtained.

6 Conclusion

Our results showed that COPD patients narrated how the confinement and restrictive measures of the first wave did not have a negative impact on their lives. On the contrary, fear (in all areas and situations) forced them to adopt strict protective measures to avoid contagion and impacted their daily lives. Moreover, they have experienced barriers in access to primary care, great difficulty in the use of masks, and the refusal of some patients to the COVID-19 vaccine was relevant. The content analysis showed how the main emotion was fear, and how the global polarity of the speech of patients with COPD was positive.

Future studies should analyze adherence and the use of face masks in COPD patients, and the reasons for accepting or refusing vaccination. These results may help managers to understand the impact that confinement rules and the adoption of protection measures against contagion had on the daily life of patients, as well as the importance of maintaining and the developing specialized COPD monitoring units.

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 Clinical Research Ethics Committee of the Complejo Hospitalario Universitario de Canarias (Canary Islands Health Service, Spain; code: CHUNSC_2020_79—October 15, 2020). 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

DP-C: Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing. DP-O: Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Writing – review & editing. CC-M: Supervision, Writing – review & editing. JC-Z: Data curation, Formal analysis, Writing – review & editing. CG-B: Conceptualization, Methodology, Writing – original draft, Writing – review & editing. CF-d-l-P: Conceptualization, Methodology, Writing – review & editing. DD-P: Conceptualization, Investigation, Project administration, Visualization, 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.2024.1351754/full#supplementary-material>

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Impact of Urban-Rural Resident Basic Medical Insurance integration on individual social fairness perceptions: evidence from rural China

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Background: Achieving universal health insurance coverage has become a fundamental policy for improving the accessibility and equity of healthcare services. China's Urban-Rural Resident Basic Medical Insurance (URRBMI) is a crucial component of the social security system, aimed at promoting social equity and enhancing public welfare. However, the effectiveness of this policy in improving rural residents' social fairness perceptions (SFP) remains to be tested.

Objective: To examine the impact of the urban-rural resident basic medical insurance (URRBMI) on rural residents' social fairness perception (SFP) in China.

Methods and samples: The study utilizes city-level and national micro-survey (CGSS) datasets, applying a time-varying difference-in-difference (DID) approach to analyze the equity effects of URRBMI. Excluding urban samples, the final dataset consists of 20,800 rural respondents from 2010, 2011, 2013, and 2015, covering 89 cities.

Results: Key findings reveal that URRBMI has a significant negative effect on SFP. The impact varies depending on the integration model and intensifies over time. Additionally, the negative effect shows heterogeneity based on income, age, health, and region.

Conclusion: This study highlights the complexities and impacts of integrating China's urban and rural healthcare systems. It provides a detailed understanding of the role of URRBMI in rural China, emphasizing the need for targeted approaches to improve rural residents' perceptions of social fairness. The research offers specific policy recommendations, such as establishing differentiated contribution standards, implementing welfare policies favoring rural residents, and adopting varied reimbursement rates for different diseases.

KEYWORDS

equal opportunities, social security, Urban-Rural Resident Basic Medical Insurance (URRBMI), social fairness perception (SFP), rural China

1 Introduction

Comprehensive health insurance coverage has become a cornerstone policy globally, aimed at improving the availability and equity of healthcare services (1–4). As the world's largest developing country, China has achieved the landmark feat of establishing a nationwide health insurance system in 2011 on a scale unparalleled in the history of global healthcare (5).

Even though there is a significant expansion in societal health insurance protection during the early 2000s, China is still grappling with the challenges of persistent inefficiencies and imbalances in its healthcare system (6–8). Historically, China's Health Insurance System has been divided into the Urban Residents' Basic Medical Insurance (URBMI) for urban residents and the New Rural Cooperative Medical Scheme (NRCMS) for rural residents. This dual-structured framework in a notable disparity in healthcare benefits between urban and rural residents (9, 10), with urban residents enjoying more privileges in terms of reimbursement, healthcare accessibility, and resource allocation (9, 11, 12). An unfair healthcare system not only perpetuates but also exacerbates the socio-economic divide, severely undermining the overall welfare of rural residents. This inequality transcends material wellbeing and profoundly affects residents' subjective perceptions of social fairness.

Individual social fairness perception (SFP) reflects the equitable outcome of resource distribution and plays a critical role in maintaining social stability (13, 14). Many developed countries, intergovernmental organizations, and scholars consider subjective national wellbeing, such as SFP, as an indicator of social progress (15, 16). Pursuing equality or fairness is a major goal of healthcare systems worldwide (2, 17). Individual SFP is closely linked to a well-functioning and just medical insurance system, prompting governments to reform the existing health insurance model. To promote urban-rural equity and eliminate disparities in medical insurance benefits, the State Council integrated URBMI and NRCMS in 2016, forming the Urban-rural Resident Basic Medical Insurance (URRBMI). Overcoming the disadvantages of the urban-rural fragmented urban-rural healthcare system, especially regarding payment and reimbursement processes, depended on large-scale fiscal investments (5, 18). According to China's 2020 national fiscal data, over 31% of health finance expenditures were allocated to subsidize the basic medical insurance fund. The URRBMI policy, aimed at equalizing health services, is crucial for improving medical service opportunities for rural residents and strengthening economic protection, and has been proven to make substantial progress in enhancing welfare equity for lower socio-economic groups (9, 19).

Two streams of literature are relevant to this study: the formation of SFP and the equity of benefits under URRBMI. Extensive studies have developed a comprehensive framework to explain the complex factors affecting social fairness perceptions. Mainstream determinants identified include institutional elements such as democratic participation (20), policy trust (21), and strategies related to social security and income distribution (22). Additionally, some researchers assert that the formation of SFP is intrinsically linked to an individual's social class from a sociological structural perspective. Additionally, researchers assert that the formation of SFP is intrinsically linked to an individual's social class from a sociological structural perspective. This dynamic manifests a dichotomy with vested interests advocating for the maintenance of existing distributional mechanisms. In contrast, disadvantaged groups are inclined toward a fair distributional model rooted in the 'principle of equality (23, 24). Furthermore, some academics argue that fairness judgments are not solely based on the absolute value of acquired benefits but are significantly influenced by

relative, comparative outcomes. This concept is known as "relative deprivation theory" (25, 26). A wealth of empirical studies have verified that comparisons with a reference group affect individuals' subjective wellbeing (27, 28).

Concerning the equity of benefits under URRBMI, existing research debates whether URRBMI encourages medical resources and insurance reimbursements to favor disadvantaged groups. The majority of the studies conclude that URRBMI has unified the payment standards and reimbursement benefits for urban and rural residents at the system design level, alleviating the health inequalities perpetuated by systemic stratification (9, 11, 12). The primary beneficiaries of this policy shift are the socioeconomically disadvantaged groups, particularly those with lower income and poorer health conditions, who have seen a significant uplift in their access to healthcare (9, 29, 30). Conversely, a segment of scholars contend that the merging health insurance policies could inadvertently intensify disparities in accessing healthcare services (31, 32). They argue that the benefits of insurance are actualized through the purchase of medical services. Wealthier individuals, with their greater financial resources, are capable of accessing a broader range of higher-quality medical services, resulting in more substantial health insurance reimbursements and protections. This situation ultimately leads to "reverse subsidization", where the economically disadvantaged inadvertently end up subsidizing the more affluent (32, 33).

Existing research has made significant progress in addressing the welfare inequities under China's URRBMI system, examining factors such as consumption, medical service utilization, and poverty alleviation. However, an important question remains: does the URRBMI policy, aimed at equal opportunity, enhance the SFP of rural residents? There is a substantial gap in the literature concerning the impact of this system on subjective fairness perceptions, particularly from the perspective of relative deprivation. Field surveys reveal that despite the positive impact of URRBMI on healthcare conditions for farmers, a paradoxical sentiment remains among some individuals, who perceive NRCMS as more beneficial. It remains to be answered whether the URRBMI system can successfully uphold the successes of prior reforms and authentically boost the SFP among rural residents. Our examination of China's health insurance integration process not only provides clarity on the Chinese model and its mechanisms but also holds wide-reaching implications for the formulation of healthcare and welfare policies in other nations with similar development situations.

This paper aims to delve into the impact of equal opportunity in healthcare services on SFP based on the URRBMI institution, combining the dimensions of "vertical sense of fairness" and "horizontal sense of fairness". Through quantitative analysis, this study attempts to answer a crucial question: whether a basic public service system based on "equal opportunity" can effectively enhance residents' perception of fairness and function as a "social stabilizer". Compared to prior studies, this paper offers three notable contributions: Firstly, existing literature on the impact of URRBMI primarily focuses on health equity and income equality. This study concentrates on the effects of medical resource allocation on individuals' subjective perceptions, thereby extending the discussion scope of the urban-rural integrated

medical insurance system. Secondly, equal opportunity is the core of the URRBMI, and SFP reflects rural residents' subjective views on urban-rural equity. The effectiveness of the "equal opportunity" approach in medical resource allocation in enhancing rural residents' SPF warrants further examination. This paper examines the relationship between the equalization of basic public service opportunities and the sense of fairness among rural residents. Lastly, few studies have utilized the China General Social Survey (CGSS) database for policy effect evaluation using a difference-in-differences (DID) model. This is primarily due to the CGSS database not providing direct administrative codes or names for the cities of the samples, making it challenging to identify the regions where policies were implemented. This study addresses this limitation by using respondents' detailed birthplace information (city, county/district) and matching it with samples where rural residents' birthplace and current location are consistent. By inferring the corresponding prefecture-level city codes and names, this approach enables the combination of nationwide micro-survey data with the URRBMI policy, thereby expanding the application scope of CGSS data.

The subsequent parts of this document are structured as follows: Section 2 reviews the institutional background of URRBMI and outlines the theoretical framework, Section 3 introduces the econometric methods and describes the datasets involved in the study, Section 4 reports the empirical results, and Section 5 distills the research conclusions and proposes policy recommendations.

2 Background and theoretical framework

2.1 Institutional background

2.1.1 Background of the integration of URRBMI

Since the beginning of the 21st century, China has successfully established a basic healthcare system covering the vast majority of urban and rural residents, with the Urban Resident Basic Medical Insurance (URBMI) and the New Rural Cooperative Medical Scheme (NRCMS) being its integral components (34). By 2016, the coverage of these two systems had exceeded 95%. URBMI and NRCMS operate on a strictly differentiated basis according to household registration. The NRCMS is a health insurance policy targeting the rural population, which has been implemented since 2003. NRCMS has effectively served as a commendable policy in providing basic medical security for Chinese farmers. However, significant disparities in medical benefits between residents living in urban and rural areas have perpetuated longstanding health inequalities in rural areas.

To mitigate these disparities, in 2016, the State Council published the document entitled "Opinions on Integrating Urban-Rural Resident Basic Medical Insurance Systems". Building upon the experiences of URBMI and NRCMS, the URRBMI was established, characterized by the implementation of a "six-unification" standard, encompassing uniform coverage, financing policy, security treatment, medical insurance catalog, designated management, and fund management, thereby achieving equal opportunity in the utilization of medical insurance benefits.

Regional variations in the institutional design of integrated urban and rural medical insurance primarily manifest in two models: "one system, one standard" and "one system, multiple standards". The former adopts a unified standard for financing and treatment design, while the latter implements differentiated financing and treatment levels within a unified policy framework. The "one system, one standard" design implements a unified and singular standard for funding and benefits across urban and rural areas. For instance, Guangzhou's 2015 guidelines state that the individual contribution for urban and rural residents' medical insurance is 152 RMB per person, with uniform contributions entitling residents to identical benefits. Conversely, the "one system, multiple standards" design, while maintaining a unified policy framework, employs differentiated funding and benefit levels based on the "more pay, more gain" principle, allowing residents to choose their contribution level according to their needs. For example, Luzhou's 2015 contribution standards for urban and rural adult residents' medical insurance offer a low tier (90 RMB/person) and a high tier (220 RMB/person), with residents selecting their preferred level. Correspondingly, inpatient medical benefits are adjusted according to the contribution level, with two different reimbursement rates for covered medical expenses, reflecting the principle of proportional rights and obligations.

In addition, we collect and organize policy documents from various regions and find that there are differences in the implementation time of the URRBMI institutions in different cities. Chengdu, the earliest city to integrate urban and rural residents' medical insurance, completed the integration of urban resident insurance and the new rural cooperative medical scheme as early as 2009. In contrast, some areas, such as Nanjing, did not complete the integration until 2019. This gradual implementation offers a unique quasi-natural experimental condition for an in-depth exploration of the relationship between URRBMI and rural residents' SFP using a progressive difference-in-differences model. Among the cities involved in the study period, 20 cities adopted different financing and governance models based on their specific circumstances at various times¹.

2.1.2 Transition from NRCMS to URRBMI

During the integration process, accounts from NRCMS and URBMI merged into a unified URRBMI account, achieving integrated management of medical insurance fund expenditures for both urban and rural areas (Table 1). Additionally, the structure of medical insurance accounts and the reimbursement ratios underwent significant changes. During the NRCMS period, independent personal medical fund accounts were established to increase farmers' willingness to enroll, with individual insurance premiums deposited into these accounts for covering out-of-pocket expenses for medications, outpatient, and hospitalization services. Under URRBMI, personal medical fund accounts were gradually phased out, consolidating individual payments and government subsidies into a social pooling account. In terms of reimbursement ratios, unlike the centralized coordination during the NRCMS period, regions have the autonomy to set their reimbursement

¹ Detailed information is provided in [Supplementary Table S1](#).

TABLE 1 Characteristics of NRCMS and URRBMI Insurance Systems.

	NRCMS	URRBMI
Target population	Rural residents	Urban and rural residents
Voluntary enrollment	Yes	Yes
Individual contribution	Yes	Yes
Government subsidy	Yes	Yes
Enrollment unit	Household	Household
Reimbursement ratio	Outpatient: 20%–50%	Outpatient: 40%–50%
	Hospitalization: 30%–60%	Hospitalization: 55%–90%
Integration level	County	City
Fund management	DREMS	FBFAMS; SFA; DREMS

In the table, FBFAMS, Fund Budgeting and Final Accounting Management System; SFA, Special Fiscal Account, and DREMS represents Dual Revenue and Expenditure Management System.

ratios for residents' health insurance during the URRBMI period. Notably, there are obvious differences in the reimbursement rates across regions, possibly reflecting differential considerations of local healthcare needs and financial capacity.

2.2 Theoretical framework

As a measure to integrate urban-rural health insurance in China, URRBMI has indeed made significant progress in equalizing the medical treatment and resource disparity between urban and rural residents (6, 12). The increase in reimbursement rates and the expansion of medical service coverage are indicative of a substantial reduction in the inequality of healthcare resource utilization among these populations. For instance, the policy has elevated reimbursement for certain chronic illnesses and major medical expenses, enhancing the affordability of healthcare for rural inhabitants. However, there persists a contradictory sentiment among some rural individuals, who perceive URRBMI as not contributing to an increased sense of fairness. To explore whether URRBMI improves farmers' SFP, we have developed a theoretical analysis and hypotheses.

The SFP of rural residents is shaped by both longitudinal (LF) and horizontal fairness (HF) perceptions (14, 35). LF perception emerges as farmers compare the benefits received under URRBMI with those from the NRCMS period. The formation of HF occurs when the farmer compares himself with urban residents or others who enjoy similar benefits. With the blurring of the urban-rural boundary and the widespread use of digital technology in rural areas, farmers' access to information has been greatly broadened, which has changed their point of reference in assessing SFP (14, 15, 36). Grounded in the conceptual frameworks of LF and HF, this study examines the mechanisms of URRBMI affecting farmers' SFP with a focus on premium payment and reimbursement.

Firstly, we analyze the impact of URRBMI on rural residents' SFP from the perspective of payment reform. An analysis of

historical data reveals a progressive increase in the personal contribution requirements for URRBMI². Since 2018, individual insurance expenses have constituted over 1.5% of the average disposable income of rural residents, indicating a relative increase in their financial burden compared to the NRCMS period. On the other hand, since urban-rural populations have been included in the same insurance system and are subject to the same contribution standards, the vast group of low-income rural residents have taken on more responsibility for health insurance financing than they did before. This inadvertently creates the trap of "exploitation of low-income by high-income earners". Hence, post-integration, rural residents potentially experience a subjective sense of loss in terms of premium payments, both in longitudinal comparison with the NRCMS period and in horizontal comparison with urban residents.

Secondly, we analyze the impact of URRBMI on rural residents' SFP from the perspective of reimbursement reform. Although there has been a nominal increase in the reimbursement ratio for rural residents under URRBMI compared to the NRCMS period, the actual perceived reimbursement ratio has not met the farmers' expectations. Medical expense payments in China involve a co-payment scheme between medical insurance funds and residents. Under the co-payment reimbursement system of URRBMI, the allocation of medical resources and payment is tightly linked to income levels. Given the generally lower income of farmers, who also need to set aside funds for future agricultural production, their real disposable income is considerably lower, resulting in a higher medical burden compared to urban residents. Furthermore, the distribution of healthcare resources across China shows a marked difference between urban and rural areas, as premium healthcare facilities are mainly found in major cities and their hospitals. This disparity leads to higher transportation costs and labor costs for farmers to access healthcare. The unified urban-rural medical insurance achieves only "formal equality of opportunity" in reimbursement standards, failing to perform the fundamental role of income redistribution in social security. The above reasons have resulted in a permanent disadvantage of "relative deprivation" of the rural population. Drawing from the preceding analysis, we formulate Hypothesis I.

Hypothesis I: URRBMI will reduce rural farmers' subjective SFP.

Based on the above analysis, we find that the decrease in farmers' SFP is more likely to derive from the loss of "horizontal access" through the positioning of urban residents as reference points. In terms of URRBMI's implementation, it is categorized into two models: "one system, one standard" and "one system, multiple standards". The central government's setting of the minimum standards for URRBMI means that the former approach does not significantly alter the premium burden or actual reimbursement ratio for rural residents. Conversely, the latter model, which involves differentiated funding and benefit levels within a unified

² According to the urban-rural residents' health insurance contribution standards for the past years jointly issued by the National Health Insurance Bureau, the Ministry of Finance and the State Administration of Taxation, from 2015 to 2022, the minimum standard of individual contributions for rural residents to participate in the basic social health insurance increased from 200 yuan in 2015 to 350 yuan in 2022.

policy framework, may be the fundamental cause of the reduced SFP among farmers. In the current context of significant income disparity between urban and rural residents, urban dwellers are more likely to choose higher payment tiers. Following the principle of “more pay, more benefits”, those in higher tiers receive greater reimbursement ratios, leading to a widened gap in reimbursement between tiers and further intensifying the “inverse distribution” of medical resources. We propose Hypothesis II.

Hypothesis II: The impact of differentiated integration models on rural residents’ SFP varies, with the multi-standard URRBMI model exerting a more depressive effect.

Assuming that Hypothesis I and Hypothesis II are valid, URRBMI leads to lower SFP among rural residents. They believe that urban residents have access to more healthcare resources. Under this premise, urban residents benefit from enhanced health human capital, which in turn elevates personal and family productivity, and improves their income conditions (37). This leads to urban families continually accessing greater medical resources, creating a “virtuous cycle”. In contrast, the situation for farmer families is the opposite. As the income disparity between urban-rural residents increases, the unequal distribution of medical resources between these groups may become more severe than it was at the beginning of the integration. We propose Hypothesis III.

Hypothesis III: The negative effect of URRBMI on the rural residents’ SFP will increase over time.

3 Data and method

3.1 Datasets

This study utilizes both macroeconomic statistical data and micro-level survey data. The macroeconomic data is sourced from the “China Urban Statistical Yearbook”, “China Regional Economic Statistical Yearbook”, “China Health Statistical Yearbook”, and other relative statistical yearbooks. The micro-level data is derived from the China General Social Survey (CGSS) provided by the China Survey and Data Center at Renmin University of China. This data encompasses information on Chinese society, communities, families, and individuals involving adult citizens aged over 18 years. Given that the NRCMS had essentially achieved full rural coverage by 2010, this study has retained sample data from 2010 onwards.

Due to privacy protection considerations, the CGSS database ceased to provide codes for survey regions after the year 2015. Consequently, this study utilizes data up until 2015, which includes codes for regional samples. It is important to note that the CGSS data do not directly reveal the prefecture-level city of respondents but only display codes for their provinces and municipalities. Therefore, this research retains samples where the birthplaces of rural residents coincide with their current locations, and employs respondents’ detailed addresses of their birthplaces (including cities and districts) to deduce the codes corresponding to each prefecture-level city. Excluding urban samples, the final dataset comprises 20,800 rural respondents from the years 2010, 2011, 2013, and 2015, spanning 31 provinces and 89 cities. Among the surveyed cities in the CGSS, 20 cities, including Chongqing and Chengdu, implemented the integration of urban and rural resident medical insurance before 2016. During the integration process, each city

adopted different funding and reimbursement models based on their specific circumstances. Detailed information is provided in [Supplementary Table S1](#).

3.2 Models and variables

In this study, mixed cross-sectional data are used to construct the asymptotic difference (DID) model. The specific model is constructed as follows ([Equation 1](#)):

$$Equ_{cit} = \alpha + \beta Treat_c \times Post_{ct} + X'_{it}\chi + Y'_{ct}\delta + \mu_c + \mu_t + \varepsilon_{cit} \quad (1)$$

The explanatory variable Equ_{cit} represents the SFP of rural resident i of city c in time period t . The SFP is measured using the question “In general, do you think that today’s society is fair”. Based on respondents’ answers, ratings of “not at all fair”, “somewhat unfair”, “neutral”, “somewhat fair”, and “completely fair” are assigned numeric scores of 1, 2, 3, 4, and 5, forming an ordinal variable.

$Treat_c$ is utilized to identify cities implementing URRBMI. If a city has implemented URRBMI, it is assigned a value of 1, otherwise, it is 0. $Post_{ct}$ is the timing of URRBMI, assigning a value of 0 to years before integration and 1 to the year of integration and thereafter. We ultimately obtained 2,606 samples for the treatment group and 18,194 samples for the control group. μ_c represents regional fixed effects; μ_t denotes year fixed effects; ε_{cit} is a random disturbance term; α and β are parameters to be estimated; χ and δ are vectors of parameters to be estimated.

This article incorporates several control variables (X) as follows: Gender (1 for males, 0 for females), Age, Education level (assigned values from 1 to 13 based on the highest education level), Political affiliation (1 for Communist Party or democratic party members, 0 otherwise), Marital status (1 for cohabiting, first marriage, or remarried with spouse, 0 for others), Health level (values from 1 to 5), Employment type (1 for non-agricultural employment, 0 otherwise), Personal income (natural logarithm of total personal income last year), and Digital literacy (1 for frequent media use, 0 otherwise). Descriptive statistics of these variables are presented in [Table 2](#).

4 Empirical results

4.1 Benchmark regression results

This study employs a two-way fixed effects regression, with the results presented in [Table 3](#). The regression in Column (1) indicates a significant negative impact of URRBMI on rural residents’ SFP. We add individual-level and city-level control variables in Columns (2) and (3) in turn, and the results are consistent with Column (1). Specifically, URRBMI leads to a 10.1% decrease in rural residents’ SFP according to the results in Column (3). Hypothesis I is verified.

To further discuss the impact of different integration models on rural residents’ SFP, we identify cities with “one system, one standard” and cities with “one system, multiple standards”. The regression results are shown in Column (4). The URRBMI of the multi-standard model has a stronger suppressive effect on the SFP

TABLE 2 Descriptive statistics of variables.

Variables	Full sample		Treatment group		Control group	
	Mean	SD	Mean	SD	Mean	SD
SFP	3.151	1.050	3.226	1.009	3.140	1.055
Gender	0.474	0.499	0.473	0.499	0.474	0.499
Age	48.324	15.891	48.358	16.456	48.319	15.806
Marriage	0.821	0.383	0.804	0.397	0.824	0.381
Party	0.047	0.211	0.045	0.208	0.047	0.212
Education	3.555	2.035	3.529	2.248	3.558	2.002
Health	3.463	1.187	3.387	1.156	3.473	1.190
Employment	0.291	0.454	0.304	0.046	0.289	0.454
Income	8.349	3.970	8.267	4.011	8.361	3.964
Digital	0.149	0.356	0.189	0.392	0.1433	0.351

TABLE 3 Benchmark regression results.

Variables	(1)	(2)	(3)	(4)
	SFP	SFP	SFP	SFP
$Treat_c \times Post_{ct}$	−0.127*** (0.044)	−0.107** (0.042)	−0.101** (0.041)	-
DID (one-standard model)	-	-	-	−0.067 (0.047)
DID (multi-standard model)	-	-	-	−0.194*** (0.056)
Individual-level control variables	-	Yes	Yes	Yes
City-level control variables	-	-	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes
City-fixed effect	Yes	Yes	Yes	Yes
N	20,800	20,800	20,800	20,800
R ²	0.028	0.054	0.055	0.055

(1) ** and *** Denote significant at the 5% and 1% levels. (2) Standard errors in parentheses are clustered at the township level.

of rural residents, implying that this type of healthcare integration design is less conducive to the enhancement of rural residents' sense of social equity. The reason may be that under the "more pay, more benefits" principle, higher contributions entail higher reimbursement ratios and subsidies. For higher-income urban residents, the cost difference between high and low tiers is minimal relative to their disposable income, making them more likely to pay higher premiums. This results in urban residents receiving higher medical subsidies compared to rural residents at lower tiers. Consequently, low-income farmer groups are disadvantaged in the distribution of medical insurance benefits, exacerbating negative

perceptions of social fairness among rural residents. Hypothesis II is verified.

4.2 Identification condition test of DID

To obtain an unbiased estimate of the policy variable's Difference-in-Differences (DID) coefficient β , it is essential that this variable is uncorrelated with the random disturbance term ε_{cit} , fulfilling $cov(Treat_c, \varepsilon_{cit}) = 0$ and also satisfying $cov(Post_{ct}, \varepsilon_{cit}) = 0$. Therefore, this paper needs to address two key issues: the randomness in the selection of cities for urban-rural resident medical insurance integration and the randomness concerning the timing of this integration.

4.2.1 Randomness issue in the selection of cities for URRBMI integration

Due to the absence of specific documents as reference standards for the selection of cities for URRBMI integration, this paper attempts to identify the key determinants influencing the choice of cities for insurance integration. Specifically, considering that URRBMI is coordinated at the city level, the study examines potential determinants from the perspective of city characteristic variables. Following the existing study (38), a Logit model is constructed to estimate the probability of various factors influencing the implementation of URRBMI in a region. The dependent variable is whether a city is designated for integration, with cities under URRBMI integration coded as 1 and others as 0. Factors related to the city's medical development level, such as economic development, urban population size, healthcare financial investment, the proportion of healthcare investment in total fiscal expenditure, the number of hospitals and clinics, and the number of beds in hospitals and clinics, are selected as explanatory variables for whether a city integrates URRBMI. Moreover, as the decision to integrate URRBMI primarily references the city's data from the previous year, explanatory variables are included as one-period lagged terms in the model, with price variables indexed to the base year of 2009.

TABLE 4 Identification condition test.

Variables	URRBMI
Economic development level	0.141*
	(0.078)
Urban population size	−0.001***
	(0.000)
Healthcare financial investment	−0.314***
	(0.099)
Proportion of healthcare investment in fiscal expenditure	0.015
	(0.017)
Number of beds in hospitals and clinics	0.337**
	(0.148)
Number of hospitals and clinics	0.002***
	(0.001)
N	6,620
R ²	0.3679

Standard errors in parentheses are clustered at the township level. *, **, *** Denote significance at the 10%, 5%, and 1% levels, respectively.

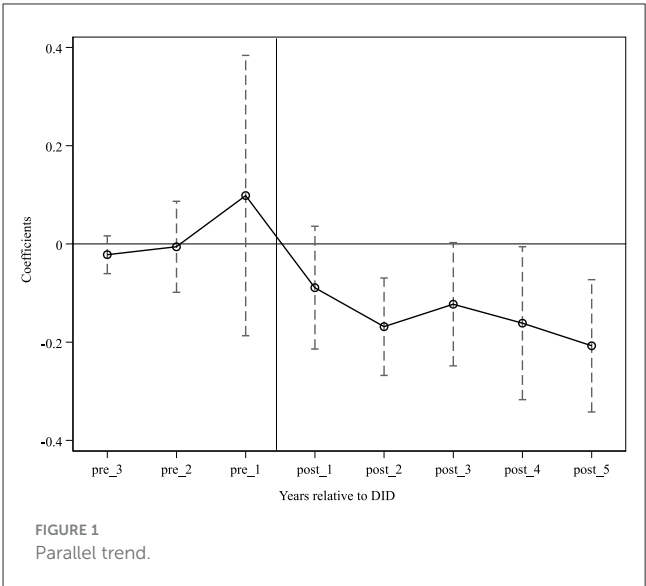
The estimation results are shown in Table 4. The findings indicate a correlation between the decision to merge medical insurance for urban and rural residents and factors such as the city’s economic development level, urban population size, healthcare financial investment and healthcare level (number of hospital beds and the count of medical facilities including hospitals and clinics). Therefore, to control for potential endogeneity in the selection of cities for URRBMI integration, the model should include one-period lag suggestions terms of the aforementioned city characteristic variables. Additionally, the lagged term of the proportion of healthcare expenditure in total fiscal expenditure is also included in the model to mitigate estimation biases caused by omitted variables.

4.2.2 Randomness issue in the timing: parallel trend test

The second condition for the applicability of the Difference-in-Differences (DID) model is the satisfaction of the parallel trend assumption. In this study, this implies that there were no systematic differences in the social fairness perception among rural residents across regions prior to the implementation of URRBMI integration. A parallel trends test model is constructed in this section. The model is as Equation 2.

$$Equ_{cit} = \alpha + \sum \beta_t Treat_c \times ryear_{ct} + X'_{it} \chi + Y'_{ct} \delta + \mu_c + \mu_t + \varepsilon_{cit} \tag{2}$$

Where, $ryear_{ct}$ represents relative year dummy variables. Due to the different timings of URRBMI integration across cities, there is a need to establish time variables that account for these relative differences. Consequently, this study employs the widely used event study methodology to conduct this test. Specifically, the year when



URRBMI was integrated is labeled as 0, the subsequent year (or n years after) is assigned a value of +1 (+n), and the year prior (or n years before) is given a value of −1 (−n). Other variables and parameters are consistent with Model (1). Following Fajgelbaum et al. (39), due to a smaller number of observations at the extremes, all relative years ≤ -3 are uniformly coded as −3, and all years greater than or equal to +5 are coded as +5, resulting in a year span of [−3,5].

For a more intuitive observation of the parallel trend assumption test and the dynamic effects of the integrated medical insurance impact, the 90% confidence interval of the coefficients is illustrated in Figure 1. As indicated in the figure, before the implementation of URRBMI, the regression coefficients are not significant, suggesting that the URRBMI shock does not lead to significant differences in rural residents’ SFP. This satisfies the pre-trend assumption. After the integrated medical insurance program, the absolute value of the regression coefficients gradually increases, indicating that the mitigating effect of URRBMI strengthens over time. Hypothesis III is thus validated.

The parallel trends test offers a clearer view of the dynamic effects of URRBMI (Figure 1). It is evident that before the implementation of URRBMI, the regression coefficients are insignificant, indicating that the URRBMI shock does not lead to significant differences in the SFP of rural residents, thus meeting the pre-trend assumption. Post-integration, there is a gradual increase in the absolute value of the regression coefficients, suggesting that the diminishing effect of URRBMI intensifies over time. Hypothesis III is verified.

4.3 Robustness test

4.3.1 Adjusting the sample of the experimental group

Considering that the sample period of this paper is ended in 2015, cities that implemented health insurance coordination in the year of 2015 may not be able to show the policy effect instantly. To

TABLE 5 Robustness test results.

Variables	(1)	(2)	(3)	(4)
	DID	PSM-DID	Oprobit	Probit
$Treat_c \times Post_{ct}$		−0.163*** (0.062)	−0.111** (0.044)	−0.057*** (0.021)
DID_new	−0.155*** (0.049)			
Individual-level control variables	Yes	Yes	Yes	Yes
City-level control variables	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes
City-fixed effect	Yes	Yes	Yes	Yes
N	20,800	4,546	20,800	20,800
R ²	0.055	0.068	0.022	0.040

*, **, *** Denote significance at the 10%, 5%, and 1% levels, respectively.

validate whether the benchmark regression estimates are robust, we run the regression after setting the $Treat_c$ variable to 0 for the cities that implemented URRBMI in 2015. The regression results are shown in Column (1) of Table 5, which shows that the regression results are consistent with the benchmark results.

4.3.2 PSM-DID analysis

To minimize the selectivity bias more effectively, this paper further uses the fixed utility model based on propensity matching for estimation. As this paper uses mixed cross-section data, year-by-year matching is used in performing the matching. The kernel density plots before and after matching are shown in Figure 2, and the regression results of the matched samples are shown in Column (2) of Table 5, which shows that there is a consistency between the regression results and the baseline results.

4.3.3 Replacing the estimation model

Firstly, considering SFP is an ordered discrete choice, we conducted robustness checks using an ordered probit model for Model (1). The regression outcomes, as shown in Column (3) of Table 5, are consistent with the baseline regression results. Secondly, acknowledging the data characteristics of SFP, categorical variables may better capture respondents' true sentiments regarding social fairness. We transformed the ordinal variables into binary ones, assigning a value of 0 to responses "completely unfair", "somewhat unfair", and "neutral", and a value of 1 to "somewhat fair" and "completely fair". The results displayed in Column (4) of Table 5 reaffirm the findings of the baseline regression.

4.3.4 Placebo test

To further examine whether the impact of URRBMI on rural residents' SFP is driven by extraneous random factors, this paper

performs placebo tests following the methodology of Cai et al. (40). Given that this study is predicated on a multi-period DID model, the extraction of experimental group samples necessitates both locational randomness and temporal randomness. We randomly select 21 cities out of 89 as the treatment group. A random year is chosen for each city as its policy year, creating a new treatment group with random city and policy time. Model (1) is estimated 1,000 times.

The distribution of the regression coefficients and probability density are depicted in Figure 3. The kernel density graph of the coefficient estimates nearly coincides with a normal distribution centered at zero, and the 1,000 estimated coefficients yield a mean of −0.0007 and a variance of 0.0502. This indicates that for randomly generated integration cities, no statistically significant inhibitory effect of URRBMI on SFP is observed, confirming the robustness of the benchmark regression.

4.4 Heterogeneity analysis

4.4.1 Income heterogeneity analysis

Under the "pay first, reimburse later" scheme of URRBMI, rural residents' income directly affects their access to medical resources. Therefore, we examine the income heterogeneity in URRBMI's impact on rural residents' SFP. We use the poverty line of 2011 as the income threshold, categorizing households with income below this line as poor and others as non-poor. The results for income heterogeneity are shown in Columns (1) and (2) of Table 6. We find that URRBMI does not reduce the SFP of poor households. This is likely linked to China's special medical subsidy policies for poor rural households. To prevent impoverishment due to illness, some regions in China have implemented special medical subsidy policies for people experiencing poverty. For example, in Anhui Province, low-income, poverty-stricken or monitored rural residents receive extra subsidies for their medical expenses. In terms of reimbursement, after deductions through basic medical insurance and major illness insurance, the policy also provides a minimum of 60% assistance for the self-paid portion for those eligible for medical aid. This indicates the enhancement of SFP for groups like poor households still relies on special government subsidies, demonstrating a strong policy dependence for their welfare improvement.

4.4.2 Age heterogeneity analysis

To investigate whether rural older adults have benefited from this round of medical insurance reform, thereby enhancing their perception of social fairness, this study categorizes sample households into older adults and non-older adults groups, examining the differential impact of URRBMI on the SFP of these two categories. Following the social security system's classification, which distinguishes between the older adults and non-older adults using the age threshold of 60 years, respondents aged 60 and above are defined as older adults, while others are considered non-older adults. The results, as presented in Columns (3) and (4) of Table 6, indicate that URRBMI integration mainly decreases the SFP among rural residents below 60 years of age, with no significant

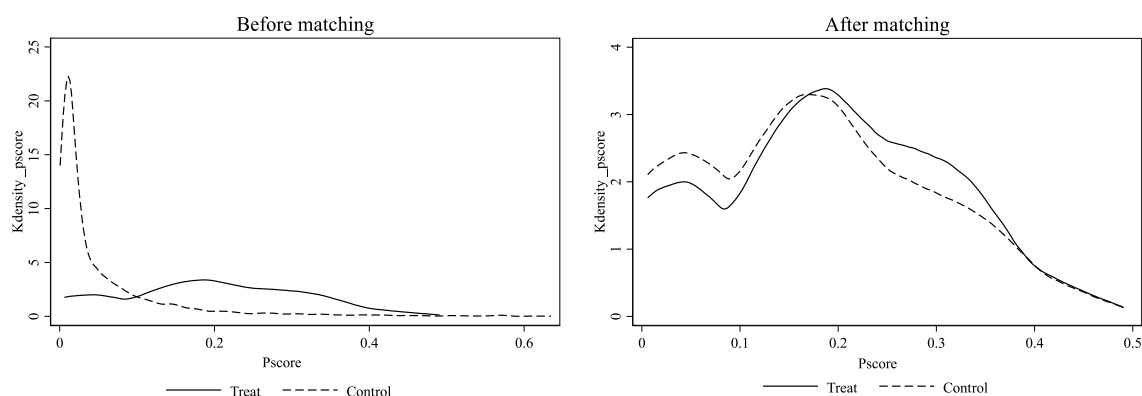


FIGURE 2
Kernel density.

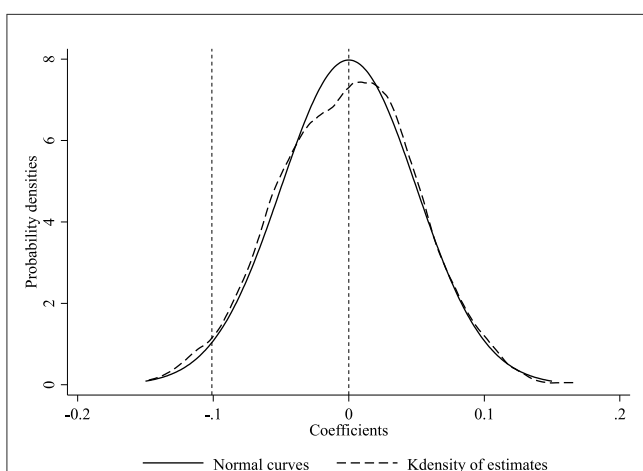


FIGURE 3
Placebo test. The dashed line represents the kernel density curve of the coefficient estimates; the solid line is a normal distribution curve with a mean of zero.

impact on residents aged 60 and above. The notable difference could be attributed to the fact that younger people are the primary users of the Internet. The advancements in network technology, promoting interconnectivity, have had a more profound effect on rural youth, altering their reference points for horizontal comparisons. Consequently, rural youth, who find themselves at a disadvantage in comparison with urban residents, are likely to experience a reduced SFP.

4.4.3 Health heterogeneity analysis

The health status of individuals significantly influences their access to and utilization of medical resources, making the analysis of health heterogeneity crucial for a comprehensive understanding of the impact of URRBMI on rural residents' SFP. We use self-rated health as a basis for measuring respondents' health levels, dividing the sample households into healthy and unhealthy groups. The regression results for health heterogeneity, as shown in Columns

(5) and (6) of Table 6, indicate that URRBMI's diminishing effect on SFP occurs in both groups. During the NRCMS period, if a farmer had no medical insurance reimbursement in a payment year, the self-contributed portion in their personal account could be used for purchasing medicines at pharmacies. After the cancellation of personal accounts, for healthy farmers, the self-contributed portion becomes entirely a cost for risk transfer, leading to a decrease in their sense of benefit. For farmers with poorer health, this reduction in SFP may stem from greater healthcare needs, higher healthcare costs, and lower incomes associated with lower human resource levels.

4.4.4 Region heterogeneity analysis

In China, medical resource distribution varies greatly across regions. The effectiveness of resident medical insurance is highly dependent on regional healthcare levels. This necessitates an examination of the varied impact of URRBMI on rural residents' SFP across different areas. Considering that there is a remarkable disparity between the level of medical care in the western region and the other regions, this study categorizes the sample into western and non-western areas for analysis. The regression results for this regional heterogeneity, detailed in Columns (7) and (8) of Table 6, reveal that the negative impact on rural residents' SFP is more pronounced in the western region. This disparity indicates that in regions with uneven medical resource distribution, rural residents in areas lacking medical resources struggle more to benefit from the integrated medical care system.

4.5 Further analysis

In the previous section, we discover that URRBMI has a suppressive effect on the SFP of rural residents. This finding prompts us to ponder the broader implications of URRBMI on other subjective perceptions held by rural residents. In this part, our focus shifts from the impact of URRBMI on rural residents' subjective SFP to its effects on other dimensions of residents' subjective experiences. This encompasses their

TABLE 6 Heterogeneity analysis.

Variables	(1) Poor	(2) Non-poor	(3) Older adults	(4) Non-older adults	(5) Healthy	(6) Unhealthy	(7) Western	(8) Non-western
$Treat_c \times Post_{ct}$	−0.078 (0.068)	−0.108** (0.044)	−0.043 (0.070)	−0.128*** (0.045)	−0.095** (0.045)	−0.102* (0.059)	−0.154*** (0.055)	−0.012 (0.055)
Individual-level control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City-level control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	5,841	14,958	5,468	15,332	11,436	9,364	6,653	14,147
R ²	0.067	0.045	0.042	0.033	0.060	0.053	0.062	0.050

*, **, *** Denote significance at the 10%, 5%, and 1% levels, respectively.

perceptions of the fairness of income distribution, their satisfaction with public healthcare services, and their satisfaction with the allocation of public services between urban-rural populations. Income distribution fairness perception (IDFP) is derived from respondents' views on income disparities, with responses to "Some people earn more, some less, do you think this is fair?" rated from 1 to 5, ranging from "strongly disagree" to "strongly agree". Public healthcare services perception (HSP) measures satisfaction with government-provided medical services, with responses from "very dissatisfied" to "very satisfied" also rated 1 to 5. Public healthcare resources distribution satisfaction (HRDS) assesses views on the equity of public service distribution, rated similarly from 1 to 5 based on satisfaction levels.

The regression results are shown in Table 7. The results show that after the implementation of the URRBMI integration, rural residents' healthcare services perception (HSP) and healthcare resources distribution satisfaction (HRDS) decreased significantly. The findings suggest that although the URRBMI is intended to integrate the rural and urban healthcare systems, its implementation may not fully address underlying disparities, especially subjective inequalities. The gap between policy goals and actual outcomes suggests that truly improving the subjective sense of equity among rural residents will require complementary government measures in other dimensions. For example, combining social welfare programs with health care policies to address wider socio-economic inequalities to improve the overall life satisfaction of rural residents.

5 Conclusions and policy implications

Promoting social equity and people's wellbeing is the ultimate destination of high quality development of social security. As an essential component of China's social security system, URRBMI assumes the responsibility of promoting the redistribution of healthcare resources and maintaining social equity. We

TABLE 7 Further analysis results.

Variables	(1) IDFP	(2) HSP	(3) HRDS
$Treat_c \times Post_{ct}$	0.011 (0.041)	−0.104*** (0.039)	−0.116*** (0.043)
Individual-level control variables	Yes	Yes	Yes
City-level control variables	Yes	Yes	Yes
Year-fixed effect	Yes	Yes	Yes
City-fixed effect	Yes	Yes	Yes
N	20,800	3,970	20,800
R ²	0.031	0.057	0.031

*, **, *** Denote significance at the 10%, 5%, and 1% levels, respectively.

innovatively combine city-level data with large-scale national micro-survey data (CGSS) and conduct a quasi-natural experiment based on the asymptotic implementation of the URRBMI using the time-varying difference (DID) method. The study finds that: (1) URRBMI has a significant negative impact on rural residents' SFP. (2) The impact of differentiated integration models on rural residents' SFP varies, with the multi-standard URRBMI model exerting a more depressive effect. (3) The negative effect of URRBMI on the rural residents' SFP will increase over time. (4) The effect of URRBMI on the SFP of rural residents is heterogeneous according to the income, age, health, and region of the rural household. Specifically, URRBMI has a significant negative effect on the non-poor, the non-older adults, the western region, and the healthy and non-healthy, while it does not have a significant effect on the SFP of the poor, the older adults, and the rural residents in the non-western region.

The findings of this study reveal that although the equalization medical insurance policy, designed with “fairness” in mind, aims to integrate rural and urban healthcare systems and address the inequality in medical resource utilization, relying solely on the expansion of the URRBMI with uniform contribution models and reimbursement rates is insufficient for achieving urban-rural equity. This singular approach has proved to be ineffective in enhancing rural residents’ perceptions of social fairness. The continuous revision and reform of social security systems represent a progressive journey toward achieving fairness. To genuinely improve the subjective fairness perceptions of rural residents, the URRBMI policy must be combined with supplementary government measures. Based on the study’s findings, the following policy recommendations are proposed:

Firstly, establish differentiated contribution standards based on actual income levels across regions and between urban and rural areas. This involves two key aspects: (1) Adjust the contribution standards for rural residents according to regional development conditions. On one hand, lower the personal contribution standards for rural residents in less developed areas to mitigate the trend of policy dropouts, safeguard the basic medical rights of low-income rural residents, and reduce the risk of poverty due to illness. On the other hand, use central or local government subsidies to compensate for the reduced contributions from rural residents, ensuring the total amount of the medical insurance fund in underdeveloped areas remains stable and preventing a decrease in local residents’ medical benefits. (2) Adjust individual contribution standards based on rural residents’ income levels. According to the income disparity between urban and rural residents, appropriately reduce the contribution standards for rural residents while increasing the contribution standards for urban residents. This approach balances the actual payment burden, maintains the consistency of contribution levels between urban and rural areas, and ensures the stability of the local medical insurance fund.

Secondly, adjust the reimbursement system to favor rural areas and residents. This includes gradually adding appropriate healthcare services for rural areas to the medical insurance reimbursement catalog, such as allocating part of the medical insurance fund to increase free physical examination programs for rural residents and gradually increasing the proportion of medical insurance funds used for rural healthcare institutions. Additionally, the government can allocate a portion of the medical insurance funds to support village and township health clinics in providing medication delivery services for chronic diseases, simplifying the process of obtaining medications for chronic illnesses and reducing transportation costs for rural residents. As the incidence of chronic diseases rises in rural areas, frequent trips to medical institutions impose high transportation and time costs on rural residents, especially those in remote areas³. Establishing a medication delivery service through village clinics can assist rural residents in more conveniently obtaining their required medications.

Lastly, implement differentiated reimbursement rates for various diseases, with a focus on common diseases among rural residents and those with low-income levels. This involves setting disease-specific reimbursement methods based on the severity of diseases, clinical treatment processes, and other characteristics in different regions. The government should set varying reimbursement standards based on disease incidence rates in different areas, raising reimbursement levels in regions with higher rates. Additionally, the reimbursement rate for common and chronic diseases at primary healthcare institutions should be increased. The treatment processes for these conditions are well-established, and the differences in treatment outcomes across healthcare levels are minimal. Directing patients with common and chronic diseases to primary healthcare facilities will reduce the regional financial burden and alleviate the pressure on top-tier medical institutions. This approach ensures that the medical insurance system effectively facilitates patient triage.

Data availability statement

The data used in this study is subject to the following licenses/restrictions: The Chinese General Social Survey (CGSS) data is a significant resource for studying Chinese society and is widely utilized in scientific research, education, and governmental decision-making. Access to the CGSS data requires registration and application through the official system, with approval needed to obtain the data. For further information or to request access, please contact the CGSS data management team at <http://cgss.ruc.edu.cn/>.

Author contributions

DL: Conceptualization, Formal analysis, Methodology, Software, Writing – original draft, Writing – review & editing. YC: Conceptualization, Data curation, Formal analysis, Project administration, Supervision, 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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³ According to national and provincial policies, “prescription limit management is implemented for outpatient chronic diseases, generally prescribing medications for 0.5-1 month at a time, with a maximum of 3 months.”

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Supplementary material

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Exploring public opinion on health effects of prepared dishes in China through social media comments

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Introduction: In the 2020s, particularly following 2022, the Chinese government introduced a series of initiatives to foster the development of the prepared dishes sector, accompanied by substantial investments from industrial capital. Consequently, China's prepared dishes industry has experienced rapid growth. Nevertheless, this swift expansion has elicited varied public opinions, particularly concerning the potential health effects of prepared dishes. Therefore, this study aims to gather and analyze comments from social media on prepared dishes using machine learning techniques. The objective is to ascertain the perspectives of the Chinese populace on the health implications of consuming prepared dishes.

Methods: Social media comments, characterized by their broad distribution, objectivity, and timeliness, served as the primary data source for this study. Initially, the data underwent preprocessing to ensure its suitability for analysis. Subsequent steps in this study involved conducting sentiment analysis and employing the BERTopic model for topic clustering. These methods aimed to identify the principal concerns of the public regarding the impact of prepared dishes on health. The final phase of the study involved a comparative analysis of changes in public sentiment and thematic focus across different time frames. This approach provides a dynamic view of evolving public perceptions related to the health implications of prepared dishes.

Results: This study analyzed over 600,000 comments gathered from various social media platforms from mid-July 2022 to the end of March 2024. Following data preprocessing, 200,993 comments were assessed for sentiment, revealing that more than 64% exhibited negative emotions. Subsequent topic clustering using the BERTopic model identified that 11 of the top 50 topics were related to public health concerns. These topics primarily scrutinized the safety of prepared dish production processes, raw materials, packaging materials, and additives. Moreover, significant public's interest was in the right to informed consumption across different contexts. Notably, the most pronounced public opposition emerged regarding introducing prepared dishes into primary and secondary school canteens, with criticisms directed at the negligence of educational authorities and the ethics of manufacturers. Additionally, there were strong recommendations for media organizations to play a more active role in monitoring public opinion and for government agencies to enhance regulatory oversight.

Conclusion: The findings of this study indicate that more than half of the Chinese public maintain a negative perception towards prepared dishes, particularly concerning about health implications. Chinese individuals display considerable sensitivity and intense reactions to news and events related to prepared dishes. Consequently, the study recommends that manufacturers directly address public psychological perceptions, proactively enhance production processes and service quality, and increase transparency in public communications to improve corporate image and people acceptance of prepared dishes. Additionally, supervisory and regulatory efforts must be intensified by media organizations and governmental bodies, fostering the healthy development of the prepared food industry in China.

KEYWORDS

prepared dishes, public opinion, social media comments, topic modeling, sentiment analysis

1 Introduction

In recent years, the convenience food market has expanded rapidly due to the accelerated pace of life and the impact of the epidemic, driving demand for convenient food products (1, 2). The global convenience food market revenue may reach 653.6 billion US dollars in 2024, and most of the revenue, about 154 billion US dollars will come from China, accounting for approximately 23.56% of the total market (3). According to statistics, the market size of Chinese prepared dishes reached 48.54 billion US dollars in 2022, with an increase of 21.3%. China's prepared dishes market is also expected to maintain a high growth rate in the future, and the scale of the prepared dishes market will reach 1,072 billion yuan in 2026 (4).

This growth has made prepared dishes a hot spot in both academic and industrial sectors. Existing studies have elucidated the definition that prepared dishes are a general term for foods that are convenient to cook, people do not need to cook or simply cook to eat (5, 6), which is finished or semi-finished dishes made with one or more agricultural products as the main raw materials and are pre-processed or pre-cooked and pre-packaged through standardized flow operations (7, 8). Furthermore, the classification, production, preservation and other technologies of prepared dishes were researched (9–15). Particularly in the context of China's rapidly growing prepared dishes market, researchers have begun to focus on public opinion regarding these products. Various studies have revealed, through questionnaire surveys and in-depth interviews, the factors including perceived risk and trust (16), attitude, subjective norm, and perceived control (17), different consumer cognition and product features (18–20), affecting the consumption intention of prepared dishes. Also, market research reports have been driven by consumption events. For example, during the 2022 Chinese New Year, a survey indicated high purchase rates of prepared dishes (over 80%), with 60% choosing them for the Chinese New Year dinner. Despite widespread acceptance, over 60% of consumers expressed dissatisfaction, pointing to a gap between product offering and consumer expectation (21). The reason for such contradictory situations is closely related to Chinese society and food culture. In the view of most Chinese, dishes not only meet the survival requirements of human beings but also are closely related to people's attitudes towards life and artistic aesthetics, so they highly value

individuality and oppose standardization. Following Chinese family traditions, personally cooking for family members is also important to family ethics. For complex reasons, most Chinese prefer to rely on natural food and condiment raw materials and reject chemical synthetic materials. Most Chinese think additives are very unhealthy. At the same time, Chinese people excessively reject long-term preserved food for nutrition loss during the preservation process and advocate fresh ingredients. In addition, Chinese people pay more attention to their offspring's health than their own. So Chinese consumers' current high acceptance of prepared dishes is a helpless compromise in the face of social changes and life pressures. Thus, it is easy to understand why the recent introduction of prepared dishes on campus has raised concerns about nutritional adequacy, leading the majority of people to hold an opposing attitude, particularly parents worried about their children's health (22). Subsequently, the dialogue around public health concerns about prepared dishes has become increasingly prominent. Thus, public perceptions regarding the health effects of prepared dishes have also become an imperative concern in China.

However, previous related work has not focused sufficiently on public opinion regarding the health effects of prepared dishes and still relies on traditional data collection methods such as closed-ended questionnaire surveys, which have limitations in terms of quantity, timeliness, duration, geographic scope, richness, and objectives (23, 24). While survey experiments play a vital role in understanding people perceptions, they might be influenced by biases such as social desirability bias, response bias, and common method bias (25, 26). Additionally, some psychometric questionnaires struggle to capture human emotions, which are subjectively experienced in specific contexts, making their objective assessment difficult (27, 28). Consequently, it becomes challenging to grasp prompt public opinion on health effects of prepared dishes and observe the constant change in attention. Some scholars argue that adoption of more objective data and research methods in the studies on food industry can help to resolve these problems (29, 30). Fortunately, with the rapid progress of information and communication technology, especially influential social media platforms, myriad user-generated contents (UGCs) are recorded, stored, and accumulated, forming an important type of big data, which are publicly available, easily collected, low cost,

spontaneous, passionate and insightful (31). According to the report, the number of people using social media worldwide has reached 4.74 billion in 2022 and is expected to reach 5.85 billion by 2027, affecting more than half of the world's population (32). People find social media platforms convenient to share their opinions (33), sentiments (34), attitudes (35), purchase intention (36), etc., through comments by natural language. Social media comments are notable not just for their depth and usability but also for the automated retrieval of this UGCs, representing a significant technological advancement in public psychological perception analysis (37, 38), and can serve as a valuable supplementary data source for research in food industries (39, 40). These dynamic data augments traditional survey methodologies by offering a deeper understanding, tracking evolving trends, temporal patterns, and spatiotemporal patterns across various scales—particularly beneficial in areas where gamut surveys are lacking (41, 42).

Recently, in the food domain, mining and analyzing user-generated comment text from social media platforms can provide us with valuable insights into public opinion analysis for health effects of prepared dishes (30, 40). Scholars could explore the public attitude towards organic foods through Twitter posts (29), natural food products opinion expressed on social media comments (43), “coffee’s effects on health” information about food product attributes perception sharing on Twitter (44) and public perceptions regarding alternative meat through Sina Weibo (45). Simultaneously, the application of natural language processing (NLP) methods—including text preprocessing, topic modeling, sentiment analysis, and machine learning or deep learning (24, 29, 30, 40, 44–47)—to food-related text data analysis enables scholars to extract valuable insights from comment corpus without the cumbersome computational work (48, 49). In contrast to conventional way to collect peoples’ responses, social media comments and NLP approaches could deliver us current public perception with big data dynamically and get real-time feedback which is very vital in this fast-changing world. Nonetheless, the Chinese public opinion on health effects of prepared dishes has not been fully studied, particularly using objective data from social media.

Therefore, compared to previous research, this study pivots towards a fresh perspective by harnessing the expansive reach and immediacy of social media platforms to capture and analyze public opinions on the health effects of prepared dishes in China. By focusing explicitly on mining public opinions from social media, this study not only taps into real-time public perception but also broadens the scope of analysis beyond the limitations of conventional data collection methods. It presents an opportunity to explore the multifaceted nature of public discourse surrounding the health implications of prepared dishes, capturing a broad spectrum of opinions. This approach enables a timely and detailed examination of public’s concerns, preferences, and expectations, providing valuable insights that could influence policy-making, inform industry strategies, and encourage the development of healthier convenience food options.

The remainder of the paper is structured to unfold as follows: Section 2 introduces the methodology employed for collecting and analyzing social media comments to gauge public opinion on the health effects of prepared dishes in China. Section 3 discusses the findings, shedding light on the public’s health concerns. Section 4 concludes with a summary of key insights, offering implications for the prepared dishes industry and public health strategies. Section 5 analyzes the study’s limitations, introducing future research directions to understand public opinion and navigate the complexities of public health perceptions.

2 Research design and methods

2.1 Research design

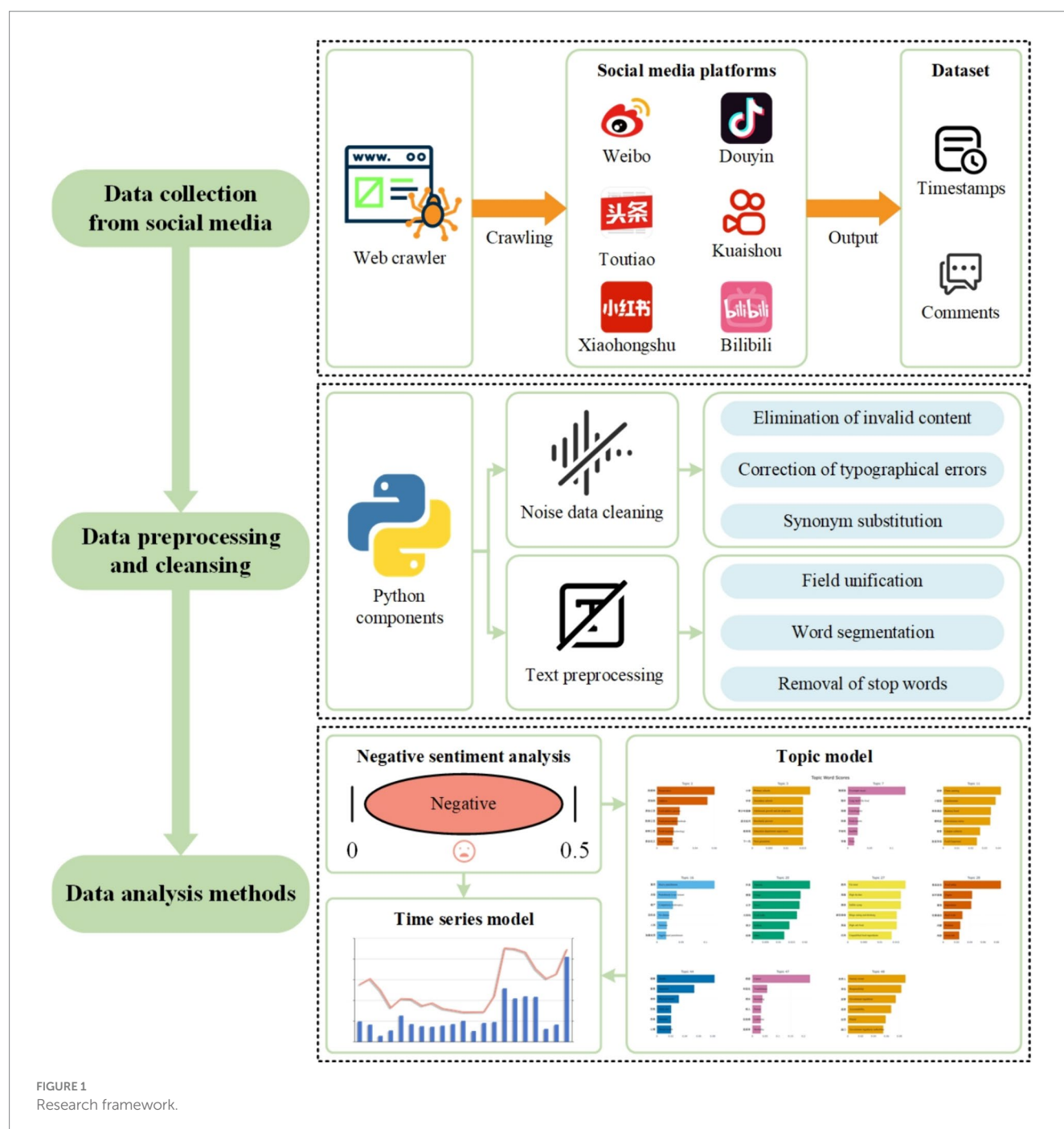
This study introduces an analytical framework for big data, emphasizing the importance of examining all comments on social media platforms to capture a comprehensive public opinion on the health effects of prepared dishes in China. Theoretical foundations suggest that including diverse perspectives, regardless of individual prominence, allows for a more representative aggregation of opinions (29, 41, 45, 50). To facilitate this extensive analysis, the study uses a set of NLP techniques to increase automation efficiency. Connecting theory to practice, data analysis in this context is carried out using two distinct methodologies: top-down and bottom-up (51, 52). In a top-down approach, the process starts with identifying a specific problem and using domain-specific knowledge to form hypotheses, which are later tested through data analysis. In contrast, this study uses a bottom-up approach, avoiding predetermined hypotheses and instead focusing on thorough data collection and analysis. This method depends on using algorithms to discover hidden patterns, providing insights directly drawn from the data.

Continuing from the methodological foundations laid out, the study’s focus shifts to the application of these principles in understanding the opinions of the Chinese public towards health effects of prepared dishes. By not presupposing any initial hypotheses, the research remains open to discovering authentic public opinions, irrespective of the data’s origin. This method is especially useful for examining sentiment trends and health topics in negative comments as they change over time. The transition from theoretical underpinning to practical application informs the subsequent steps in the research process. After establishing the methodology, the selection of social media comments for analysis was guided by the objective to capture a wide range of opinions. This objective consideration shapes the overall research design, which is detailed in the subsequent sections covering data collection, preprocessing, and analytical techniques. Each phase of the workflow is interconnected, ensuring that the study’s design and execution are coherent and aligned with the overarching goal of understanding public’s opinion about the health effects of prepared dishes in a comprehensive and unbiased manner. Based on the above thoughts and methods, the research framework is depicted in Figure 1, outlining the methodological steps as follows:

Step 1: data collection from social media. Following the research goals, the initial step involves selecting social media platforms (e.g., Weibo, Toutiao, which are Twitter-like social media platform in China) based on their influence and data availability (53, 54). This stage includes determining the types of data to be collected and the methods for data collection.

Step 2: data cleansing and preprocessing. This crucial step enhances data quality and reliability by eliminating extraneous information, which prepares the data for analysis.

Step 3: data analysis methods. Adopting a systematic approach to data analysis, this research employs various methods, including sentiment analysis, topic modeling, and time series analysis, to derive meaningful patterns from the preprocessed data (55, 56). Initially, sentiment analysis is conducted using the SnowNLP natural language processing tool, specifically focusing on the sentiment intensity regarding prepared dishes. Subsequent to sentiment analysis, neural topic modeling, utilizing BERTopic model suitable for comment texts, is



applied to cluster topics for negative comments on prepared dishes. The final analytical step involves employing a time series model to examine fluctuations in sentiment and topics. In this case, it could facilitate a discussion on changing public opinions towards prepared dishes.

2.2 Data collection

Plenty of social media comments about the Chinese public opinion on the health effects of prepared dishes should be collected to reach the research goal. The first step involves identifying appropriate social media platforms as data sources. Considering China's emphasis on data sovereignty, the adoption of strict data control policies such

as Cybersecurity Law of the People's Republic of China (57), the development of Internet protection protocols within physical territorial boundaries by "splinternet," which restrict Internet access for Chinese citizens to social media platforms in other countries (58, 59), and the varied preferences in social media usage, this research draws data from six mainstream Chinese social media platforms, as detailed in Table 1. Among them, Weibo, established in 2009, is an early internet social platform allowing users to share succinct, real-time updates. According to Weibo's financial report for the third quarter of 2023, it boasted 593 million monthly active users. Toutiao, renowned for its data mining-based recommendation engine, reports 260 million monthly active users. Xiaohongshu, a platform fostering community content, has seen its active monthly paying users exceed

TABLE 1 The summary of comments collection and preprocessing from social media platforms.

Social media platform	Collected comments	Preprocessed comments	Percentage (%)
Weibo	48,021	18,370	9.1
Toutiao	90,709	38,858	19.3
Xiaohongshu	32,584	12,673	6.3
Douyin	236,619	89,384	44.5
Kuaishou	115,482	21,789	10.8
Bilibili	82,785	19,919	9.9
Total	606,470	200,993	100.0

200 million since 2023, with 70% being post-1990s individuals. Douyin and Kuaishou, leading China's short video publishing sector, reports 730 million monthly and 654 million active users until 2024. Bilibili, a video community popular among the youth, averages 336 million monthly active users (60). People could share their views, attitudes, information, and ideas at any time through the above platforms, sending out text, pictures, and videos; the users could also repost these contents with the option of adding their comments.

Upon selecting the social media platforms and data types, the data collection methodology warrants further consideration. The web crawler, an automated tool for web information retrieval, has been utilized to extract social media data effectively (61–63). It navigates within defined boundaries to isolate pertinent information, discarding irrelevant content (64). Starting from a specific URL, the crawler accesses linked URLs to collect and parse valuable data from each page. Utilizing the Requests3 library, the crawler navigates search pages within set parameters, receiving HTML files from the internet, which are then locally saved (65). The keyword “预制菜” (yuzhicai) was chosen to refine the search and tailor the content crawling process. The resulting dataset comprises comments with essential attributes like “created_at” (comment timestamp), “text” (comment content) and platform_name, facilitating the collection and storage of data pertinent to prepared dishes. Subsequently, this study uses Python crawler programming to capture 606,470 public social media comments about prepared dishes from 13 July 2022 to 25 March 2024, as shown in Table 1.

2.3 Data preprocessing

2.3.1 Noise data cleaning

In the process of data collection from various social media platforms, the acquisition of some invalid and incorrect data is inevitable due to the inherent diversity and unstructured nature of these sources. This can result in the initial dataset being non-standard and unsuitable for direct analysis. Consequently, in alignment with methodologies outlined in prior research (40, 66), this study employed Python 3.10 to preprocess and cleanse a dataset comprising 606,470 original comments. This step was crucial to eliminate irrelevant content and rectify inaccuracies, ensuring the integrity of the subsequent analysis. The data cleaning process encompassed several key actions: (1) Elimination of invalid content: The dataset was purged of comments containing spam, irrelevant links, excessive punctuation, emoticons, and special characters, which do not contribute to the study's objectives. A web cleanup technology was employed to systematically filter out such content, ensuring that only relevant data

was retained for analysis. (2) Correction of typographical errors: Given the informal nature of communication on social media platforms, typographical errors are common. These errors were identified and corrected to maintain the linguistic accuracy of the dataset. This step is essential for ensuring the reliability of text-based analysis. (3) Synonym substitution: The Chinese language is characterized by a rich synonymy, which can introduce ambiguity into text-based data. To enhance the efficiency of the text mining model and reduce potential ambiguities, synonyms within the comments were standardized according to the context provided by the original data.

2.3.2 Text preprocessing

Comments on social media platforms tend to be colloquial, lacking standardized structure and format. To facilitate meaningful analysis, the data must undergo extensive preprocessing, which includes: (1) Field unification: Due to varying data formats across social media platforms, it was necessary to standardize field names for essential elements like comment content, topics, and timestamps during collection. This harmonization ensures consistency across the dataset, making it more manageable and analyzable. (2) Word segmentation: For this task, we utilized Jieba, a Chinese text segmentation tool within the Python programming framework. Jieba offers a comprehensive dictionary for segmenting Chinese text into meaningful phrases. Importantly, it allows for dictionary customization, enabling the inclusion of specialized terms not present in the default dictionary. In this study, culinary-related terms were added to enhance the precision of text analysis in the context of prepared dishes. (3) Removal of stop words: The study employed a stop word list to filter out irrelevant words from the comments. Stop words, such as “this” and “that,” are commonly excluded in natural language processing to conserve storage and enhance the efficiency of information retrieval systems (67, 68).

Through above data preprocessing steps, the raw data was transformed into a unstructured corpus reflecting public attitudes towards prepared dishes, comprising 200,993 comments as detailed in Table 1. This unstructured dataset serves as a foundation for the subsequent analysis, ensuring both the relevance and the quality of the insights derived.

2.4 Data analysis methods

Natural language processing (NLP), a subset of machine learning, enables researchers to analyze, manipulate, and potentially generate human language. This study employs text-mining techniques such as

sentiment analysis, topic modeling and time series model to automatically identify and classify patterns within large datasets, generating insights from unstructured text corpora.

2.4.1 Sentiment analysis

Sentiment analysis, also known as opinion research, investigates linguistic features in terms of sentiment. It is a process that uses text analysis and computational linguistics to systematically identify, extract, quantify, summarize, and analyze subjective texts with sentimental overtones, helping researchers to elucidate the relationship between the formation of public opinions (29, 41, 45) and events (55, 69). At present, the methods of sentiment analysis mainly include dictionary-based and rule-based methods, as well as methods based on statistical machine learning (42). Dictionary-based sentiment analysis primarily involves training a sentiment dictionary. This paper utilizes the National Taiwan University Semantic Dictionary (NTUSD) and HowNet Dictionary, both widely used for sentiment analysis in Chinese, to develop positive and negative sentiment dictionaries and investigate public sentiments towards prepared dishes.

The sentiment value calculation and sentiment orientation assessment employ the SnowNLP library, a Python-based natural language processing component, has been widely applied in sentiment analysis research of social media texts (40, 42). The workflow of SnowNLP, as shown in Figure 2, first passes the Chinese text corpus to the module. Subsequently, SnowNLP will traverse the words in the text and look for any matches in the sentiment dictionary. Once matched, the emotional polarity (positive or negative) of the words will be determined and the number of positive and negative emotional words in the text will be calculated. In order to analyze emotions more accurately, SnowNLP also considers the relationships between words and sentence structures, such as the influence of negative words. Calculate sentiment scores based on the number, polarity, and context of emotional vocabulary SnowNLP to represent the intensity of emotions.

2.4.2 Topic modeling

The endeavor of topic modeling involves leveraging statistical techniques to unearth the latent semantic frameworks within extensive text corpora (70). Grasping the central topics present in an array of texts, encompassing news articles, social media contributions, and various commentaries, furnishes valuable perspectives and

strategic intelligence crucial for managerial decision-making processes across diverse sectors (29, 47, 50). This analytical approach not only demystifies the content's inherent topics but also facilitates a nuanced understanding, enabling organizations to navigate through the informational deluge with informed precision.

The classical approaches to topic modeling predominantly encompass Latent Dirichlet Allocation (LDA) and Probabilistic Latent Semantic Analysis (PLSA), which have been recognized as the most prevalent methodologies in the field (71, 72). Despite their widespread adoption, these models exhibit several limitations, including susceptibility to stop words, disregard for word order, the prerequisite of pre-calculating the optimal number of topics, and a lack of suitability for analyzing short texts such as social media comments. In response to these challenges (73), introduced BERTopic, a novel approach that leverages BERT embeddings alongside c-TF-IDF to generate dense clusters, facilitating the interpretation of topics and ensuring the preservation of significant words within topic descriptions. This methodology has demonstrated considerable efficacy in topic modeling across diverse domains (74–77). Consequently, as depicted in Figure 3, the present research endeavors to apply the BERTopic model to the analysis of social media comments pertaining to prepared dishes, aiming to mine the underlying topics. BERTopic generates coherent topics through follow steps:

1. Document embeddings. BERTopic uses the Sentence-BERT (SBERT) framework. Therefore, in the process of mining social media comments related to prepared dishes, BERT embedding word vectors are first used, which preserve context sensitivity and relationships, and then represent the comment text as points or vectors in a continuous vector space.
2. Document clustering. First, the Uniform Manifold Approximation and Projection (UMAP) is to reduce the dimensionality of embeddings, has been shown to better preserve both local and global data features, which has three calculation processes.
 - Constructing the K-Nearest Neighbor (KNN) graph. For each point m in a high-dimensional dataset, find its nearest K nearest neighbors. This can be achieved by calculating the distance between point m and all other points in the dataset, and then selecting the nearest K points. For point m and one of its nearest

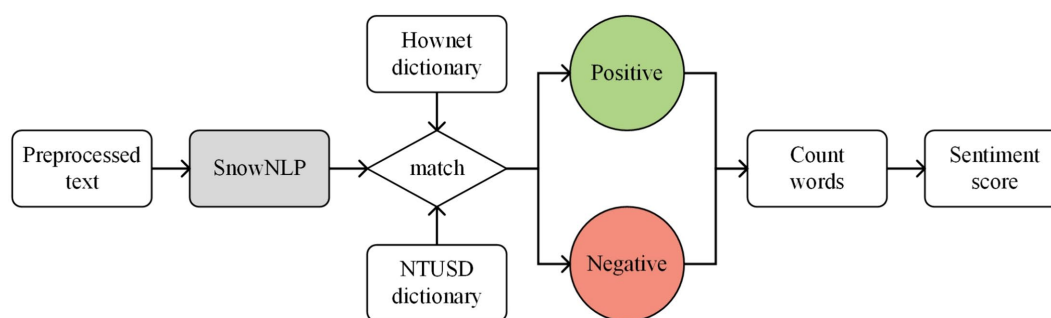


FIGURE 2
Flowchart of SnowNLP.

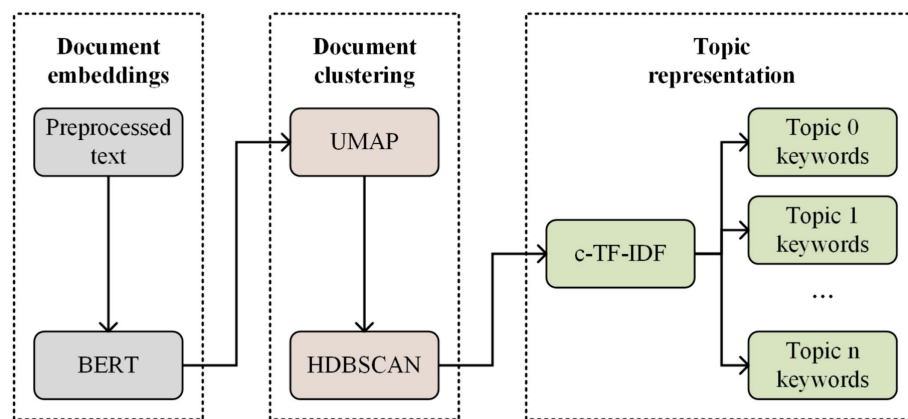


FIGURE 3
Workflow of BERTopic.

neighbors n , the distance $d(m, n)$ can be calculated using Euclidean distance, illustrated in Equation 1.

$$d(m, n) = \sqrt{\sum_{i=1}^D (x_{m_i} - x_{n_i})^2} \quad (1)$$

Where D represents the dimensionality of the data, x_m and x_n are the coordinate values of point m and n in the i -th dimension, respectively.

- Calculating high-dimensional joint probabilities. In order to establish similarity relationships between high-dimensional samples, UMAP adopts a joint probability distribution. The calculation process is shown in Equation 2.

$$P(n/m) = \frac{\exp(-d(m, n)/\sigma_m)}{\sum_{k \neq m} \exp(-d(m, k)/\sigma_m)} \quad (2)$$

The joint probability $P(n/m)$ is computed based on the distance between point m and its neighbors, with σ_m serving as a local scale parameter that adjusts the sensitivity of distances within the neighborhood of point m .

- Adjusting for probability consistency. After the joint probability calculation of all comment data points is completed, in order to ensure the consistency of probabilities between any two data points, an expression is introduced in Equation 3).

$$B = A + A^T - A \odot A^T \quad (3)$$

Among them, A represents the weighted adjacency matrix composed of all $E(m, n)$, \odot represents the Hadamard product of the matrix, and B is the modified weighted adjacency matrix, used to ensure consistency and symmetry between data points.

Subsequently, the reduced embeddings are clustering used the Hierarchical Density-based Spatial Clustering of Applications with Noise (HDBSCAN), an advanced version of DBSCAN that using a soft-clustering approach allowing noise to be modeled as outliers. This prevents unrelated documents to be assigned to any cluster and is

expected to improve topic representations, which has two calculation processes.

- Modeling distance probabilities in low-dimensional space. In the UMAP algorithm, the distance probability modeling of low dimensional space is achieved through the curve family

$$\frac{1}{1 + s \cdot c(2t)}, \text{ where } s \text{ and } t \text{ are hyperparameters used to adjust}$$

the sensitivity of the model and maintain the topological structure. The probability function constructed in low dimensional space is specifically expressed in Equation (4).

$$F(m, n) = \left(1 + s(y_m - y_n)^{2t}\right)^{-1} \quad (4)$$

Among them, $y_m - y_n$ represents the distance between any two data points y_m and y_n in a low dimensional space, reflecting the relative positional relationship between comment data points after dimensionality reduction.

- Cross-entropy loss function. In order to ensure that the reduced dataset can maintain the structural characteristics of the original dataset as much as possible, it is necessary to optimize by minimizing the difference in similarity distribution between data points in high-dimensional space and low dimensional space. This difference can be quantified through the cross entropy loss function, which is used to measure the similarity between two probability distributions. Its specific expression is shown in Equation (5).

$$L = - \sum_{m, n} \left[E(m, n) \log(F(m, n)) + (1 - E(m, n)) \log(1 - F(m, n)) \right] \quad (5)$$

In this expression, $E(m, n)$ represents the joint probability between data points m and n in high-dimensional space, while $F(m, n)$ is the simulation probability between corresponding points in low dimensional space. By optimizing this loss function, points in low dimensional space can be adjusted to better reflect the data structure in high-dimensional space, especially in

maintaining the relative distance and distribution pattern between data points.

3. Topic Representation. The c-TF-IDF was used to evaluate the degree of importance of words within a clustered cluster, generates topic representation. The c-TF-IDF of a single word in topic t was calculated. The frequency of each word w for each topic $t(w_t)$ was divided by the total number of words $n(n_t)$ in the documents of topic t , which is the extension of TF-IDF. Subsequently, the average number of words m in each topic t was divided by the total frequency of word w across all i topics. The calculation of c-TF-IDF is shown in Equation (6).

$$c\text{-TF-IDF}_t = \frac{w_t}{n_t} \times \log \left(1 + \frac{m}{\sum_{j=1}^i w_j} \right) \quad (6)$$

2.4.3 Time series model

Time series data can reflect the dynamic characteristics of the described phenomenon over time. Peoples' sentiments orientation and discussed topics towards the health effect of prepared dishes can be reflected in publics' opinion, including positive or negative sentiments and the main topic focus of attention, and their changing trends for prepared dishes. Then, continuous data collection across time allows time-series analysis, which is significant in exploring a corpus for expressing public opinions of longitudinal data. In order to better understand publics' opinion to various topics and sentiments changes of prepared dishes, this paper employs the time-series concept to divide the research period into time intervals using the captured social media comments, refers to the previous research (40, 78) and adopts the Mann-Kendall method to analyze the attitude changes of prepared dishes. The Mann-Kendall trend test is a non-parametric test method proposed by Mann and Kendall (79, 80), also known as the distribution-free test. It is suitable for analyzing time series with continuous increasing or decreasing trends (monotonic trends) whose advantage is sample data does not need to satisfy the assumption of normal distribution, nor is it disturbed by individual outliers. Therefore, it is widely used in academic research related to trend testing.

As follow, set a time series X as the statistic H in the Mann-Kendall test. The calculation of H is shown in Equations (7) and (8).

$$H = \sum_{f=1}^{k-1} \sum_{p=f+1}^k \text{sgn}(x_f - x_p) \quad (7)$$

$$\text{sgn}(x_f - x_p) = \begin{cases} 1 & \text{if } x_f - x_p > 0 \\ 0 & \text{if } x_f - x_p = 0 \\ -1 & \text{if } x_f - x_p < 0 \end{cases} \quad (8)$$

Among them, k represents the total number of time series data points, x_f represents the data point of former time, and x_p represents the data point of present time.

The following formula can be obtained by standardizing the statistic H , as shown in Equation (9).

$$C = \begin{cases} \frac{H-1}{\sqrt{\text{var}(H)}} & \text{if } H > 0 \\ 0 & \text{if } H = 0 \\ \frac{H+1}{\sqrt{\text{var}(H)}} & \text{if } H < 0 \end{cases} \quad (9)$$

The statistic C obeys a standard normal distribution. If the p -value is less than the significance level ($\alpha = 0.05$), it indicates a significant increasing or decreasing trend.

3 Results and discussion

3.1 Results

3.1.1 Public sentiment analysis of prepared dishes

Following the preprocessing procedure, this study obtained a total of 200,993 eligible comments, which were then subjected to sentiment scoring using SnowNLP. SnowNLP assigns scores ranging from 0 to 1, representing the probability that a comment has a positive sentiment. In this study, comments scored within the range of [0, 0.5] were classified as negative sentiment, while those scored in the range of [0.5, 1] were classified as positive sentiment. Public sentiment orientation on prepared dishes is show in Figure 4; negative comments accounted for 64.11%, while positive comments took up 35.89%. It is evident that the Chinese public holds a majority of negative sentiments towards prepared dishes.

Then, in Figure 4, the left side shows the sentiment distribution across various score segments, revealing a significant disparity in how sentiments are distributed. This detailed analysis of sentiment scores highlights the varying degrees of emotional expression among the comments. Concerning the comments with negative sentiments, a substantial majority of the comments fall within the negative range of [0.0, 0.2], suggesting a strong prevalence of negative emotional expressions regarding prepared dishes. Conversely, the positive sentiments, primarily found within the range of (0.6, 0.9]. This can be attributed to a substantial portion of individuals acknowledging the benefits of prepared dishes, such as convenience, speed, and ease of storage (16, 19). Additionally, given China's large population, the prepared dish industry is poised to become a substantial sector with numerous stakeholders (17, 18, 20).

It is generally known that people exhibit negative emotions when voicing concerns about their health (22). Consequently, it becomes essential to delve deeper into these expressions, particularly focusing on topics related to public health present within the negative comments. Therefore, in this step, a total of 128,856 negative sentiment comments related to prepared dishes have been identified. The next step will involve analyzing topics related to public health within these negative comments.

3.1.2 Topic analysis of negative comments

In the second step, the BERTopic model was employed to conduct a cluster analysis of 128,856 negative sentiment comments. This study identified and analyzed the 50 most frequently occurring topics, labeled Topic0 to Topic49. Topics beyond Topic49, starting from Topic50, exhibited a drop in the proportion of negative affective

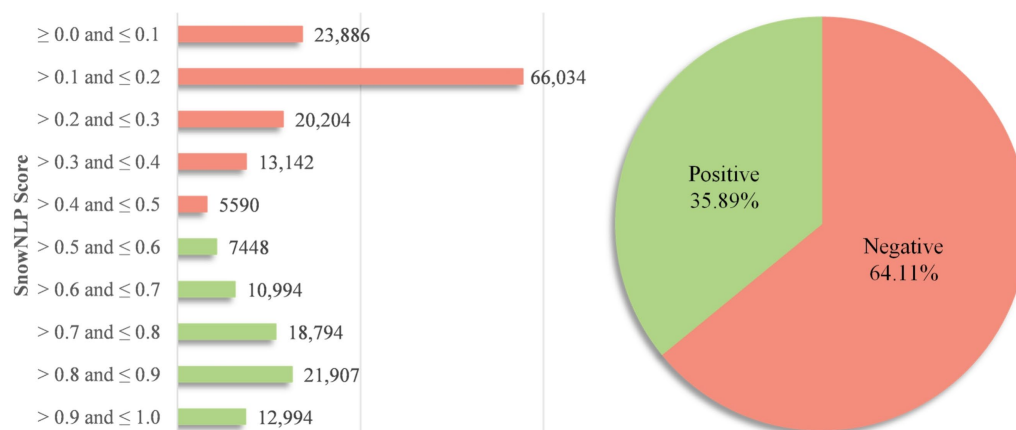


FIGURE 4
Sentiment distribution of all comments.

comments to less than 2%. Given this minimal contribution to the study's objectives, these topics were deemed peripheral and consequently excluded from further analysis.

Subsequently, to focus on the effects of the Chinese public on the health implications of prepared dishes, it is necessary to select health-related topics from the first 50 topics for further analysis. Due to the inherent variability and richness of language used in social media comments, where multiple expressions may convey similar meanings, this study chose to respect the diversity and complexity of such language by not standardizing or altering it. This approach acknowledges the natural arbitrariness and richness of user-generated content, allowing for a more authentic analysis of sentiment and expression. The selection of topics for analysis adheres to several guiding principles: (1) The topics must contain keywords explicitly related to the production and consumption of prepared dishes, or directly pertain to health, disease, and potential harm, ensuring relevance to the core subjects of investigation. (2) Due to the complex nature of the production and consumption chains of prepared dishes, topics that include keywords associated with these processes are also incorporated. Special emphasis is placed on scenarios linked to educational settings and adolescent health, recognizing the heightened sensitivity and potential impacts in these areas. (3) Topics concerning market supervision, regulatory measures, and the enforcement of penalties for production and marketing practices detrimental to health are also selected. This inclusion reflects the importance of governance and accountability in safeguarding public health within the prepared dish industry.

Based on the above principles, 11 topics were found to be closely related to public health concerns, as depicted in Figure 5. Meanwhile, the proportion of these 11 health-related topics in all negative affective comments is shown in Figure 6.

For the 11 selected topics, an analysis of the corresponding keywords under each topic provides insight into the public's concerns about the health impacts of prepared dishes. Figure 5 illustrates several key findings:

Firstly, Topic 2, the third most discussed topic, includes keywords such as "Preservative, Additive, Food chemical," which reflect people's doubts about the health effects of using preservatives and various additives in the production of prepared dishes. Then, Topic 7 features words like "Overnight meals, Inedible, Toxic," emphasizing concerns about the safety and health implications of the long-term storage process

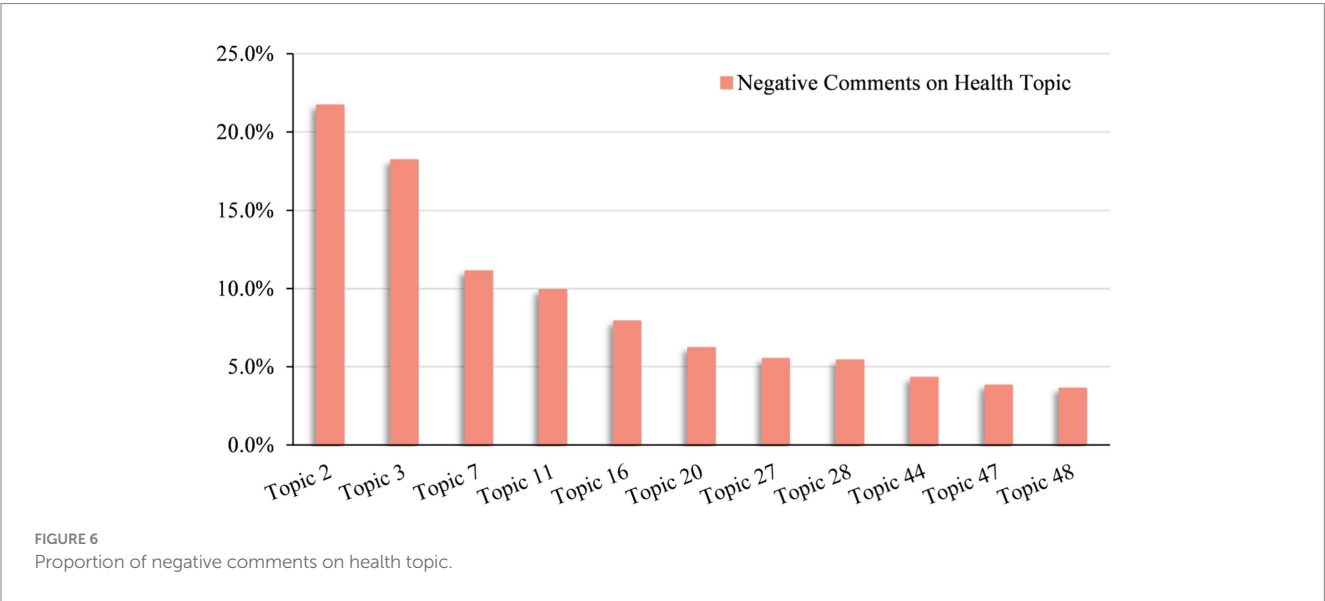
typical of prepared dishes. Topic 27 includes terms such as "Fat meat, High salt food, Edible syrup, Unqualified food ingredients," indicating public concerns over the use of ingredients that are high in sugar and fat, and even potentially unsafe animal tissues in pre-packaged food products. These three topics reflect legitimate people concerns arising from the technical aspects of prepared dishes and the potential health issues associated with their production processes.

Furthermore, by analyzing keywords such as "Adolescent growth and development, Resolutely prevent, Physical health, Harmful, Mental health, Cancer, Leukemia" in Topics 3, 44, and 47, it becomes apparent that people are discussing the detailed impact of prepared dishes on health, linking an increasing incidence rate of cancers and other diseases in young people to these products.

Additionally, Topics 3, 11, and 20 address the environments where people encounter prepared dishes, with keywords like "Primary schools, Secondary schools, Chain catering, Luncheonette, Takeout, and Food stalls." These discussions reveal that prepared dishes are commonly found in small restaurants, chain convenience stores, and food stalls, with takeout being the most prevalent distribution method. There is particular concern over the extensive use of prepared dishes within the canteens of public primary and secondary schools, which has elicited strong negative reactions.

Then, according to the third principle of topic selection, keywords such as "Food safety, Urgent, Importance, Heavy punishment, Factory owner, Government regulation, and Accountability" found in Topics 28, 16, and 48 underscore significant concerns about the impact of prepared dishes on health. These topics identify the potential harms of prepared dishes as stemming from a perceived lack of corporate social responsibility and the profit-driven moral degradation of business owners. Consequently, there is a public demand for increased media oversight to prevent unethical business practices and for government regulatory bodies to intensify the severity of penalties for such malpractices. There is also expressed dissatisfaction with the current laws and regulations that govern these enterprises.

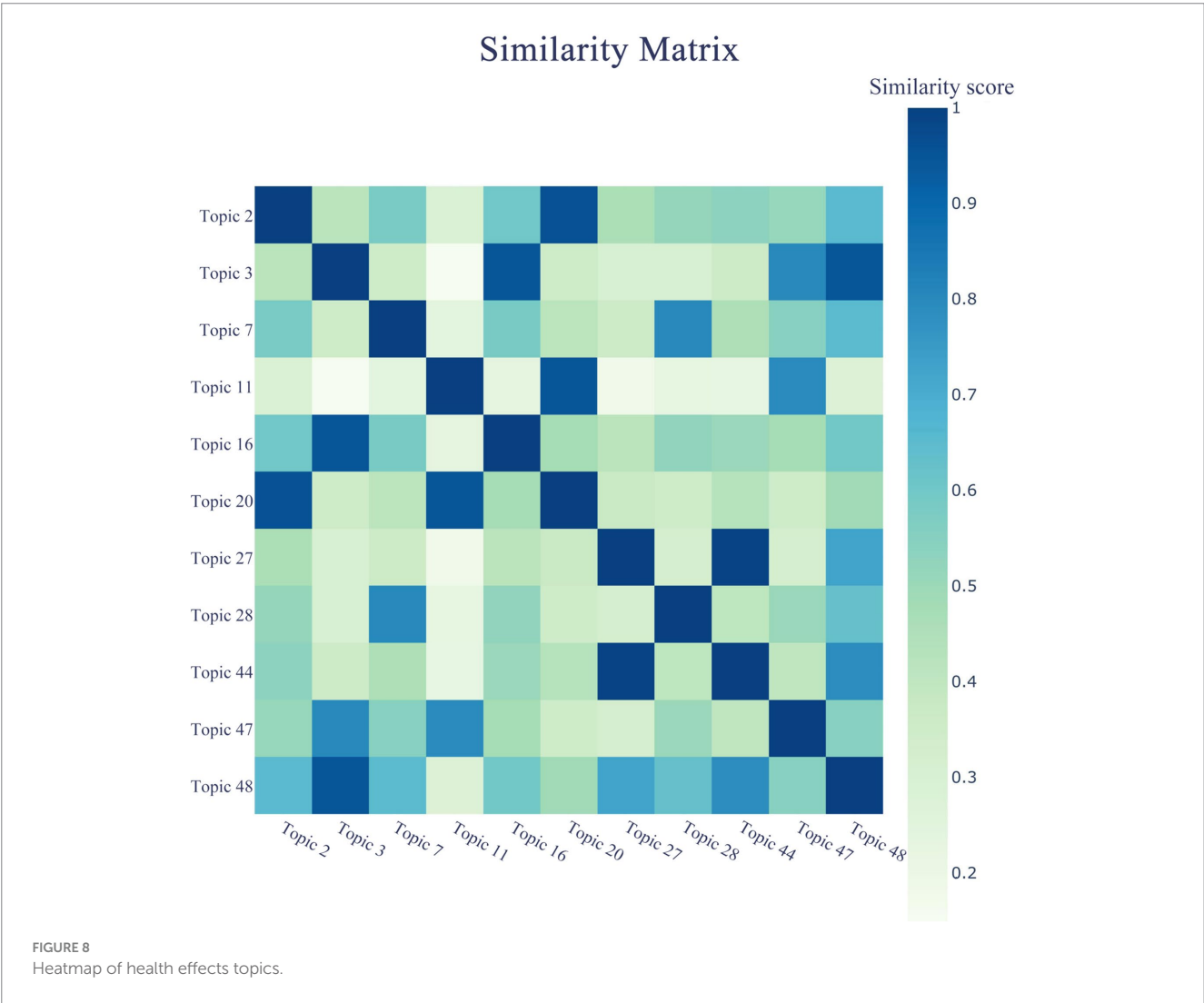
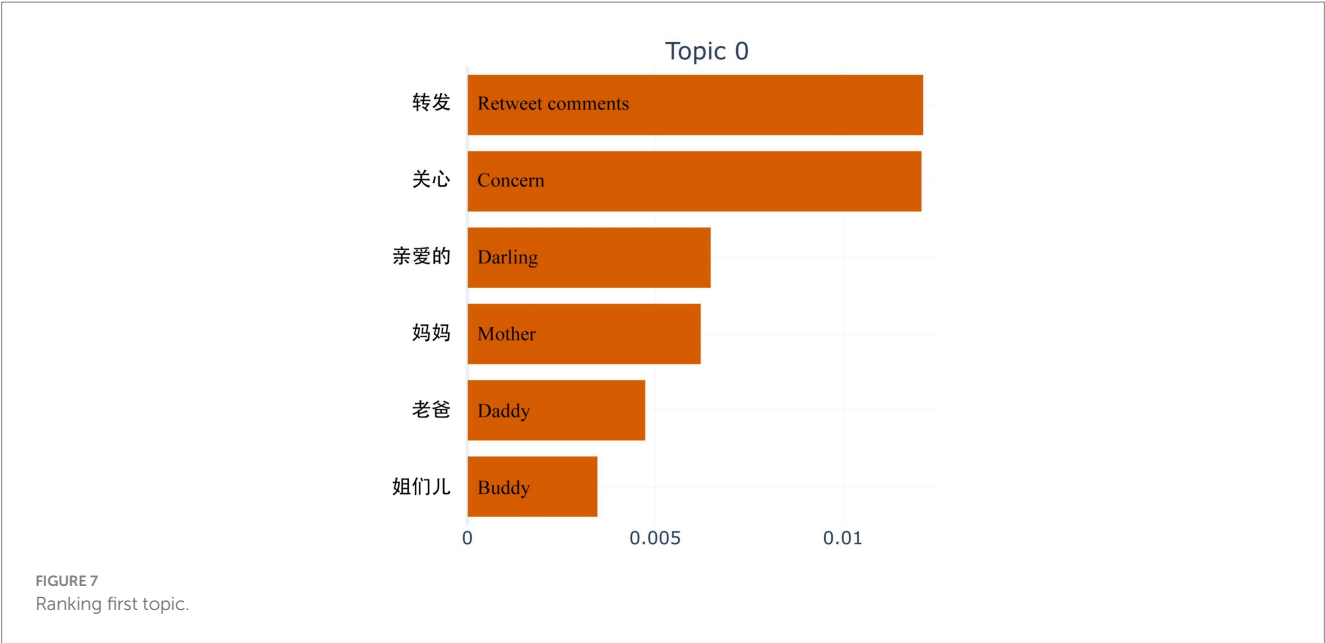
Finally, although Topic 0 was not selected as a health-related topic, it ranks first and needs to be discussed separately in this study. In Figure 7, Topic 0 corresponds to the importance level of the corresponding keyword, and "Retweet comments" ranks first, indicating that a significant people belief that prepared dishes pose



health risks. Retweeting these concerns to friends and relatives is seen as a protective measure in situations where individuals feel alarmed and powerless to effect change directly.

An equally noteworthy experimental result is the heatmap of negative comments on the health effects of prepared dishes, which provides relevant information on public focus areas regarding the health effects of prepared dishes. This tool helps establish an intuitive understanding of the relationship between these focus topics.

In Figure 8, the depth of colors indicates the degree of correlation or similarity between topics. Topic 27 includes words such as “Fat



meat, High salt food, Edible syrup, Unqualified food ingredients,” while Topic 44 contains phrases like “Health, Important, Physical health, Daily diet.” With a correlation score of 0.9, this suggests that the public generally believes prepared dishes, which are high in fats, sugars, oils, and salts and contain low-quality ingredients, pose a serious threat to physical and mental health. Similarly, Topics 2 and 20 include terms such as “Preservative, Additive, Food chemical, Takeout, Cheap, Never, and Food stalls,” with the same high correlation score of 0.9. This indicates that the production and processing technologies of prepared dishes are closely linked to the environments in which they are produced, significantly impacting public health perceptions and influencing negative public comments.

Furthermore, the correlation score between the phrases “Primary schools, Secondary schools, Adolescent growth and development, Resolutely prevent” in Topic 3, “Factory owner, Responsibility, Accountability, Punish” in Topic 48, and “Heavy punishment, Compulsory bankruptcy, and Sentence” in Topic 16 reached 0.8. This demonstrates strong public opposition to the introduction of prepared dishes on school campuses and a pressing call for government departments to strictly regulate companies that fail to adhere to regulations. The aim is to prevent the introduction of prepared dishes into schools through administrative measures such as accountability and punishment, minimizing their impact on youth health.

Lastly, Topics 11, 20, and 47, with a correlation score of 0.7 and including keywords such as “Chain catering, Luncheonette, Business hotel, Takeout, Cheap, Never, Cancer, Youthfulness, Increasing,” reveal that in locations such as chain restaurants, small restaurants, and business hotels—where dining out is common—prepared dishes frequently appear on dining tables. The ubiquity of prepared dishes in physical restaurants has penetrated daily meals, raising fears that long-term consumption may cause serious health issues, including cancer. Additionally, the correlation between the terms “Overnight meals, Carcinogenic, Inedible, Toxic” in Topic 7 and “Food safety, Urgent, Importance, Great risk” in Topic 28 is 0.7. This reflects public concern that the long-term storage of prepared dishes may produce

carcinogenic and toxic substances that jeopardize health, underscoring the urgent need to address prepared dishes within the scope of food safety management.

In summary, the correlation analysis of the health impact of prepared dishes on related topics comprehensively interprets the public’s real and objective reactions to prepared dishes food, including their cognition, concerns, and appeals, from the lexical level to the thematic level.

3.1.3 Sentiment and topic changes analysis of based-time series

Figure 9 illustrates the changes in the number of prepared dishes-related comments and the percentage of negative sentiment per month from July 2022 to early March 2024. From 2022 to July 2023, the number of social media comments discussing the health effects was relatively small, averaging no more than 5,000 comments per month. During this period, the proportion of negative sentiments averaged no more than 50%, indicating that the public maintained a relatively neutral stance towards prepared dishes when discussing them on social media platforms, with limited discussion about their impact on health. This trend may be attributed to the “No. 1 Central Document issued in February 2023,” which focused on cultivating and developing the prepared dishes industry, possibly leading to fewer health-related comments and more neutral emotions.

Since then, the social media comments number on health effects of prepared dishes has had noticeable fluctuation, but an overall upward trend can be observed. Notably, comments engagement peaked in September 2023, coinciding with the start of the school year. At this time, some primary and secondary schools in parts of China began introducing prepared dishes, sparking heated discussions and strong negative reactions due to concerns over the health implications of such meals. The related event “Health concerns caused by prepared dishes on campus.”

Subsequently, in January 2024, as depicted in Figure 9, comments related to health decreased, and the intensity of negative emotions

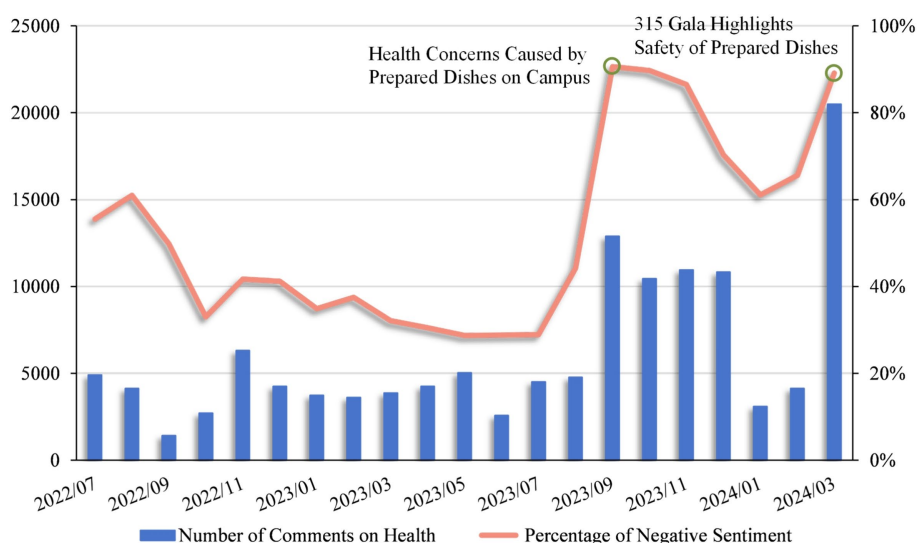


FIGURE 9
Number of comments on health and percentage of negative sentiment per month.

softened. This change demonstrates the extensive social discussion and the previously strong negative sentiments concerning the use of prepared dishes in schools. Chinese education authorities have adopted a cautious approach regarding the use of prepared dishes in schools and implemented corresponding regulatory measures, as indicated by the incident “Prohibition of prepared dishes in primary and secondary schools across various provinces and cities.” However, these measures had little effect on reversing the public’s negative perceptions of prepared dishes, with negative sentiment still exceeding 60% at that time.

Finally, it is evident from Figure 9 that the number of comments and the proportion of negative emotions related to the health of prepared dishes reached their peak in March 2024. The corresponding event is “March 15, 2024, China’s annual consumer rights protection day.” Some official media reports on certain manufacturers illegally producing processes and using raw materials have once again raised public concerns and strong negative emotions about the health impact of prepared dishes.

Overall, the fluctuations in the number of comments and sentiments across different events reveal the sensitivity of the Chinese public to issues related to prepared dishes. Positive publicity often leads to suspicion and negative reactions, while cautious policies and government actions often receive public support.

3.2 Discussion

In contrast to the traditional self-report method, this study adheres to a data-driven research paradigm (51, 53, 81), subjecting the data to strict cleaning and preprocessing. The primary purpose was to identify objective public expressions within social media comments, thereby establishing a semantic analysis framework encompassing “Sentiment Analysis—Topic Mining—Time Series Analysis.”

Initially, sentiment analysis of 200,993 social media comments disclosed that approximately 64% exhibited negative emotion, reflecting public opposition to prepared dishes. This finding, however, differs from prior research. For example, a study focused on consumers’ cognition and purchase intentions indicated a positive attitude towards prepared dishes in supermarket interview surveys involving 1,209 participants (18). Additionally, a questionnaire survey of 1,767 respondents demonstrated that over 90% of adults accepted prepared dishes, with outdoor camping scenarios being the most favored, accounting for 52.8% (82). We believe that the difference between our research results and previous ones comes from the research based on social media data, where the expression of public opinions and questionnaire surveys are in entirely different environments. Due to the close relationship between social media and contemporary life, we believe that people can freely express their opinions on a particular topic rather than being limited by the scope of survey questionnaires. Therefore, previous studies in many fields have shown that social media comments have better objectivity, especially when the data volume and coverage are sufficient. Although expressing opinions through social media data often lacks strict comparison and reasoning processes compared to questionnaire data, it is easier to express them intuitively. More importantly, for significant news events, policies, and other external factors, social media data has higher real-time sensitivity, spreads faster, and retweets more frequently (83). Also, scholars have suggested that social media data

analysis is a valuable supplement to the in-depth, context-rich insights provided by survey data analysis, with its extensive breadth and capacity to capture real-time, large-scale trends (45, 84). Previous analyses of questionnaire and interview data have indicated that the Chinese public concerns regarding the food safety and perceived health risks associated with prepared dishes (17–20). In the present study, previous research results guided the analysis based on social media comments. Consequently, the design of the semantic analysis framework focused first on identifying negative comments and then on exploring health-related topics within those negative comments, as people often express negative emotions when discussing health concerns.

Secondly, topic mining of 128,856 negative comments identified 11 topics related to the health effects of prepared dishes. Compared with a previous empirical study on the perceived health risks of prepared dishes (19), which has five questions in the designed questionnaire, our results are more fine-grained. Our study contributes to this line of research by further measuring the public’s perception of the health effects of prepared dishes using objective data derived from social media comments. Moreover, based on the 11 health-related topics identified, we ranked them by the proportion of negative comments. The top-ranked topic, Topic 2, involved keywords such as “Preservative, Additive, Food chemical,” which confirmed previous survey results showing that the public was most concerned about illegal additives in prepared dishes, accounting for 68.55% (22). Further, after interpreting the meaning of each topic and discussing the correlation between the topics through the heatmap output of the BERTopic model, we validated these findings by comparing them with previous studies on prepared dishes from different perspectives. For instance, Topic 3 highlighted concerns about prepared dishes in primary and secondary school canteens affecting students’ health. This topic ranked second in negative comments, supporting previous survey results indicating that 54.68 and 42.6% of the public do not accept prepared dishes in primary and secondary school canteens (22, 82). Similar to present studies, topics 16, 28, and 48 present the public’s spontaneous demands for punishment, supervision, and accountability for the health effects of prepared dishes, which coincide with the proposed measures in the previous research results (17, 18, 20, 85, 86). The topic mining results of this study not only prove that the social media comment data can reflect the needs and opinions in the “real world” but also present issues that have not been paid attention to in previous studies. For example, Topic 20 reveals public concern about the health impact of take-out meals and a rejection of the use of prepared dishes in such meals, an area not covered in earlier surveys (82). In particular, topic 0 is also a manifestation of the unique properties of social media data, and the keyword “Retweet comment” ranks first in the topic, which proves that negative comments are spread quickly and forwarded more on the Internet (45, 83). This explains why most health-related content in our study about prepared dishes expressed by the public on social media platforms contains negative emotions.

Last but not least, it is important to acknowledge that previous empirical or survey studies have typically covered a specific period (17–20, 22, 82), with public opinion potentially evolving dynamically over time. This temporal limitation can obscure understanding of how perceptions respond to new information or events. This study employs automated web crawling and advanced big data analytics to monitor real-time changes in public perceptions of prepared dishes. The results

of our study reveal that significant events, such as “Health Concerns Caused by Prepared Dishes on Campus” and “March 15, 2024, China’s annual consumer rights protection day,” frequently capture social media attention. These events trigger a surge in comments, controversies, and expressions of negative emotions. Although social media comment data often follows intuition and lacks in-depth thinking and sufficient rational judgment, these features may introduce bias in research (83). However, they can highlight the sensitivity of social media data to event-driven fluctuations, which is consistent with the researchers’ observations. Therefore, social media data has unique advantages over traditional survey methods in fields that require high real-time performance. For instance, this approach has been successfully utilized in studying public perceptions of various food products, including alternative meats (45), organic foods (29), and coffee (44). The immediacy and breadth of data from social media allow for a more instantaneous and comprehensive observation of public opinion compared to conventional questionnaire surveys and interviews. This ability to capture real-time shifts in public sentiment is invaluable for businesses and governmental bodies. It enables a swift and nuanced understanding of emerging trends and public concerns regarding the health effects of prepared dishes. The key is that stakeholders can make wiser decisions and take timely intervention measures to address public concerns, ensuring their strategies remain relevant and effective in a rapidly changing social environment. This is very important for the Chinese government and enterprises eager to promote the development of prepared dishes.

4 Conclusions and implications

4.1 Conclusions

In response to the growing awareness of health hazards and related issues associated with prepared dishes, this study aimed to explore public perceptions regarding the health effects of these products. People are now more willing to express their opinions on social media platforms. Thus, this study used this kind of data to explore the concerns of the Chinese public about the health of the rapidly developing prepared dishes industry with a fast response time. Our study utilized public comments on social media, employing a semantic analysis framework based on NLP technology to identify and analyze the most discussed health effects of prepared dishes within negative comments and tracking their evolution over time. The findings demonstrate that individuals are more willing to express their opinions on social media platforms, free from external biases. The results obtained through semantic recognition of comment data from these platforms provide relatively objective and verifiable insights.

Academically, this research is the first early-stage study to use social media comments and NLP methods to examine public perceptions of the health effects of prepared dishes. It enriches existing literature by providing a broader and more nuanced understanding of public opinion towards prepared dishes. Unlike traditional methods, this study explores real-time observations, offering a more dynamic view of public opinion than phased observations from surveys and interviews. The results show that the public initially had concerns about several technical aspects of the prepared dishes industry, including production processes, food ingredients, additives, and packaging materials, which were perceived as potential health hazards.

There was also notable distrust of companies involved in producing prepared dishes, with strong calls for increased media scrutiny and government regulation. Additionally, the act of retweeting comments further amplified public discourse, vividly expressing individual concerns about the potential health risks of these products. Practically, our findings can help policymakers and businesses strengthen the regulation of prepared dishes, ultimately building public confidence and ensuring the sustainable growth of this market. This information empowers stakeholders to make informed decisions and take actions that benefit public health and the industry.

In conclusion, this study addressed these limitations compared to previous research, which primarily relied on surveys and interviews and was often limited by factors such as small sample sizes and a lack of real-time responsiveness. Our research findings are mutually consistent with existing studies in major aspects, and they have better real-time performance and more extensive coverage. Moreover, some differences compared to previous research reflect new characteristics of changes in the expression of the public will. That is, the negative emotions of the public towards a particular product or category, especially those related to food safety and health, will quickly spread to a larger audience through social media. The characteristics of these changes suggest that government management departments, enterprises, and researchers should attach importance to such changes.

4.2 Implications

For the government, the role of regulatory bodies is crucial in maintaining the integrity and safety of the food industry, particularly concerning prepared dishes. With China’s rapid urbanization and changing lifestyle dynamics, governmental agencies must prioritize enacting stringent food safety regulations to protect public health, enforcing existing laws and adapting regulatory frameworks to address the new challenges the prepared dishes industry poses. Proactive government oversight is necessary to ensure that enterprises adhere to high product quality and safety standards. Moreover, government initiatives to stimulate industrial prosperity during economic downturns should integrate robust mechanisms for capturing and responding to public sentiment, ensuring that growth does not compromise food safety standards.

For enterprises and manufacturers, due to public concerns about the health effects of prepared dishes, it is imperative to prioritize aligning their operations with both public expectations and regulatory standards. This alignment is crucial in navigating the complexities of public health concerns and consumer skepticism. Manufacturers, in particular, play a pivotal role in innovating safer and more nutritious food preparation technologies that can mitigate health risks associated with prepared dishes. These entities must invest in the continuous improvement of food quality, diversification of flavors, and enhancement of nutritional values to meet the evolving demands of consumers. Additionally, fostering transparency about ingredient sourcing, production processes, and safety measures is essential to build trust and facilitate informed consumer choices.

For the general public, the advent of “we-media” has significantly transformed their role from passive consumers to active participants in the discourse surrounding food safety and industry practices. The widespread dissemination of information empowers the public to express concerns and demand transparency and accountability from

food producers. The study underscores the necessity for public engagement in dialogue and decision-making processes related to food policies. By voicing their concerns, the public can influence industry practices and governmental policies, contributing to the overall improvement of food safety standards.

For the prepared dishes industry to thrive sustainably, a multi-stakeholder approach is essential. Governments must continually enforce and refine regulations; businesses and manufacturers must innovate and maintain high standards; and the public should remain engaged and informed. This collective effort will ensure that the prepared dishes industry grows and contributes positively to public health and safety.

5 Limitations and future research

5.1 Limitations

It should be noted that, due to various limitations, this study was unable to establish a causal relationship between the characteristics of prepared dishes and public responses. Instead, the research was confined to objectively presenting the psychological perceptions of the public on specific health-related topics associated with prepared dishes.

Utilizing machine learning techniques, this research conducted sentiment analysis and topic clustering on comments from Chinese social media regarding prepared dishes. The findings indicate a generally negative sentiment among the Chinese public concerning the potential health risks associated with these dishes. For topic clustering, this study employed the BERTopic model, which demands considerable computational power. Thus, the corpus size used in the research is constrained. Moreover, given the strong correlation between food and public health, alongside cultural differences, it is anticipated that both the promotion of prepared dishes in China and the enhancement of public acceptance will undergo a protracted and dynamic process. Consequently, the conclusions of this study are confined to the objective presentation of current data, reflecting these limitations.

5.2 Future research

The large-scale promotion and popularization of prepared dishes in China are likely to be significant, making the accumulated experience from this study valuable for long-term future research. Due to constraints in resources and time, this study did not delve into fine-grained aspects such as population segmentation and geographical distribution, areas that merit further exploration. Additionally, to enhance the precision and efficiency of future

research, serious consideration should be given to the selection of more advanced machine learning models. Particularly, with advancements in large-scale natural language processing models, an alternative avenue for expanding this research is presented, suggesting potential improvements in approaches.

Author contributions

TS: Conceptualization, Writing – original draft, Funding acquisition. HY: Data curation, Writing – review & editing, Methodology. LL: Writing – review & editing, Conceptualization, Supervision. JC: Software, Visualization, Writing – review & editing. JZ: Supervision, Validation, Writing – original draft, Methodology. JW: Writing – review & editing, Conceptualization, Supervision.

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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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A scoping review of COVID-19 vaccine hesitancy: refusal rate, associated factors, and strategies to reduce

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Objective: This study aimed to investigate the evidence regarding vaccine hesitancy including refusal rate, associated factors, and potential strategies to reduce it.

Methods: This is a scoping review. Three main databases such as PubMed, Scopus, and Web of Science were searched from 1 January 2020 to 1 January 2023. All original studies in the English language that investigated one of our domains (vaccine hesitancy rate, factors associated with vaccine hesitancy, and the ways/interventions to overcome or decrease vaccine hesitancy) among the general population were included in this study. The data were charted using tables and figures. In addition, a content analysis was conducted using the 3C model of vaccine hesitancy (Confidence, Complacency, and Convenience) that was previously introduced by the WHO.

Results: Finally, 184 studies were included in this review. Of these, 165, 181, and 124 studies reported the vaccine hesitancy rate, associated factors, and interventions to reduce or overcome vaccine hesitancy, respectively. Factors affecting the hesitancy rate were categorized into 4 themes and 18 sub-themes (contextual factors, confidence barriers, complacency barriers, and convenience barriers).

Conclusion: Vaccine hesitancy (VH) rate and the factors affecting it are different according to different populations, contexts, and data collection tools that need to be investigated in specific populations and contexts. The need to conduct studies at the national and international levels regarding the reasons for vaccine refusal, the factors affecting it, and ways to deal with it still remains. Designing a comprehensive tool will facilitate comparisons between different populations and different locations.

KEYWORDS

COVID-19, vaccine hesitancy, refusal rate, strategy, scoping review

Introduction

The World Health Organization (WHO) declared coronavirus disease 2019 (COVID-19) a global pandemic in March 2020 (1, 2). The COVID-19 pandemic has caused adverse health and socioeconomic impacts; as of January 2024, approximately 6.5 million people have died around the world (3). In May 2020, people all over the world agreed that getting vaccinated

was important to stop the spread of COVID-19 (2, 4). The quick development of a COVID-19 vaccine gave hope for life to go back to normal. Despite the successful public vaccine uptake, many people delayed or refused to take the vaccination (5, 6).

With the development of multiple vaccines, there have been discussions about vaccine hesitancy (7). Although the effectiveness of vaccines depends on their availability, the increasing availability of vaccines has created the problem of VH. Vaccine hesitancy, which ranges from uncertainty about vaccines to outright opposition, was identified by the WHO in 2019 as one of the most important health problems in the world. This hesitancy poses challenges in controlling diseases that vaccines can prevent (8, 9).

Vaccine hesitancy is defined by the WHO as “the delay in the acceptance or refusal to vaccinate despite the availability of vaccine services” (10). Vaccine hesitancy is a complex phenomenon that is influenced by a wide range of contextual, individual, and group factors, including geographical, cultural, and socio-demographic factors, socioeconomic status, and perceptions of risk (1, 11, 12). Several studies explored COVID-19 vaccine acceptance and its determinants in China, Indonesia, Italy, Ireland, Japan, the United Kingdom, and the United States between March and December 2020 (7). Some of these studies indicated that factors such as age, income, and education levels are associated with a higher likelihood of accepting a vaccine (13–15).

A survey found four important issues: (1) People with chronic diseases worry more about getting COVID-19. (2) People wonder how being vaccinated will affect their chronic disease. (3) Some people are not sure if the COVID-19 vaccine is helpful. (4) There is too much information about COVID-19, and it confuses and worries patients (16).

Several reasons including personal and social are associated with vaccine hesitancy among parents. Gender, nationality, occupation, and being a healthcare worker were factors affecting the vaccination acceptance participants (17). More people were willing to get vaccinated if they trusted the government, had gotten a flu shot before, and saw COVID-19 as a danger to themselves and their community (15, 18–20).

Understanding the factors affecting vaccine hesitancy and identifying effective interventions can help with COVID-19 vaccination coverage and improve the healthcare system's preparedness to plan and implement policies aimed at improving prevention programs for vaccine-preventable diseases. Many cross-sectional and review studies have been conducted in this field. However, there are few studies that report and synthesize the vaccine hesitancy rate, factors associated with vaccine refusal, and interventions to overcome or decrease vaccine hesitancy. This scoping review aimed to identify and synthesize the available evidence in the three dimensions of vaccine hesitancy rate, effective factors, and interventions to prevent it.

Subjects and methods

Protocol and registration

This scoping review was conducted based on the Joanna Briggs Institute guidelines (21). Furthermore, we reported this study following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) (22).

Eligibility criteria

All original studies that investigated at least one of our domains of vaccine hesitancy or refusal rate, factors associated with hesitancy or refusal of the vaccine, and the ways of interventions to overcome or decrease this phenomenon among the general population were included in this study. All non-English language studies were excluded from the study. We also excluded the studies if the full text was not available through database search or contact with authors.

Information sources and search

Our search was conducted from 1 January 2020 to 1 January 2023 in three electronic databases: PubMed, Scopus, and Web of Science (WoS), using a combination of MeSH terms and free terms. Our general keywords were as follows: COVID-19, vaccine, and hesitancy. Full search strategies for databases are available in [Supplementary material S1](#). We also searched the references of the included studies.

Selection of sources of evidence

All records were imported to EndNote software version 20, and duplicates were removed. Two independent reviewers piloted screening with a random sample of 10 studies based on eligibility criteria (agreement rate: 93%), and disagreements were resolved with a third reviewer. Then, they started screening based on title, abstract, and full text. The final included studies were entered into the charting process.

Data charting process and data items

To increase the agreement between reviewers, a data charting form was developed and independently piloted on a random sample of 10 included articles. This form includes data items of the first author, corresponding author, publication year, study design, country of origin, data collection period, participant group, sample size, ethical approval, funding statement, mean age, gender percent, the objective of the study, vaccine hesitancy or refusal rate, factors associated with or affecting hesitancy rate, and interventions to reduce or overcome hesitancy rate. Our definition of hesitancy rate was based on the WHO definition: “delay in acceptance or refusal of vaccines despite availability of vaccination services” (23).

Synthesis of results

We categorized included studies by whether the major focus was vaccine hesitancy. The main domains were vaccine hesitancy rate, factors associated with vaccine hesitancy, and interventions to reduce or overcome hesitancy. The data were charted using tables and figures. Furthermore, we performed a content analysis using the 3C (Confidence, Complacency, and Convenience)

model of vaccine hesitancy that was previously introduced by the WHO for categorizing the factors associated with vaccine hesitancy (24).

Patient and public involvement

As our design is a scoping review, patients or the public were not involved in any stage of the study including design, data collection, synthesis, reporting, and dissemination of this research.

Results

Selection of sources of evidence

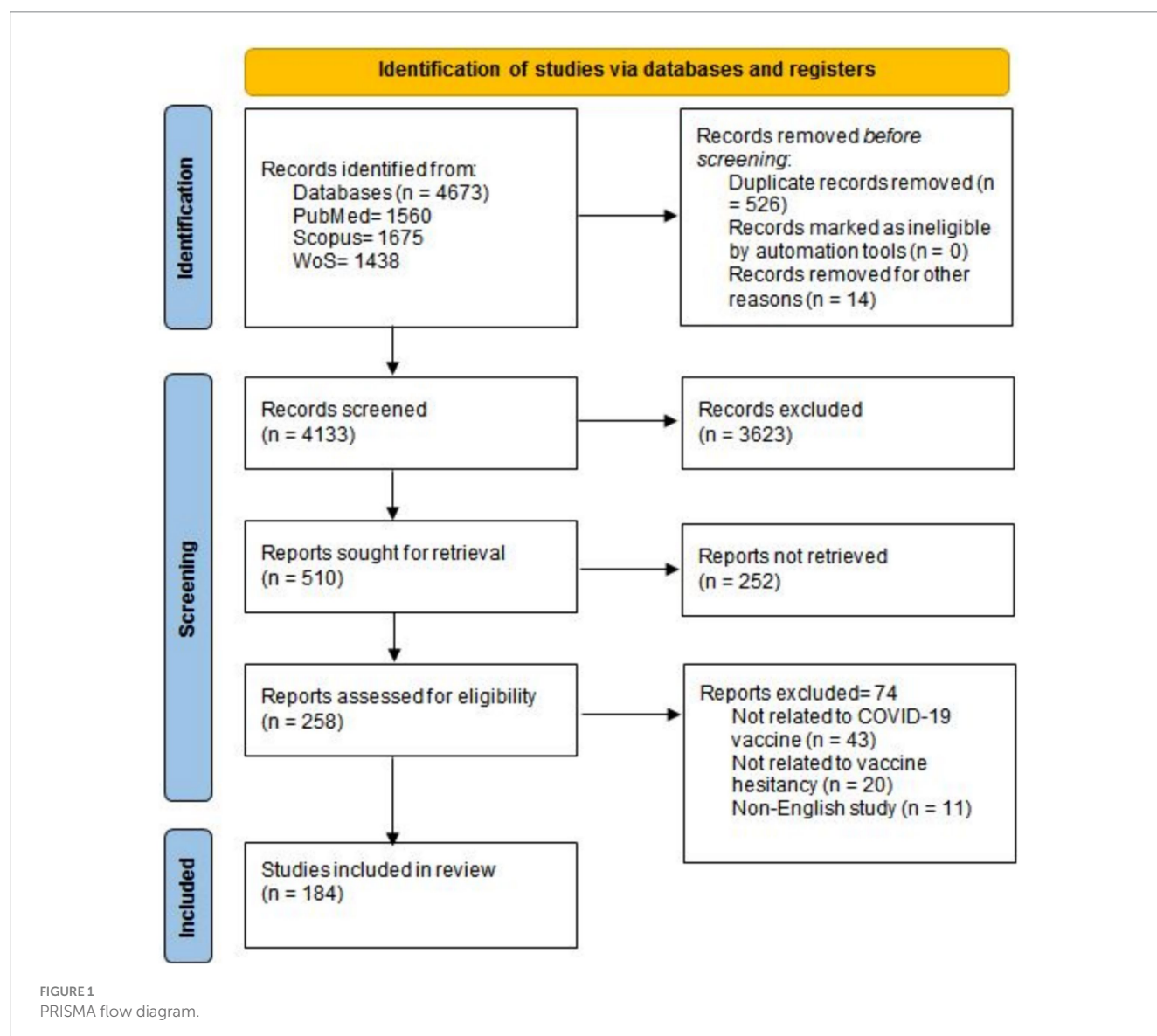
Our database search resulted in 4673 records. After duplication and initial screening, 258 records met the eligibility criteria and were considered for full-text screening. Finally, 184 articles were included

in this scoping review (5, 7, 12, 25–197). The PRISMA flow diagram of the study selection process is represented in Figure 1.

Characteristics of sources of evidence

Studies were conducted across five continents: 60 from the Americas, 58 from Asia, 38 from Europe, 11 from Africa, and 4 from Oceania. Thirteen studies were multinational, 51 studies (27.7%) were conducted in the USA, and 14 studies were conducted in China (7.6%). The distribution of the included studies between countries is represented in Figure 2.

Of the 184 included studies, 175 were cross-sectional, 4 were cohort, 3 were qualitative, and 2 were randomized clinical trials (RCTs). The highest number of articles published in 2021 was 179. Funding and ethical statements were reported in 144 and 137 studies, respectively. The sample size of the included studies ranged from 20 to more than 1 million. Of the 184 included studies, 165 (89.6%) reported the hesitancy rate regarding COVID-19 vaccines, 181 (98.3%)



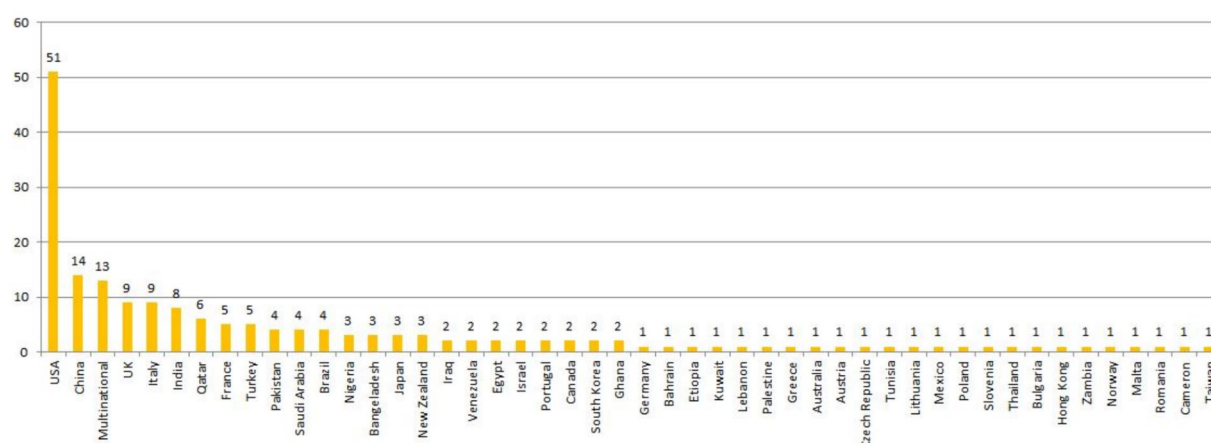


FIGURE 2

Distribution of the final included studies by country.

reported the factors associated with COVID-19 vaccine hesitancy, and 124 (67.4%) reported potential interventions to reduce or overcome COVID-19 vaccine hesitancy among participants. The summary characteristics of the included studies are reported in [Table 1](#).

The hesitancy rate of the vaccine was different among the studies depending on the type of population, sample size, and method of conducting the study, and it ranged from less than 3% to more than 80%. Factors affecting vaccine hesitancy and interventions suggested by individual studies to overcome it are reported in [Supplementary materials S2, S3](#).

Synthesis of results

Factors affecting the hesitancy rate are categorized into 4 themes and 18 sub-themes including contextual factors, confidence barriers, complacency barriers, and convenience barriers. Contextual factors include two main sub-themes: socio-demographic predictors and political-economic-cultural factors. Confidence barriers include seven main sub-themes: vaccine effectiveness and efficiency; fear and concerns about vaccine development; fear and concerns about side effects, adverse events, and death after vaccination; reliability and trustworthiness of received information from the vaccine program; confidence in safety; trust in authorities, providers, and institutions; and trust in science. Complacency barriers include two main sub-themes: beliefs about identifying the severity and risk of COVID-19 and preference for alternative immunity methods. Convenience barriers to getting vaccinated include being able to physically go and get vaccinated, being able to afford it, living in an area where it is available, understanding health information, having access to good vaccination services, finding the time and place to get vaccinated, and considering cultural factors. The overall themes, sub-themes, and code summary are reported in [Table 2](#).

Discussion

Overall, 184 articles were included in this scoping review. These articles report at least one of our domains investigated in this review

including hesitancy rate, factor effecting, and strategy to prevent or reduce hesitancy regarding COVID-19 vaccines. Of the 184 included studies, 165 (89.6%) reported the hesitancy rate regarding COVID-19 vaccines, 181 (98.3%) reported the factors associated with COVID-19 vaccine hesitancy, and 124 (67.4%) reported potential interventions to reduce or overcome COVID-19 vaccine hesitancy among participants. COVID-19 vaccine hesitancy varied significantly based on the population, sample size, and method of conducting the studies, with reported rates ranging from less than 3% to more than 80% in the included studies. In addition, the main factors affecting the hesitancy rate were categorized into four groups: contextual factors, confidence barriers, complacency barriers, and convenience barriers. Public education campaigns, consultation programs, patient engagement, providing detailed information and shared decision-making programs, streaming educational content through media and broadcast channels, strengthening positive attitudes to vaccination, and reducing conspiracy suspicions were among the important interventions to reduce vaccine hesitancy during the COVID-19 pandemic.

Vaccine hesitancy rate

The rate of vaccine hesitancy was different among the studies depending on the type of population, sample size, and method of conducting the study, and it ranged from less than 3% to more than 80%. The findings of several systematic and scoping reviews are consistent with our results.

Our results were comparable to those of a scoping review conducted by Ackah et al. on an African population. Based on their results, the vaccine acceptance rate ranged from 6.9 to 97.9% ([198](#)). Another systematic review conducted by Sallam showed similar results, indicating that the highest COVID-19 vaccine acceptance rate was 97% in Ecuador, while the lowest was 23.6% in Kuwait ([199](#)).

The results of a scoping review that was conducted in high-income countries also showed a similar result to our study. Based on this scoping review, the rates of vaccine hesitancy across high-income countries or regions ranged from 7 to 77.9% ([200](#)). Furthermore, the results of a worldwide scoping review of COVID-19 vaccine hesitancy

TABLE 1 Summary characteristics of the included studies ($n = 184$).

Characteristics	Number ($n = 184$)	Percentage (%)
Publication year		
2020	5	2.71
2021	179	97.3
Study design		
Cross-sectional	175	95.1
Cohort	4	2.2
RCTs	2	1.1
Qualitative	3	1.63
Continent		
Africa	11	5.97
America	60	32.6
Asia	58	31.5
Europe	38	20.6
Oceania	4	2.17
Multinational	13	7.06
Ethical statement		
Yes	137	74.4
No	47	25.6
Funding statement		
Yes	144	78.3
No	40	21.7
Sample size		
≤ 200	14	7.6
201–500	44	23.9
501–1,000	29	15.8
$> 1,000$	97	52.7
Domain		
Hesitancy rate	165	89.6
Factors	181	98.3
Interventions	124	67.4

showed that people in different countries had varying percentages of vaccine uptake (28–86.1%), vaccine hesitancy (10–57.8%), and vaccine refusal (0–24%) (201).

Factor associated

In various studies, several factors have been mentioned that are related to not accepting the vaccine or accepting the vaccine in the case of COVID-19. These influencing factors have been different depending on the geographical context; the participants; demographic characteristics of the population; background factors; and other cultural, social, economic, and political factors in the studies. However, many of these factors have been similar in different studies, and even their causal relationships have been investigated.

TABLE 2 Factor affecting the hesitancy rate.

Main theme	Sub-theme
Contextual factors	Socio-demographic predictors
	Political-economic-cultural factors
Confidence barriers	Vaccine effectiveness and efficiency
	Fear and concerns about vaccine development
	Fear and concerns about side effects, adverse events, and death after vaccination
	The dependability and credibility of the information obtained from the vaccine program
	Confidence in safety
	Trust in authorities, providers, and institutions
Complacency barriers	Trust in science
	Beliefs about identifying the severity and risk of COVID-19
Convenience barriers	Preference for alternative immunity methods
	Physically capable of receiving the vaccine
	Able to afford the cost of vaccination
	Reside in an area and community where receiving a vaccination is accessible
	Health and language literacy
	Standard of vaccination service
	The designated schedule and location for receiving the vaccination
	The cultural background of the group

A study was carried out to explore the level and factors contributing to COVID-19 vaccine hesitancy in South Africa in order to guide the development of interventions to combat it. The study found that COVID-19 vaccine hesitancy in South Africa is primarily influenced by social factors such as age, race, education, politics, location, and employment status (202). Another study identified socio-demographic factors as the individual determinants of vaccine hesitancy. Right-wing political affiliation was the main socio-demographic psychological determinant (89). Political affiliation was identified as one of the contextual factors in our findings.

A narrative review was conducted to explore and examine the issue of vaccine hesitancy amid the COVID-19 pandemic. The review identified various factors that impact individuals' decisions to accept or reject vaccines, such as ethnicity, employment status, religious beliefs, political views, gender, age, education level, income, and other factors (203).

A scoping review was carried out on 60 studies from around the world to explore vaccine hesitancy and acceptance. Through qualitative analysis, this study identified factors that influence people's decisions on vaccination in various cultural and demographic settings. These factors include risk perceptions, trust in healthcare systems, solidarity, past experiences with vaccines, misinformation, concerns about vaccine side effects, and political beliefs, all of which play a role in addressing or reducing vaccine hesitancy (204).

The WHO acknowledges that vaccine hesitancy poses a significant risk to public health. A recent study investigated how attitudes, norms, and perceived behavioral control influence vaccination intentions. The study found that these factors were important predictors of vaccination

intentions, with attitude being the most influential (205). In our study, a positive attitude toward the government has been mentioned as an effective factor in vaccine hesitancy.

Vaccine hesitancy, characterized by a lack of trust in vaccinations and/or indifference toward them, can result in postponing or rejecting vaccination even when it is accessible. This poses a significant risk to the effectiveness of COVID-19 vaccination initiatives. Factors such as the quick development of vaccines, misinformation spread through mainstream and social media, the divided socio-political climate, and the challenges of implementing widespread vaccination campaigns may erode confidence in vaccination and heighten apathy toward COVID-19 vaccination efforts (206).

Various factors that impact the decision-making process regarding vaccines are diverse, intricate, and dependent on the specific context. These factors can be triggered or exacerbated by unregulated online information or misinformation. Kassianos et al. (207) addressed the most common concerns regarding the COVID-19 vaccination. The rise of new variants of COVID-19 has contributed to vaccine hesitancy. Healthcare professionals, who are considered reliable sources of information, need to be provided with sufficient resources and practical advice to help them address concerns effectively (207). Advice and recommendations from health professionals about getting or not getting vaccinated were discussed as one of the effective factors in vaccine hesitancy.

Although vaccination has proven to be an effective tool in combating the worldwide COVID-19 pandemic, vaccine hesitancy has become a significant challenge in various countries, including Africa. A scoping review was conducted to consolidate the current research on vaccine hesitancy in Africa. The primary reasons for hesitancy included worries about vaccine safety and potential side effects, distrust in pharmaceutical companies, and exposure to misinformation or contradictory information from the media. Factors linked to a more favorable view of vaccines included being male, having a higher education level, and a fear of contracting the virus (198). These reasons were also discussed in our findings.

According to the classification of the WHO model, health and language literacy is one of the convenience barriers, which includes negative stories, misinformation, and misperceptions focusing on the vaccine and personal knowledge. A study examined the frequency and reasons behind COVID-19 vaccine hesitancy among individuals with mental health conditions. Common factors contributing to hesitancy include distrust, false information, belief in conspiracy theories, and negative views on vaccines. Mental health disorders, particularly anxiety and phobias, may heighten the likelihood of vaccine hesitancy (208).

Vaccine hesitancy is a significant obstacle to the acceptance of the COVID-19 vaccine. A scoping review was conducted to summarize the rates of COVID-19 hesitancy and its determinants in affluent countries or regions. Factors such as younger age, gender, non-white ethnicity, and lower education levels were commonly linked to increased vaccine hesitancy. Other factors included not having a recent history of influenza vaccination, a lower perceived risk of contracting COVID-19, less fear of the virus, belief in the mildness of COVID-19, and absence of chronic medical conditions. Specific concerns about vaccine safety and effectiveness, as well as worries about the rapid development of COVID-19 vaccines, were also associated with increased vaccine hesitancy (200). All these factors are consistent with our findings.

Strategies to overcome

Considering the wide range of factors affecting vaccine hesitancy, various studies have proposed various interventions to overcome this issue. These interventions have been at various levels, including media, service delivery, community education, and even decision-making processes.

One of the important interventions that has been mentioned in many studies is holding various campaigns to educate people at the community, individual, and family level (28, 66, 134). Some of these training campaigns have been focused on equipping service providers and health sector employees, empowering them to effectively transfer this knowledge to the general public (42). In some of these campaigns, the target population has included less privileged and less educated people because some studies have shown that the level of education is one of the factors affecting knowledge and attitude in this field (47). The way of conducting these campaigns has also been different. In some cases, campaigns have been organized at the community level, following the principles of prevention. Some other campaigns have been held online through media due to the COVID-19 situation (32, 171).

Another recommended intervention in this field has been holding counseling sessions and establishing hotlines to communicate with consultants in the field of public health. In some societies, this disease is considered a kind of stigma, making online communication and telephone consultations very welcome due to the confidentiality and anonymity they offer. On the other hand, some obstacles that exist in face-to-face communication, such as the shyness of raising the issue, are reduced in such a mode of communication, and people raise relevant issues more easily (88, 186, 209).

Another important intervention for reducing vaccine hesitancy is holding educational workshops to explain the advantages and disadvantages of vaccination for different target populations. By holding such workshops and training programs, while increasing people's awareness, people are given the opportunity to know the advantages and disadvantages of an intervention and decide whether or not to receive it. In this regard, communication between doctors and patients is crucial, as because healthcare professionals are important sources for increasing confidence in vaccination. Patients tend to trust these individuals more, which facilitates acceptance of their recommendations (81, 114, 174).

Some studies showed that recommending vaccination and presenting its advantages and disadvantages through celebrities can have good effects on the general population due to their fame and followers (91). Furthermore, advertising during major events featuring celebrities can also help in this area. However, due to the conditions surrounding this disease and the need to maintain preventive measures, many of these events were held in closed settings at that time, which may have reduced their effectiveness (60, 149).

Conclusion

Based on our study, the vaccine hesitancy rate and the factors affecting it vary across different populations, contexts, and data collection methods. This underscores the need for further

investigation in specific populations and contexts. The need to conduct studies at the national and international levels regarding the reasons for vaccine refusal, the factors affecting it, and ways to deal with it is still pending. Designing a comprehensive tool will facilitate comparisons between different populations and different locations. Health and medicine authorities should strengthen the dissemination of vaccination-related knowledge for patients such as an expert consensus or guidelines through various media. Some key points should be emphasized in the knowledge sharing about vaccination, including the importance of vaccination, the safety and side effects of COVID-19 vaccines, and predictions regarding epidemiological trends of COVID-19.

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

RB: Conceptualization, Data curation, Investigation, Methodology, Validation, Writing – original draft. MS: Conceptualization, Data curation, Formal analysis, Investigation, Writing – original draft. MA-Z: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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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.2024.1382849/full#supplementary-material>

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Assessing the impact of tech-driven solutions to manage COVID-19 in Saudi Arabia: insights from health information technology professionals

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Introduction: The outbreak of the COVID-19 pandemic has disrupted the provision of healthcare services, forcing health systems, governments, and other public health stakeholders to embark on alternative means to deliver care.

Method: This scenario has fueled the adoption of digital health technologies in the healthcare industry to enhance the management of the COVID-19 pandemic. This study aimed to investigate the effect of using health information technologies (HITs) in managing the COVID-19 pandemic in Saudi Arabia from the health information technology professionals' perspectives. In addition, the study aimed to evaluate the usefulness of using HITs interventions to manage COVID-19, assess HITs information exchange capability and quality, and measure practitioners' satisfaction with HITs.

Results: The present study used a primary analysis and cross-sectional design. Data were collected using survey questionnaires and analyzed. A total of 371 participants ($n = 371$) responded to the questionnaire that was administered online, in March 2022. The study found that HITs significantly influenced the management of the COVID-19 pandemic in various areas, including consulting, screening, and monitoring. However, technical issues, among other challenges, hindered the realization of the desired outcomes.

Discussion: In addition, the study found HITs helpful in managing COVID-19, adding that these technologies improved providers' satisfaction concerning access to and value of information. The study found the need to address the challenges associated with HITs that prevent the effective deployment of HITs to manage COVID-19 and future pandemics.

KEYWORDS

health information technology, e-health, COVID-19, public health, risk health

1 Introduction

The outbreak of the coronavirus disease (COVID-19) in early 2020 posed a significant challenge to global health systems. According to Malden et al., COVID-19 led to over 100 million infections and ~2.3 million deaths by February 2021 (1). Following the outbreak of the health pandemic, governments across the world implemented stringent measures, such as lockdowns and social distancing mandates, to counter the spread of COVID-19 infections. However, despite these unprecedented measures, Malden et al. emphasized that a long-term solution to the global health pandemic entailed producing vaccines and effective treatments (1). In addition, the authors argued that some scholars

and providers believed that health information technology (HIT), such as electronic health records (EHRs), could play an essential role in bringing the outbreak under control (1). For example, in China, the health system and public health stakeholders leveraged HIT for monitoring, detecting, issuing warnings, preventing, and controlling the outbreak (2). HIT constitutes different information and communication technologies, such as telehealth and remote monitoring devices, used in collecting, transmitting, displaying, and storing patient data (3, 4). Thus, the COVID-19 pandemic was the primary catalyst for promoting HIT adoption in many health systems globally.

During the COVID-19 pandemic, the use of HIT to contain COVID-19 infections increased in the Middle East. Hassounah et al. claim that based on the lessons learned from the global experiences with the 2009 H1N1 pandemic, the Middle East launched a GPS-based risk evaluation tool and used Google Maps to represent COVID-19 cases in the region and the world geographically (5). The Kingdom of Saudi Arabia was among the many nations that proactively implemented disease containment measures to restore people's health and wellbeing and end the pandemic. According to Alghamdi et al., Saudi Arabia's Ministry of Health (MOH) launched digital health platforms (DHTPs) that offered follow-up care and monitoring services related to COVID-19 outbreaks. DHTPs enable information communication technologies (ICTs) to offer health services remotely and support decision-making processes for health experts (6). In addition, other health technologies, such as artificial intelligence (AI), Machine Learning (ML), and mobile health applications, enable healthcare professionals and relevant stakeholders to screen people in large gatherings, predict infection rates, monitor the spread of infections, and attain faster diagnosis (6). In the Kingdom of Saudi Arabia, Khan et al. report that HITs were used in disease surveillance and contact tracing (7). This way, the country improved patient outcomes and minimized the effect of the outbreak.

Given the need to contain the spread of COVID-19 infections and the essential role of sharing data to support decision-making processes as emphasized by crucial global health players, this study aims at determining and evaluating the effect of using health information technologies on managing and responding to the COVID-19 pandemic in Saudi Arabia from health information technology practitioners' perspectives. In addition, this study aims to evaluate the usefulness of applying digital health technology in managing COVID-19, assessing the information exchange capability and information quality provided by HITs, and measuring user satisfaction with HITs.

2 Importance of the study and justifications

The study's importance and justification for Saudi Arabia proceed from the fact that the COVID-19 pandemic has sharpened the need for HITs progress in rapid diagnosing and other aspects of healthcare management at hospitals required for saving as many lives as possible. The unprecedented rate of spread has caused the need to change the usual lifestyle to reduce the spread of coronavirus, including minimizing human contact, and HITs help to fulfill this goal by advancing the e-health systems. In general,

the application of ITs in healthcare primarily aims to solve the following tasks: electronic registration (no-contact is critical in terms of COVID-19); monitoring and management of the medical care quality; shortening the time for examination and treatment of infected patients; providing consulting medical support; no-contact monitoring of the patient's parameters; providing telemedicine support in the affected areas of Saudi Arabia. In addition, the introduction of information technology in medicine and health care significantly saves the time of medical personnel, which means that it allows employees of medical institutions to devote more time to patients.

It is also worth emphasizing that the need for the study is dictated by clarifying how HITs could upgrade the availability of medical services at hospitals in the face of the pandemic spread. This matter is especially vital for the part of the population located in geographically remote areas and people with disabilities. The whole process of HITs introduction into the healthcare management aims to create a unified medical information space that allows doctors to communicate with each other, refer to the latest technologies' assistance, and interact with the functioning equipment and patients directly from the workplace in real-time. To provide a theoretical reference on how HITs have been used and could be upgraded in Saudi Arabia to respond to the COVID-19 epidemic, this study will review and evaluate the healthcare information technologies that have been applied for managing the outbreak in Saudi Arabia hospitals. The evaluation results will be based on health information technology practitioners' perspectives.

3 Research methodology

3.1 Purpose of the study

This study aims to determine and evaluate the effect of using health information technologies on managing and responding to the COVID-19 epidemic in Saudi Arabia from health information technology practitioners' perspectives. The research objectives (ROs) of this research are:

1. Evaluating the effect and usefulness of using health information technologies intervention in managing COVID-19.
2. Assessing the Information exchange capability and information quality provided by health information technologies.
3. Measuring the level of user's satisfaction of health information technologies.

3.2 The development of the survey instrument

The implemented survey questionnaire for this study consists of three parts as following:

1. The first section contains the demographical data that include gender, age, education level, and occupation.
2. The second section is about the effect of using health information technology interventions to manage COVID-19 that contain rapid diagnosis of patients with COVID-19, test of suspected individual, remote monitoring of patients with

COVID-19 isolated at the hospital, home monitoring of infected patients who do not need to be isolated at the hospital, robotic based treatment of the infected patient, Tele-Health consultation, and pharmaceutical delivery.

3. The third section contain the factors as follow:

- A. Perceived usefulness in early diagnosis and isolation of cases of COVID-19, planning of activities regarding COVID-19, providing a better experience without imposing the risks to healthcare and other workers, providing better risk assessment and global public health emergency of this virus, reducing medical errors, promoting a flexible working environment of treatment, improving treatment practices, Improving quality of patients' care, protecting the privacy of patient's information, preventing the spread of COVID-19, reducing the number of waiting list, and saving time.
- B. Information exchange capability: Health information technology provides easy and rapid information exchange (Ex: test results and patient referral information) between medical institutions.
- C. Information quality: always find the needed information, and provided information is easily understood.
- D. Perceived ease of use: Health information technologies are easy to use.
- E. Satisfaction: practitioners' satisfaction with the outcomes of health information technology.

3.3 Data collection and analyses

This research adopted a primary analysis and a cross-sectional study design. The data for the study was gathered from health information technology practitioners in the Kingdom of Saudi Arabia. The researchers administered questionnaires as the primary data collection technique. The questionnaire gathered data concerning participants' demographic elements, particularly gender, age, and occupation. In addition, the questionnaire gathered data on digital health technologies intervention used in managing COVID-19, perceived usefulness of using digital health technology in managing COVID-19, information exchange capability, information quality, and perceived ease of use and satisfaction with HITs. The questionnaire was administered via an online survey form. The participants accessed the questionnaire through a web link (URL) and could fill it out at any time or place. Responses to the survey were measured using a 5-point Likert scale.

A total number of 371 participants responded to the survey questionnaire in March 2022. The study's sample size included all Saudi electronic university students who are healthcare practitioners or healthcare administrators. In addition, the study's population comprised other health information technology practitioners from different healthcare organizations in Saudi Arabia. This study adhered to ethical research standards, including obtaining ethical approval from Saudi Electronic University's institutional research board (IRB), participants' consent forms, and other research-related forms and assuring participants of their privacy and confidentiality.

TABLE 1 Cronbach's alpha for reliability.

Dimension	Number of items	Cronbach's Alpha
Digital health technologies intervention during COVID-19	7	0.781
Perceived usefulness	12	0.966

TABLE 2 Pearson correlation for validity of digital health technologies.

Items	Correlation
Rapid diagnosis of patients with COVID-19	0.689**
Testing of the suspected individual.	0.701**
Remote monitoring of patients with COVID-19 isolated at the hospital	0.715**
Home monitoring of infected patients who do not need to be isolated at the hospital.	0.655**
Robotic based treatment of the infected patient	0.629**
Tele-health consultation	0.611**
Pharmaceutical delivery.	0.613**

**Correlation is significant at the 0.01 level (2-tailed).

The data collected in the study were analyzed using SPSS statistical software version 26. This data analysis tool extracted the data and performed the descriptive analysis. Since all investigated variables in this study are categorical, the frequency distribution table is used to display the number of occurrences of each variable. Frequency counts, percentages, and bar charts are plotted for all variables to visualize the data.

3.4 Validity and reliability

In this research, Cronbach's Alpha was calculated for Reliability analysis and Pearson correlation coefficient was used for measuring validity of the dimensions.

According to Table 1, it is notable that the dimensions have excellent reliability where Cronbach's Alpha values >0.7 for both dimensions.

As showing on Tables 2, 3, all items have high validity where the correlation coefficients between dimension and its items are significant and >0.4 .

4 Results

This study aimed to determine and evaluate the effect of using health information technologies on managing and responding to the COVID-19 pandemic in Saudi Arabia from health information technology practitioners' perspectives. In addition, the present study evaluated the usefulness of digital health technologies in managing COVID-19, assessed information exchange capability and quality, and measured user's satisfaction with HITs. This section presents the results of the study and integrates the findings with existing literature.

TABLE 3 Pearson correlation for validity of perceived usefulness.

Items	Correlation
Early diagnosis and isolation of cases of COVID-19:	0.809**
Planning of activities regarding COVID-19:	0.845**
Providing a better experience without imposing the risks to workers:	0.856**
Providing better risk assessment and global public health emergency of this virus	0.874**
Reducing medical errors	0.831**
Promoting a flexible working environment of treatment	0.895**
Improving treatment practices:	0.911**
Improving quality of patients' care:	0.860**
Protecting the privacy of patients' information:	0.846**
Preventing the spread of COVID-19:	0.835**
Reducing the number of waiting lists.	0.843**
Saving time.	0.850**

**Correlation is significant at the 0.01 level (2-tailed).

4.1 Demographic data

Table 4 presents that most participants were female, constituting 57.4% of the total sample, while males accounted for 42.6% of the respondents. Furthermore, age demographics indicate that 37.7% of respondents fall within the 18–25 years age group, 21.6% are in the 26–30 years age bracket, 19.4% are aged 31–35, 12.4% are between 36–40 years old, and 8.9% are 41 years old or older. In terms of educational qualifications, the majority of respondents hold a bachelor's degree, comprising 75.7% of the sample. Additionally, 14.8% have obtained a Diploma, while 4.9% possess a master's degree. A smaller proportion, 3.2%, have achieved a Doctorate, and 1.3% hold a Professional's degree. Regarding occupation, the study's participants encompass a variety of professional backgrounds. Administrators make up 35.3% of the respondents, while students account for 10.0%. Other healthcare-related roles, including nurses (5.9%), pharmacists (3.0%), physicians (1.9%), and radiologists (1.6%), are also represented. The remaining 42.3% of respondents fall under the category of "Other" occupations, indicating a diverse range of professional backgrounds within the study population.

4.2 The effect of using health information technologies intervention to manage COVID-19 in Saudi Arabia

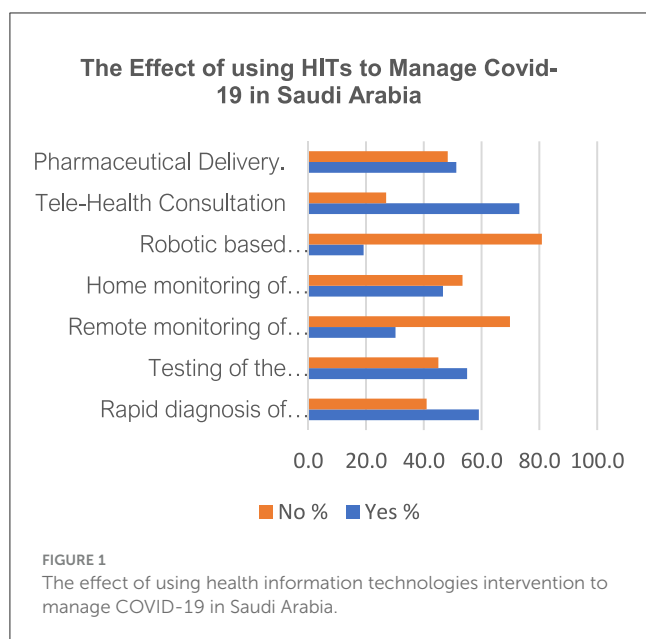
Recently, there has been a strong drive from public health stakeholders, including governments, health agencies, and health systems, to accelerate the adoption of modern technologies in healthcare. The COVID-19 pandemic challenged healthcare stakeholders to adopt innovative approaches to care delivery and protect people and patients from contracting COVID-19 infections. For example, Garfan et al. found that following the outbreak of

TABLE 4 Descriptive statistics for demographic data.

Items	Frequency	Percent
Gender	Female	213
	Male	158
	Total	371
Age	18–25	140
	26–30	80
	31–35	72
	36–40	46
	41+	33
	Total	371
Level of education	Bachelor's degree	281
	Diploma	55
	Master's degree	18
	Doctorate	12
	Professional's degree	5
	Total	371
Occupation	Administrator	131
	Students	37
	Nurse	22
	Pharmacist	11
	Physician	7
	Radiologist	6
	Others	157
	Total	371

the COVID-19 pandemic, hospitals implemented telehealth in both urgent and non-urgent medical care, especially in telemonitoring, tele-management, tele-screening, and teleconsulting (8). Figure 1 shows how implementing healthcare technologies in Saudi Arabia influenced COVID-19 management. The current research found that adopting HITs in Saudi Arabia led to telehealth consulting, improved pharmaceutical delivery, and aided screening and monitoring of patients with COVID-19 (Figure 1). This study's results concur with the findings by Khoshrounejad et al., who reported that following the outbreak of the COVID-19 pandemic, telemedicine was widely adopted and applied in screening, triage, prevention, diagnosis, treatment, and follow-up (9). For example, according to the authors, telemedicine helped providers monitor the health status of discharged patients and provide recommendations to manage symptoms in asymptomatic patients (9). Similarly, a study investigating the role of health technologies in managing COVID-19 argued that telehealth systems promote remote consultations, help practitioners manage patients with suspected COVID-19 symptoms remotely, and enable real time monitoring for patients in isolated zones (10, 11). Hence, HITs improve the management of COVID-19.

Implementing health technologies to help mitigate COVID-19 faced significant challenges that hindered the attainment of



the desired outcomes. Khoshrounejad et al. identified various barriers, including staff's rejecting the deployed technologies, concerns about the accuracy of subjective patient evaluations, and technical issues (9). For example, the authors mentioned that modern health technologies hindered practitioners from undertaking a comprehensive physical assessment and evaluating vital signs (9). Notably, these challenges, especially technical issues and concerns for the accuracy and effectiveness of telemonitoring and teleconsulting, could be why the respondents indicated that medical innovations in Saudi Arabia did not improve robotic-based treatment of infected persons and remote monitoring of patients with COVID-19 in isolation (Figure 1). For example, Krenitsky et al. argue that on many occasions, patients and practitioners could not connect via the telehealth video interfaces, leading to phone visits that limited providers' capacity to conduct virtual physical exams and gauge patients' general appearance, including other observable vital signs (12). Furthermore, even if patients connected well with their providers via health technologies, Prasad et al. recount that physicians depended on patients' reports of salient symptoms to make a diagnosis, which could lead to reduced diagnostic accuracy (13). Therefore, addressing the many issues that derail the effectiveness of HITs in healthcare is critical for ensuring the provision of quality, safe, and effective patient care.

4.3 Perceived usefulness of using digital health technologies intervention in managing COVID-19

Technological innovations in the healthcare industry have emerged as suitable alternatives to patient care approaches and complementary care delivery vehicles. According to James et al., integrating medical technologies into the healthcare industry enhanced patients' access to care (14). In addition, the authors report that apart from increased accessibility, medical technologies

save time and contribute to efficiencies, particularly in simple consultations (14). Following the outbreak of the COVID-19 pandemic, Bhatia reported that telehealth aided practitioners with remote access (15). According to the author, this capability was highly beneficial, especially for older adults at a greater risk of infection (15). Similarly, Hoffman noted that medical technologies, such as telehealth, reduced the need for in-person visits to the doctor's office, preventing the spread of COVID-19 infections (16). In addition, the authors reported that telemedicine increased access to care, especially among the underserved communities with limited access to COVID-19-related services (16). Wosik et al. noted that face-to-face interactions between doctors and patients increased the probability of disease transmission and the need to isolate exposed healthcare professionals (17). Thus, apart from increasing access to needed care, medical technologies ensured the safety of at-risk groups, including healthcare experts, children, and persons with underlying conditions.

Figure 2 above shows healthcare professionals' perceived value of using digital health innovations to manage COVID-19. This study found that deploying digital health technologies helped Saudi Arabia's health care providers to diagnose and isolate COVID-19 cases early, plan COVID-19-related activities, deliver a better experience to patients without imposing COVID-19 risks to health workers, and establish a suitable risk assessment tool to ensure an effective global public health emergency response. In addition, this study reported that health practitioners believed that digital health technologies reduced medical errors, promoted a flexible working environment for treating patients, enhanced treatment modalities, improved patient care, ensured patients' privacy and confidentiality, prevented the spread of COVID-19 infections, reduced the number of waiting lists, and saved time.

The relationship between practitioners' perspectives and the perceived usefulness of digital health technologies in managing COVID-19 was significant as each variable had a *p*-value exceeding 0.8, as shown in Table 1. With the high level of correlation, this study's findings conform to the results by Andrews et al. that digital health technologies helped healthcare experts evaluate patients, provide routine care for patients, and deliver uninterrupted and high-quality patient care (18). Notably, these roles were played remotely, meaning that the technologies enabled clinically table people to stay at home, decreasing physical contact between people and reducing the transmission of COVID-19.

4.4 Information exchange capability and information quality provided by health information technologies

Integrating digital health technologies is a new approach in healthcare, eliciting different opinions from relevant stakeholders, including health professionals. According to Andrews et al., healthcare providers were satisfied with the use of telehealth during the COVID-19 pandemic (18). Similarly, in a study investigating clinicians' perceptions of digital health technologies, Gentry et al. reported that providers were satisfied with the deployment of telehealth, adding that it helped them meet patient needs, preferences, and expectations (19). This outcome is mainly

Perceived Usefulness of Using Digital Health Technologies Intervention in Managing COVID-19.

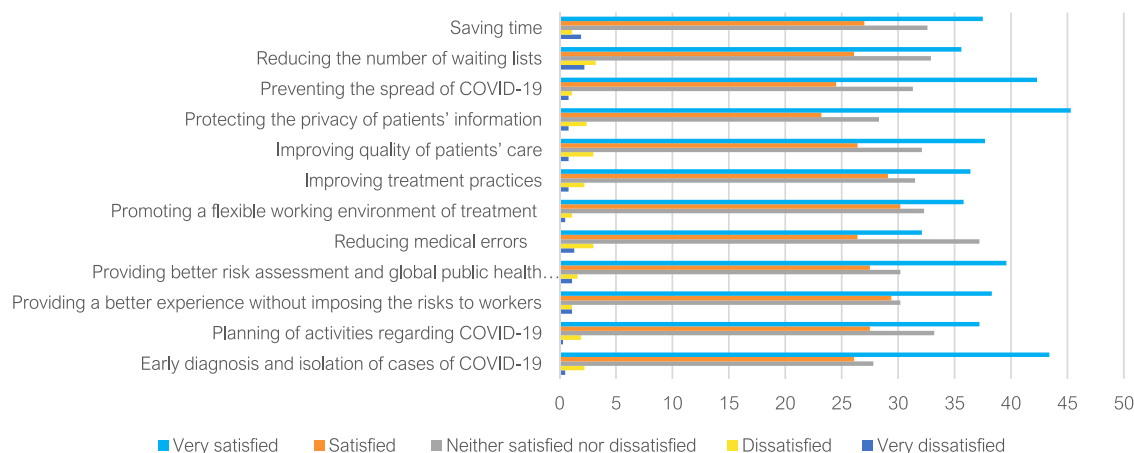


FIGURE 2

Perceived usefulness of using digital health technologies intervention in managing COVID-19.

driven by telehealth increasing doctors' access to information. In addition, practitioner training and support are critical in enhancing the effectiveness of digital health technologies (19–22). The current study reports that practitioners could easily find the information they needed and found the information provided by digital health technologies easy to understand and exchange (Figure 3). 65.5% found that HIT provides easy and rapid information exchange and 61.9% of the respondents indicated that they could find the information they needed. Also, 69.6% reported that digital health technologies were easy to understand (Figure 3). This finding indicates that providers in Saudi Arabia were satisfied with the deployment of medical innovations during the COVID-19 pandemic.

4.5 Perceived ease of use and the level of user satisfaction with health information technologies

4.5.1 Perceived ease of use

The study results reveal interesting findings concerning the satisfaction levels of respondents regarding the ease of use of health information technologies, as depicted in Figure 4. Notably, a significant portion, representing 37.2% of the participants, expressed a high level of satisfaction, indicating that they were "very satisfied" with the ease of use of these technologies.

Additionally, a substantial 28.3% of respondents reported being "satisfied," further underlining a positive sentiment toward the usability of health information technologies. Contrasting this, 32.9% of participants fell into the category of "neither," suggesting a neutral stance or mixed feelings regarding the ease of use. This diversity of responses provides valuable insight into the varying perceptions and experiences of individuals within the surveyed population in relation to health information technologies.

4.5.2 User satisfaction

The data depicted in Figure 5 highlights a noteworthy trend among the study respondents regarding their satisfaction with the outcomes of utilizing health information technology. A substantial 36.1% of the participants expressed a high degree of contentment, categorizing themselves as "very satisfied" with the results achieved using health information technology.

Moreover, a notable 27.8% of respondents indicated their satisfaction, signifying that they were "satisfied" with the outcomes of employing this technology in their healthcare context. In contrast, a significant segment, comprising 34.2% of the respondents, fell into the category of "neither satisfied nor dissatisfied," implying a nuanced perspective or a level of ambivalence regarding the outcomes experienced. This diversity in satisfaction levels underscores the complexity of assessing the impact of health information technology, suggesting that individuals' perceptions and experiences vary widely within the surveyed population.

Further analysis and exploration of these sentiments may provide valuable insights into the broader implications and potential areas for improvement in the adoption of health information technology in healthcare settings.

5 Conclusion

The current study used primary analysis and a cross-sectional design to investigate the effects of using HITs to manage the COVID-19 pandemic in the Kingdom of Saudi Arabia. Data for the study was collected from HIT practitioners' perspectives using survey questionnaires. The analysis of the data revealed that digital health technologies significantly influenced how Saudi Arabia's health systems managed and responded to the COVID-19 pandemic. In particular, this study reported that the deployment of digital health technologies in Saudi Arabia improved

Information Exchange Capability and Information Quality Provided by Health Information

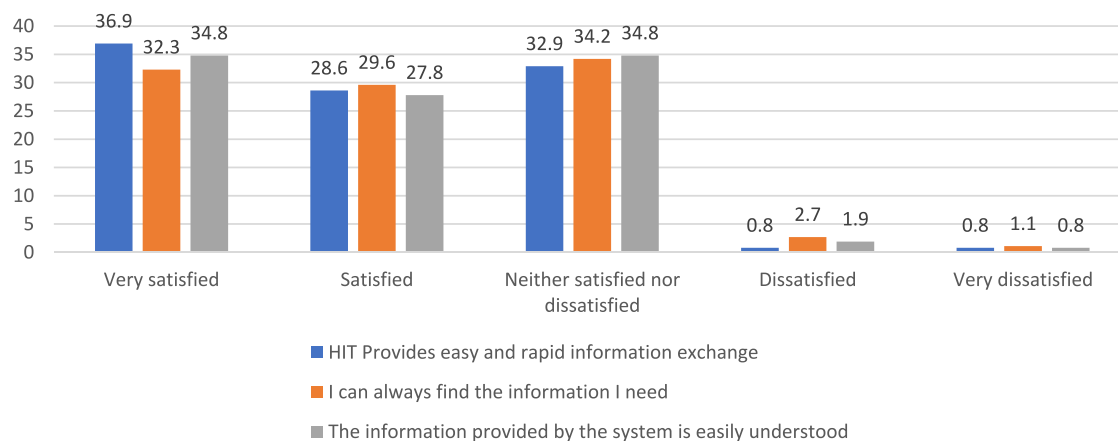


FIGURE 3

Information exchange capability and information quality provided by health information technologies.

Perceived Ease of Use

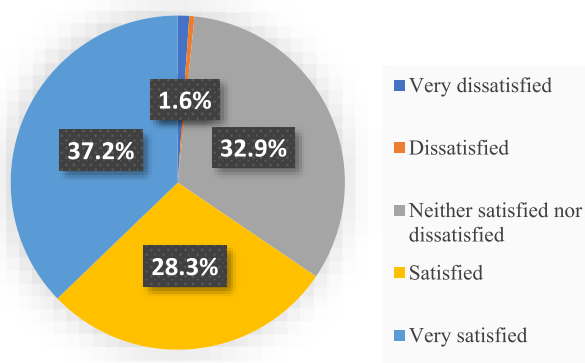


FIGURE 4

Descriptive statistics for perceived ease of use.

User Satisfaction

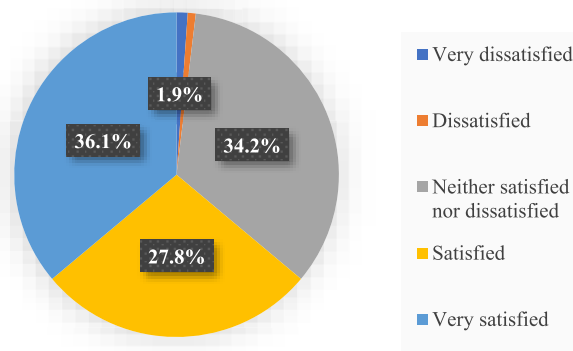


FIGURE 5

Descriptive statistics for user satisfaction.

pharmaceutical delivery, enhanced teleconsulting, and facilitated screening and monitoring of COVID-19 patients. However, several areas related to the management of COVID-19 lagged. This study found that implementing digital health technologies in Saudi Arabia did not enhance robotic-based treatment of infected individuals and remote monitoring of isolated persons with COVID-19. The current study associated these adverse outcomes with HIT challenges, including technical issues that limited providers' capacity to conduct virtual physical exams and gauge patients' general appearance and other observable vital signs. Thus, digital health technologies have the potential to improve the management of COVID-19 and future pandemics, but necessary measures must be implemented to manage associated limitations to achieve the desired outcomes.

This study also found that HITs were useful in facilitating interventions for managing the COVID-19 pandemic. Medical technologies improved early diagnosis and isolation of COVID-19 cases, enhanced the planning of COVID-19-related activities, and improved patients' care experiences while ensuring frontline workers' safety. In addition, the study discovered that digital health technologies aided risk assessment, reduced medical costs, created a flexible working environment for providers, improved treatment options, enhanced patient care quality, promoted patients' privacy and confidentiality, saved time, and controlled the spread of COVID-19 infections. The correlation between these variables and the providers' perspectives was high (p above 0.8). This study associated these outcomes with the fact that HITs allowed clinically stable people to stay at home, reducing overcrowding and physical contact that,

in turn, reduced the transmission of COVID-19 infections. Furthermore, this study found that providers in Saudi Arabia were satisfied with the implementation of digital health technologies. This study reported that the practitioners could easily find the information they needed, and the information obtained from HITs was easy to understand. Therefore, digital health technologies add value to health systems, allowing the implementation of helpful medical interventions and improving providers' satisfaction.

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 Research Ethics Committee at Saudi Electronic University under Approval No. SEUREC-CHS21125. 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.

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Implementation and improvement of policies for building healthy cities in China

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Background and purpose: With the promotion of the World Health Organization, China has also launched a healthy city construction campaign. However, healthy city construction needs to formulate a series of policies. How can the current healthy city policy in China be further improved to provide a policy basis for healthy city construction?

Materials and methods: Collected here are policy texts from the Central People's Government and local government of the People's Republic of China on healthy cities from 2009 to 2023. This paper adopts the policy tool analysis method to design a two-dimensional analysis framework of the "policy tool-construction domain." There are three types of policy tools: demand-oriented, supply-oriented, and environmental-oriented. The field of healthy city construction is based on five fields defined by WHO: healthy population, health service, healthy environment, healthy culture, and healthy society. The policy text was coded and analyzed by Nvivo software.

Results: According to the coding analysis of policy texts, among the three types of policy tools, supply-oriented policies account for 60.5%, environmental policies account for 29.1%, and demand-oriented policies account for 10.4%. In the five areas of healthy city construction, healthy environment accounted for 23.7%, healthy society accounted for 12.3%, health services accounted for 39.1%, healthy population accounted for 13%, and health culture accounted for 11.9%. From the two-dimensional perspective of policy tools and the field of healthy city construction, the five fields of healthy city construction have different emphases on the application of three different types of policy tools.

Conclusion: Currently, the supply-oriented policy, the demand-oriented policy, and the environmental policy tools are used comprehensively in healthy city construction in China. The proportion of supply-oriented policy is high, which emphasizes the government's intervention and neglects the participation of individuals and social organizations. The use of policy tools is not balanced in the five different areas of healthy city construction, which to some extent limits the effect of policy implementation and strengthens the overall effect of the healthy city construction policy.

KEYWORDS

healthy city, health services, healthy environment, healthy culture, healthy life

1 Introduction

Healthy Cities is an international initiative advocated by the World Health Organization (WHO). Advance the objective of universal health by tackling the escalating difficulties of urbanization, including environmental degradation, deteriorating infrastructure, insufficient public services, and the proliferation of chronic diseases.

The term “healthy city” was first used by the World Health Organization (WHO) in 1984 during the Healthy Toronto 2000 Conference in Toronto, Canada. The conference’s goal was to encourage broad cooperation between different organizations, sectors, and the general public to address health and urban sanitation challenges (1, 2). The inaugural Global Conference on Health Promotion convened in Ottawa in 1986, promulgated a proclamation highlighting that the establishment of a healthy city transcends mere sanitation efforts. This encompasses multiple urban sectors and stakeholders, including governmental policies, community assistance, and individual conduct (3, 4). In 1995, the World Health Organization (WHO) established a clear definition of a healthy city as “a city where the natural and social environments are perpetually improving, enabling individuals to support one another in enjoying life and realizing their full potential through the continuous enhancement of social resources” (5). The Patriotic Public Health Commission of China characterizes a healthy city as an enhanced iteration of a sanitary city. A healthy city enhances natural, social, and sanitary environments while promoting healthy lives through superior urban planning, construction, and management. To address the health requirements of the population and attain the integrated advancement of urban development and human health (6).

Between 1985 and 1986, the WHO European Region initiated the “Healthy Cities Program,” aimed at fostering the establishment of healthy cities. The World Health Organization’s European Region Office initiated the “Healthy Cities Project” in 1986. Consequently, the European Network of Healthy Cities was founded. In 1987, Canada formally initiated the Healthy City Program, encompassing the “Healthy Cities Movement” in Toronto and the “Healthy Cities and Towns Movement” in Quebec. Canada initiated the “Healthy Communities” campaign, reflecting the size and sparsity of its territory, which subsequently encompassed the entire nation (7).

The United States is actively involved in the development of sustainable cities. In 1989, the US Department of Health and Human Services officially adopted the notion of healthy communities and advocated for it on a national scale. Indiana has prioritized the cultivation of local community leadership as the principal technique for implementing the Healthy City Program. The strategy prioritized the execution of the Healthy City Program via local community engagement and development, establishing the “U.S. Model” for the creation of healthy communities (8).

During the late 1980s and early 1990s, as developed nations such as Europe and the United States initiated Healthy Cities programs, Australia, Malaysia, Japan, and New Zealand in the Western Pacific region similarly adopted the initiative. In 1996, Cambodia, Laos, North Korea, Mongolia, and South Korea launched the Healthy City Program. Countries are enhancing urban health by prioritizing healthy city design, enforcing sanitary management legislation, implementing anti-pollution measures, and including all inhabitants in urban sanitation programs. The Healthy City Program has evolved into a global initiative in urban areas worldwide. Since the inception of the Healthy Cities Program, over 2,000 cities across Asia, Africa, Europe, North America, South America, and Australia have participated (9, 10).

The notion of a healthy city was first presented in China during the 1990s, generally coinciding with the creation of national sanitary cities in the late 1980s. In 1993, China formally initiated health city planning operations. In 1994, the Dongcheng District of Beijing and the Jiading District of Shanghai launched a pilot initiative for the development of healthy cities. In 2001, Suzhou became the inaugural Chinese city to

announce its involvement in the Healthy Communities Construction Program to the World Health Organization (WHO) and establish a preliminary set of guidelines for healthy communities. Following the Severe Acute Respiratory Syndrome (SARS) epidemic in 2003, the development of healthy cities in China progressed to a phase of comprehensive and significant advancement. The second Global Conference of the Alliance for Healthy Cities occurred in Suzhou in 2006. In 2008, the former Ministry of Health of China presented the “Healthy China 2020 Strategy” and designated 10 cities, including Shanghai, Hangzhou, and Suzhou, as experimental programs. The inaugural WHO Healthy Cities Collaborating Center Network in China was created in Shanghai in 2013. The network consists of 46 groups in Shanghai, Hangzhou, Suzhou, and other cities committed to advocating for healthy lifestyles and preventing chronic diseases.

In 2012, the State Council of China promulgated the “Twelfth Five-Year Plan for Health Development,” signifying the comprehensive initiation of healthy city construction initiatives. In 2015, the Fifth Plenum of the 18th Central Committee of the Communist Party of China resolved to advance the development of health-oriented towns with distinct Chinese attributes. The State Council released “Opinions on Enhancing the Patriotic Public Health Campaign in the New Era.”

In 2016, the national “13th Five-Year Plan” encompassed the advancement of constructing a healthier China. The Patriotic Public Health Commission of China released “Guiding Opinions on the Development of Healthy Cities and Healthy Villages.” In October 2016, the State Council of China released the “Healthy China 2030” Planning Outline, which underscores the establishment of healthy cities and villages as essential measures for constructing a healthier China. In November 2016, the Patriotic Public Health Commission of China initiated the Healthy Cities trial Program, announcing a roster of 38 national trial cities. The “Shanghai Declaration on Promoting Health in the 2030 Agenda for Sustainable Development” was simultaneously issued at the 9th Global Conference on Health Promotion, effectively linking the advancement of healthy cities with sustainable development objectives. In 2017, the National Health and Family Planning Commission of China, the State General Administration of Sports of China, and the All-China Women’s Federation collaboratively released the “Action Program for Healthy Lifestyles of All People (2017–2025)” to advocate for the implementation of a sustainable development model and lifestyle. In 2018, the Patriotic Public Health Commission of China promulgated and enacted the “National Healthy City Evaluation Indicator System (2018 Edition).”

The “Healthy City Project” was a project that highlighted the importance individuals attribute to health by including all sectors of society in cooperative endeavors, encompassing urban design, building, and comprehensive health management. This strategy aims to foster synergies among the population, environment, and society through integrated development to avert diseases and enhance health. The primary objective is to create the healthiest city attainable (11). The building of a healthy city necessitates the collaborative efforts of various stakeholders, including government, businesses, communities, and the populace, alongside good urban administration in all its dimensions. Consequently, the government must implement pertinent policies, efficiently amalgamate human, financial, material, and technological resources, and synchronize the collaborative efforts of all involved parties to accomplish the objective of establishing healthy cities. Policy instruments have been employed throughout many sectors as distinct processes and strategies by individuals to attain

public management objectives (8, 12, 13). This study analyzes Chinese national and local government policy papers about healthy cities and assesses policy instruments. The objective is to furnish scientific counsel for improving policies about the advancement of healthy cities.

2 Materials and methods

2.1 Data sources

This study chose policy documents about the development of healthy cities since the launch of the “Healthy China 2020 Strategy,” introduced by the former Ministry of Health in 2008, as samples. The investigation was performed from January 1, 2008, to September 1, 2023, utilizing the terms “healthy cities” and “healthy towns.” The search duration extended from January 1, 2008, to September 1, 2023. The terms “healthy cities” and “healthy towns” were employed to examine the official websites of Chinese administrative entities at various levels, including the State Council, the Health Commission, provincial governments, and municipal governments with districts, as well as the Database of Laws and Regulations of China. This research develops inclusion and exclusion criteria to assure the accuracy and representativeness of the policy wording.

2.1.1 Inclusion criteria

The first requirement is that the phrase “Healthy City” must be included in the title of the publication. Second, the departments that are responsible for issuing licenses are the State Council of China, the National Health and Family Planning Commission of China, the provincial governments, and the local governments that have districts. To put it another way, the entity that is issuing the document must be a government department.

2.1.2 Exclusion criteria

First, the development of the Healthy City Construction Commission and the Healthy City Evaluation Standard System, both of which are examples of organizational setups and technical requirements at a particular operational level. Second, departments of the government at lower levels transmit papers that have been sent by departments and governments at higher levels. Based on the criteria outlined above, thirteen different policy texts were ultimately incorporated into NVivo 14 for policy analysis (see Table 1).

2.2 Framework for analysis

The classification of policy instruments developed by Zegveld and Rothwell served as the basis for the construction of a framework for the analysis of policy documents (14) and the two dimensions of healthy city construction. What are the reasons for selecting this specific type of policy classification and the five dimensions of healthy city construction? We contend that the construction of a healthy city should prioritize the enhancement of the natural and social-ecological environment, the improvement of public health, the overall health level of the city, the creation of an attractive and suitable environment for human settlements, and the enhancement of the comprehensive development quality and sustainable development capability of cities. This will facilitate the potential for healthy cities to develop further and become more conducive

to entrepreneurship, as well as foster a more harmonious and dynamic economic, social, and ecological environment. Furthermore, this will lead to an improvement in the quality of health and quality of life, enabling the public to enjoy a better way of life as a result of improved health. Accordingly, the aforementioned classification of healthy urban construction policy is compatible with three distinct types of policy: demand-based, supply-based, and environmental-based. Additionally, Chinese scholars concur that the foundation of healthy city construction is comprised of five key elements: health services, a healthy environment, a healthy culture, a healthy society, and healthy people. Furthermore, the “Outline for the Implementation of the Construction of a Healthy China,” as issued by the Chinese government, also encompasses the aforementioned five areas. These form the theoretical basis and research framework of the subject.

There are three categories into which policy instruments can be classified: environmental, supply, and demand policy. The five main areas of healthy Chinese construction, which include health services, the health environment, the health culture, the health society, and the health population, define the field of healthy city construction. The y-axis represents the realm of healthy city construction, which establishes a two-dimensional analysis framework (see Figure 1).

2.2.1 X dimension: policy instrument dimension

Policy instruments are the methods or modalities employed by the government to accomplish its policy objectives (15). At present, Zegveld and Rothwell's classifications are the most frequently employed. The policy instruments were categorized into three categories: environmental, supply-based, and demand-based. The classification instrument is more precisely defined and operationalized (16). Consequently, this instrument was designated as the X-axis inside the two-dimensional analytical framework of this study. Supply-oriented policy instruments predominantly entail national assistance for the development of healthy cities via cash, knowledge, and technology. The principal objective of policies advocating for the development of healthy cities. Environmental policy instruments foster the development of healthy cities through targeted planning, regulatory frameworks, financial support, and additional mechanisms. Demand-driven policy instruments facilitate the advancement of healthy cities and enhance chances for such growth via market stimulation, government procurement, and service outsourcing. Please see Table 2 for a detailed list of specific policy instruments and their definitions.

2.2.2 Y dimension: healthy city building areas

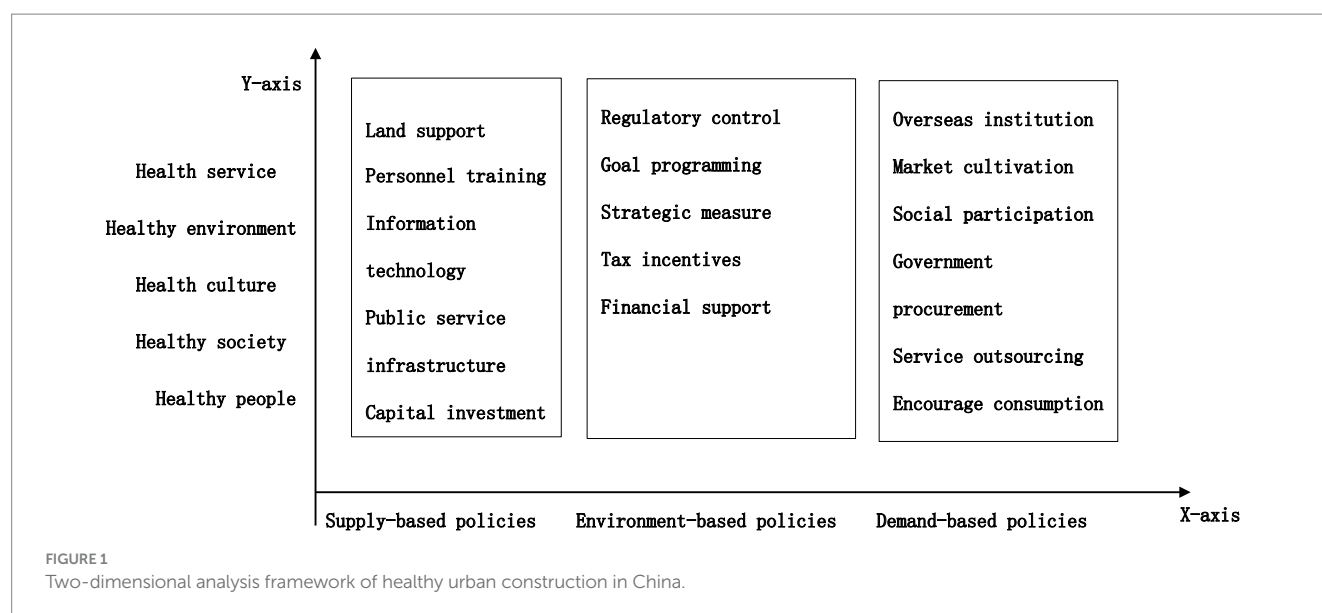
The World Health Organization (WHO) advises that every healthy city aims to attain the following objectives: establishing a friendly environment that promotes health. Improve the quality of life for the populace. Guaranteeing the fulfillment of fundamental sanitary requirements for the populace. Improve accessibility to sanitary services. The objective of healthy city development is to progressively achieve an urban model that is economically thriving, socially integrated, environmentally pristine and esthetically pleasing, culturally vibrant, secure, joyful, and habitable (17, 18). Healthy city strategies integrate social, economic, geographical, ecological, infrastructure, and various other urban systems with complex policy substance. To comprehend healthy city policy tools, one must analyze primary assessment indicators. In 2018, they were incorporated into the “National Healthy City Evaluation Indicator System” by the Patriotic Public Health Commission of China. This paper presents a Y-dimensional method for

TABLE 1 Policy texts for building healthy cities in China.

No	Name of the policy text	Publishing subject	Policy text number	Implementation date
1	The resolution of the CPC Nanning Municipal Committee and the Nanning Municipal People's Government about the establishment of a Healthy City	Nanning Municipal People's Government	Issued by the Nanning Municipal People's Government (2009) NO. 26	9 September 2009
2	Shaobing Municipal People's Government Office on the Implementation of Healthy City Creation	Shaobing Municipal People's Government	Issued by Shaoxing Municipal People's Government Office (2013) No. 87	18 June 2013
3	The Zhuhai Municipal People's Government Office on the Issuance of Opinions Regarding the Creation of Healthy Cities	Zhuhai Municipal People's Government	Zhuhai Municipal People's Government Office, 2014, No. 10.	4 April 2014
4	The Implementation of the Anhui Patriotic Health Campaign Committee's Opinions on the Construction of Healthy Cities, Healthy Villages, and Towns	Anhui Patriotic Health Committee	Anhui Patriotic Health Campaign Committee (2016) No. 45	15 July 2016
5	A Circular of the National Patriotic Health Campaign Committee on the Issuance of Guiding Opinions on the Construction of Healthy Cities, Healthy Villages, and Towns	National Patriotic Health Campaign Committee	Issued by the National Patriotic Health Campaign Committee (2016) No. 5	18 July 2016
6	The People's Government of Puyang City's Implementation Opinions on the Construction of a Healthy City	Puyang Municipal People's Government	Puyang Municipal People's Government (2016) No. 63	30 August 2016
7	A notice was issued by the General Office of the Zibo Municipal People's Government to implement opinions regarding the construction of healthy cities, villages, and municipalities.	Zibo Municipal People's Government	Zibo Municipal People's Government Office (2017) No. 45	5 April 2017
8	The General Office of the Dalian Municipal People's Government's Implementation Opinions on the Further Strengthening of the Construction of Healthy Cities, Healthy Villages, and Towns	Dalian Municipal People's Government	Issued by the Office of Dalian Municipal People's Government (No. 54)	14 April 2017
9	The Weifang Municipal People's Government Office on the Implementation of Opinions on the Construction of Healthy Cities, Healthy Villages, and Towns	Weifang Municipal People's Government	Weifang Municipal People's Government Office, (2017). 72	21 July 2017
10	The Opinion of the Longnan Municipal People's Government on the Implementation of Healthy Cell Construction, Healthy Townships and Villages, and the Healthy City	Longnan Municipal People's Government	Issued by the Longnan Municipal People's Government in 2017 (No. 54)	27 August 2017
11	The Panjin Healthy Cities, Healthy Villages, and Town Construction Implementation Program notice has been issued by the Panjin Municipal People's Government Office.	Panjin Municipal People's Government	Issued by the Panjin Municipal People's Government Office (No. 127)	6 November 2017
12	The Office of the People's Government of the City of Taian has issued a notice regarding the issuance of opinions regarding the implementation of the construction of healthy cities, villages, and towns in Taian City.	Taian Municipal People's Government	Taian Municipal People's Government Office (2018) No. 18	27 April 2018
13	Circular of the General Office of the Shanghai Municipal People's Government: Transmitting the Opinions of the Municipal Health Commission and 14 Other Departments on the Strengthening of Community Health Services in the City to Promote the Development of Healthy Cities	Shanghai Municipal People's Government	Issued by the Office of the Shanghai Municipal People's Government (2019) No. 2	16 January 2019

the development of healthy cities. Classify healthy city policies into five subsystems: a healthy environment, a healthy society, health services, healthy individuals, and a healthy culture (19), unidimensional policy instruments can reflect the primary methods and approaches of policy actions but may not fully demonstrate policy objectives and operational characteristics. Based on the research findings of experts and scholars

on healthy cities both domestically and internationally (3, 20, 21), this paper establishes a two-dimensional analytical framework of “X dimension (policy instruments) – Y dimension (healthy city construction field)” to examine the policy documents related to healthy cities. The research and policy texts of the experts are combined to construct this framework (see Figure 1).



2.3 Research methodology and policy text coding

NVivo is a software for text content analysis. The phrase “content analysis” refers to a methodological approach employed in the scientific community to investigate the fundamental nature of a phenomenon by analyzing it via its framework. The proposed method enables the reproduction of policy text content while extrapolating the outcomes. The thirteen policy documents about healthy cities in China were categorized by “policy number (Title 1–Title 2).” The idea of “non-disaggregation” establishes the minimal unit that characterizes the subject of measurement in the content analysis methodology. This concept guarantees the comprehensiveness of the meaning. A paragraph conveying a singular meaning serves as the analytical unit. In a text with several levels of meaning that may be segmented into several sentences, the sentence functions as the analytical unit (22, 23). The designation 13–4–5 indicates that the thirteenth policy document is titled “Circular of the General Office of the Shanghai Municipal People’s Government Transmitting the Opinions of the Municipal Health Commission and 14 Other Departments on Strengthening Community Health Services in the City to Promote the Development of Healthy Cities.” This chapter comprises 246 units of policy content analysis in the fifth paragraph under the fourth-level topic. We assess each analytical unit in the original text using contextual analysis to generate clear classifications for policy instruments and domains associated with the development of healthy cities. The units are thereafter categorized according to their distinct meanings. The application of policy instruments to foster the advancement of healthy cities is illustrated by quantitative data. To validate the coding’s reliability, two researchers independently coded the data, followed by a final consistency assessment of the coding outcomes. The test produced a kappa coefficient of 0.905, signifying a substantial level of consistency in the coding outcomes. Owing to spatial limitations, only a selection of coding results is presented (see Table 3).

The presentation rule of coding: Taking the title of the policy text itself as the reference basis, according to the progressive relations of

the first-level heading, the second-level heading, and the third-level heading, the coding classification is made for searching. Taking the above-mentioned measure as an example, it is located in the second secondary title in the third level title in the first document and is coded as 1–3–2. When coding, as far as possible, one paragraph is a code, but if there are several equally important different policy tools in a paragraph, it is divided by sentence.

3 Results

3.1 X dimension: basic information on policy instruments

The results of the utilization of policy instruments were derived from the categorization and generalization data based on the Healthy Cities policy content analysis unit coding form (see Table 4). The existing planning policies for the Healthy China initiative predominantly employ supply-based, environment-based, and demand-based strategies, with utilization rates of 60.5, 29.1, and 10.4%, respectively. The three types of policy instruments demonstrate notable disparities in their utilization frequency, with supply-based policies being employed more frequently than demand-based ones.

Regarding specific content, alongside the “land support” policy instrument, the remaining five supply-based policy instruments—personnel training, information technology, public services, infrastructure, and capital investment—have all been executed. Among the 163 policy instruments analyzed, 115 (70.6%) are classified as public service instruments, while 25 (15.3%) are categorized as infrastructure instruments. Information technology and financial inputs accounted for 6 and 4%, respectively, while human resource development comprises 3.6%. This indicates that in the supply-oriented policy for healthy city growth, the government prioritizes public services and infrastructure enhancement. The oversight of policy tools like “land support” and “personnel training” in supply-oriented policies can considerably restrict the quality and extent of healthy city growth.

TABLE 2 The basic types and meanings of policy tools for healthy urban construction.

Tools type	Tools name	Description of tool meanings
Demand type	Market cultivation	Enhance publicity and promotion efforts, foster and support the advancement of the health industry, and facilitate the establishment of a comprehensive and multi-tiered health service market.
	Government procurement	Government departments engage in the procurement of products from the emerging health industry, both directly and indirectly, to foster its development.
	Services outsourcing	To delegate the development, infrastructure construction, personnel training, and other necessary projects for the establishment of healthy cities to external entities.
	Overseas institutions	Investigate the international market of the burgeoning health sector and facilitate the multifaceted advancement of the health industry.
	Social participation	We will promote the active involvement and support of social entities in the development of healthy cities, integrate resources from diverse social organizations, and create a scenario where the entire population is engaged and participates collectively.
	Encouragement of consumption	To enhance consumption and advance the development of health industries through the encouragement and promotion of emerging health sectors.
Supply type	Personnel training	Facilitate talent support for the development of healthy cities, including talent training and recruitment initiatives.
	Information technology	Develop an intelligent platform for health information, enhance data collection and integration, and facilitate the interconnection and sharing of health information; advance public health communication initiatives, and establish new media channels for health promotion in the development of healthy cities.
	Public service	Implementing government functions and enhancing its active role through the establishment of a public service platform, the improvement of the service guarantee system, and the formulation of specific measures for the development of healthy cities.
	Infrastructure	This encompasses the development of infrastructure, including roads, sanitation systems, electricity provision, communication networks, and firefighting services. Examples include urban sewage and waste treatment facilities, as well as sanitary public toilets designed for safety and hygiene.
	Land support	To develop healthy urban environments through the provision of land use indicators, the revitalization of land resources, and the optimization of land use approval processes.
	Investment	The government will facilitate the efficient development of healthy cities through financial investment and subsidies.
Environmental type	Regulatory control	The implementation of diverse laws and regulations aims to enhance the quality and safety supervision system for agricultural products, reinforce oversight of food and drugs, and mitigate the incidence of food and drug safety events.
	Goal programming	The government develops a healthy city plan by analyzing the primary factors influencing health in the current context.
	Tax preferences	Implement preferential policies for the development of healthy cities via tax reductions and fee waivers.
	Strategic measures	Implementing diverse environmental remediation activities, enhancing the ecological protection system, and refining the health management system and mechanisms are essential for achieving policy objectives effectively.
	Financial support	Facilitate credit and guarantees for the construction of diverse facilities; ease financial constraints within the health sector, among other measures.

No	Planning name	Content analysis unit for policy texts	Code
1	The decision of the CPC Nanning Municipal Committee and Nanning Municipal People's Government on Building a Healthy City	<p>3 Main tasks and measures for building healthy cities</p> <p>3.1 Strengthen the construction and management of urban public facilities and vigorously create a healthy environment.</p> <p>3.1.1 Strengthen infrastructure construction. By the requirements of a high-starting point plan, high-intensity investment, high-standard construction, and high-efficiency management, large projects improve the urban and rural infrastructure network and meet the needs of the people's healthy life.</p> <p>3.2 Strengthening disease control and health services and vigorously improving health services</p> <p>3.2.1 Improve the disease prevention and control system. Accelerating the capital construction of specialized institutions for disease prevention and control at all levels, improving equipment and facilities, and raising the quality of professional teams.</p> <p>3.3 Strengthening health education and management, and vigorously cultivating a healthy population</p> <p>3.3.1 The proliferation of preventive healthcare immunizations is a primary goal. According to the State Council's Regulations on Vaccine Circulation and Immunization Planning Administration, the Government has taken on increased responsibility for developing and refining the long-term management framework for immunization planning, ensuring effective preventive healthcare and health promotion across all demographics, and improving the quality and management of immunization planning efforts. The program targets rural and migratory populations, progressively broadening the range of pediatric immunizations within the immunization initiative, guaranteeing the execution of preventative vaccination efforts, and creating a solid platform for health promotion.</p>	<p>1-3-1-1</p> <p>1-3-2-1</p> <p>1-3-3-1</p>

13	Circular of the General Office of the Shanghai Municipal People's Government transmitting the Opinions of the Municipal Health Commission and Fourteen Other Departments on Strengthening Community Health Services in the City and Promoting the Development of Healthy Cities.	<p>4 Main tasks</p> <p>4.2 Strengthening community medical and health services</p> <p>4.2.1 Creating health accounts focused on residents. Enhance the electronic health records of residents in the city by progressively incorporating the records of community residents' visits to diverse medical institutions, service records from various social health management entities, student health records, physical fitness monitoring data, and residents' self-health monitoring records. Achieve the interconnectivity of information among health service institutions.</p> <p>4.3 Strengthening community services for healthy aging</p> <p>4.3.1 Developing community care and home care services. Continuously expanding the supply of older adults care services, guiding community care organizations to develop in the direction of embeddedness and multi-functionality.</p> <p>4.4 Strengthening community health promotion and education</p> <p>4.4.1. Establishing a multi-level health publicity and education system. Relying on the three-tiered network of community colleges, community schools, and village learning points, health education is being carried out to advocate a healthy lifestyle.</p>	<p>13-4-2-1</p> <p>13-4-3-1</p> <p>13-4-4-1</p>

TABLE 4 Distribution table of basic policy tools in China's healthy urban construction policy texts.

Types of policy instruments	Tool name	Policy text number	Count	Percent
Demand type	Market cultivation	2-2-3-6;3-2-5-5;3-3-4-4;7-4-2-3-6;9-3-2-3;10-3-1-2-6	6	10.4%
	Government procurement	N/A	N/A	
	Service outsourcing	N/A	N/A	
	Overseas institution	N/A	N/A	
	Social participation	1-3-3-4;1-3-4-3;2-3-4;2-4-3;3-4-3;4-6-3;5-4-4;6-5-3;7-4-5-2;8-5-3;8-5-4;...	21	
	Encourage consumption	N/A	N/A	
Supply type	Personnel training	1-3-2-3;7-5-5;9-2-3-5;10-3-1-2-6;11-4-4;13-4-3-3	6	60.5%
	Information technology	2-3-10;4-5-1-2;7-4-7;7-4-2-1;9-3-2-1; 13-4-2-1;13-4-7-1;...	10	
	Public service	1-3-1-2;1-3-1-3;1-3-1-4;1-3-3-1;1-3-3-2;2-2-2;2-2-3-3;2-2-4;...	115	
	infrastructure	1-3-1-1;1-3-2-1;2-2-1;3-3-1-2;3-3-2-2;3-3-2-3;3-3-3-1-1;3-3-3-2-1;4-5-1-3;...	25	
	Land support	N/A	N/A	
	Capital investment	5-4-2;8-5-2;9-7-2;10-4-2;11-4-2;12-6-4;13-5-4	7	
Environmental type	Regulatory control	1-3-4-4;2-2-3;3-3-1-5;4-4-2-7;4-5-1-6;5-3-11;6-3-6;9-3-6;10-3-1-3-3;...	13	29.1%
	Goal programming	1-2-2;2-1-3;3-1-3;3-4-2;4-6-2;4-3;5-2-1;6-5-2;6-1-3;...	18	
	Tax incentives	N/A	N/A	
	Strategic measure	1-3-2-1;1-3-2-2;1-3-2-4;2-3-2-3;2-1;3-3-1-4;3-3-2-4;3-3-3-1-2;4-5-1-5;...	37	
a	Financial support	N/A	N/A	

N/A means that this policy instrument is not used in the policy text.

Among the six distinct instrumental methods of demand-based strategies, government procurement, service outsourcing, overseas institutions, and encouraging consumption are not employed. Only two instruments have been executed: social participation and market incubation. Among the 27 units of policy content analysis, 21 (77.8%) pertained to social participation, whereas 6 (22.2%) were associated with market formation. Among the supply-based, environmental, and demand-based policy categories, demand-based policies employ fewer instruments, with only a limited percentage being implemented. Our healthy city policy does not prioritize a demand-driven policy framework.

3.2 Y dimension: basic information about the healthy city construction field

The coding table for the content analysis unit of the Healthy City Policy facilitated the classification, summarization, and statistical analysis of the distribution of construction areas within China's Healthy City Policy. Out of 253 policy content analysis units, 60 (23.7%) pertain to healthy environment construction, 31 (12.3%) to healthy society construction, 99 (39.1%) to health services construction, 33 (13%) to healthy population construction, and 30 (11.9%) to the culture of health construction, across the five principal domains of healthy city development. Our country has concentrated on five distinct domains of

healthy city development. The establishment of a healthy environment constituted a marginally greater proportion than the other four specialized domains.

3.3 X-Y dimension: policy instruments for healthy city construction: two-dimensional basics

The results of the two-dimensional study of healthy city policies X-Y are generated from the examination of policy instruments in the X dimension and the incorporation of healthy city building areas in the Y dimension (see Table 5). Three policy tools concentrate on each of the five overarching domains of healthy city development. In health service construction, 99 units were utilized for policy content analysis: 57 supply-oriented policies (57.6%), 23 environmental policies (23.2%), and 19 demand-oriented policies (19.2%). In health care, policymakers have primarily supported supply-oriented approaches over those based on environmental and demand considerations. 60 units are offered for the analysis of policy content in the context of creating a healthy environment. Of them, 31 (51.7%) are supply-oriented policies, whereas 29 (48.3%) are environmental policies. 30 policy analysis units are available for the creation of health culture. Of these, 25 (83.3%) are supply-oriented policies, 3 (10%) are environmental policies, and 2 (6.7%) are demand-oriented policies.

TABLE 5 Results of X-Y two-dimensional analysis of Chinese Healthy Urban Construction Policy texts.

Types of policy instruments	Concrete tool	Healthy people	Healthy society	Health culture	Healthy environment	Health service
Supply-based policies	Personnel training	0	0	0	0	6
	Information technology	0	0	1	0	9
	Public service	30	19	24	8	34
	infrastructure	1	0	0	23	1
	Land support	0	0	0	0	0
	Capital investment	0	0	0	0	7
Environment-based policies	Regulatory control	0	12	0	0	1
	Goal programming	0	0	0	0	18
	Tax incentives	0	0	0	0	0
	Strategic measure	1	0	3	29	4
	Financial support	0	0	0	0	0
Demand-based policies	Market cultivation	1	0	1	0	4
	Government procurement	0	0	0	0	0
	Service outsourcing	0	0	0	0	0
	Overseas institution	0	0	0	0	0

There are 31 policy analysis units dedicated to fostering a healthy society. Of them, 19 (61.3%) are supply-oriented policies, 12 (38.7%) are environmental policies, and there are no demand-oriented policies adopted. Within the domain of public health promotion, there exist 33 policy analysis units: 31 supply-oriented policies (94%), 1 environment-oriented policy (3%), and 1 demand-oriented policy (3%).

In total, three policy instruments were recognized throughout the five domains of healthy city development: supply-side policies, environmental policies, and demand-side policies. Nonetheless, supply-oriented policies are employed more frequently, while demand-oriented policies are somewhat less prevalent.

4 Discussion

4.1 The utilization of policy instruments exhibits considerable variability, and their structure is disproportionately distributed across various domains in the development of a healthy city

The development of healthy cities typically prioritizes supply-oriented policy instruments, while inadequately employing environment- and demand-oriented policy instruments. Categorical statistical analysis reveals that supply-oriented policy instruments with substantial government engagement are predominantly employed in initiatives focused on cultivating healthy cities. They offered several policies and actions across five distinct domains: a healthy environment, a healthy society, health services, healthy individuals, and a healthy culture. Nevertheless, demand-driven policy instruments that emphasize the independence of various social agents and amalgamate governmental power with market dynamics have not been completely utilized. Consequently, they are unable to stimulate the passion of varied participants and market dynamics (24). The implementation of this policy

instrument is contingent upon compliance with a certain set of regulations. Advocating for the government's perspective is essential when implementing a new policy. Moreover, if the policy garners community acceptance, it will transition from a supply-centric approach to one that prioritizes environmental and demand considerations. From a policy implementation standpoint, an optimal policy achieves equilibrium among several policy types. Consequently, each policy must be formulated to enhance the others to guarantee the attainment of the intended outcome (25).

4.2 The focus on healthy city development differs among urban regions

The World Health Organization (WHO) and governmental proposals for developing healthier cities have led to considerable emphasis from both central and local governments on the establishment of healthy urban environments. Relevant policy documents and action plans have been issued. The initiative and creativity of local governments in formulating policies for healthy cities are comparatively limited. Many local healthy city policies appear to be derived from the frameworks established by the central government or higher-level state entities. Their efforts have not prioritized the establishment of policies and administrative programs suitable for fostering healthy cities, tailored to the specific realities of their local contexts. Numerous entities comply with the directives established by higher-level authorities and perceive policy formulation as a political achievement, frequently overlooking the implications of its execution (26, 27).

An optimal environment is essential for the protection of human health. A statistical examination of the utilization of policy tools indicates that, at the national level, there is an emphasis on developing and advocating for healthy environments as a priority topic. This also indicates that healthy cities embody an enhanced iteration of the concept of sanitary cities (28, 29). Nevertheless, the Healthy City Program's

development is not only reliant on establishing a healthy environment to attain the objective of being the city with the greatest health standards. It necessitates extensive advancement across multiple domains.

5 Conclusion and policy recommendations

The World Health Organization's Healthy City Program is founded on two essential principles (30). Initially, we assess the condition of the city. Urbanization is a dominant tendency in the global advancement of human society. It is a fundamental necessity and an unavoidable result of the progress of societal productive forces. The evolution of urban areas has significantly enhanced human life and labor, facilitating the swift progression of the global economy. Approximately 50% of the global population resides in metropolitan, constructed environments. The swift advancement of urban growth, particularly in industrialized cities, has resulted in several social, health, and ecological issues. Social issues including elevated population density, traffic congestion, housing limitations, contaminated drinking water and food resources, deteriorating ecosystems, and violence are emerging as significant dangers to human health. The second concept pertains to a healthy city. Cities are not merely economic entities pursuing efficiency in expansion; they should also serve as optimal environments that promote human health. Cities ought to be perceived as dynamic, evolving entities. This is a contemporary prerequisite for the existence and advancement of urban areas.

"Health," in a restricted sense, pertains solely to an individual's physical well-being. The notion of "health" within a healthy city is extensive, grounded in the two pillars of the Healthy City Program, the World Health Organization's 1984 delineation of the 11 characteristics of a healthy city, and the stipulations of the 10 criteria for a healthy city established in 1996. A healthy city is a cohesive entity that includes healthy individuals, a healthy environment, and a healthy community (31, 32). China underscores the importance of establishing a robust China ought to endorse the principle of "big health," execute the strategy of "integrating health into all policies," adhere to the doctrine of "building and sharing," and leverage the responsibilities of the government, various departments, society, and individuals to collaboratively tackle health challenges arising from urbanization. The development of a healthy city can be delineated into five primary domains: a healthy environment, a healthy population, a healthy society, a healthy culture, and health services, constituting an integrated and cohesive entity.

To advance the development of healthy cities, it is essential to integrate supply-oriented, environment-oriented, and demand-oriented policies. Various policy instruments can be employed in a coordinated fashion to foster the development of healthy local cities, taking into account local conditions. Consequently, the development of healthy cities in China necessitates enhancement through the following methods.

5.1 Swiftly modifying the ratio of policy instruments

The development of healthy cities is a policy execution process that encompasses all tiers of governance. During the preliminary

phase of building, owing to inadequate hardware infrastructure and the limited knowledge among all social stakeholders, it is essential to employ top-down, supply-oriented policy instruments. Nonetheless, the establishment of a healthy city necessitates a grassroots policy implementation process, and dependence simply on governmental authorities is inadequate. The establishment of a healthy city necessitates the collaborative engagement and advocacy of all individuals due to the existence of various social entities (33). Prolonged use of coercive programs by governments frequently results in diminished efficacy and exacerbated adverse consequences. Every policy instrument possesses distinct properties. Governments must consider all three categories of policy instruments and should not overlook the selection of demand-oriented policy instruments. Demand-driven policy instruments can act as a framework for fostering public engagement (1, 34, 35).

5.2 Implement policy instruments in a comprehensive and interdisciplinary approach

The Chinese government has consistently underscored the significance of environmental cleanliness and management. In 1953, China launched a comprehensive health campaign to effectively tackle public health issues and guarantee sufficient hygienic conditions. The government has spearheaded this patriotic initiative. Collaborated with all sectors and engaged the entire community. In the last 70 years, the patriotic health campaign has concentrated on enhancing environmental cleanliness, expanding sanitary toilet access, ensuring safe drinking water, and improving health literacy among the populace. The patriotic health campaign successfully mitigated the prevalence of infectious diseases and enhanced public health. The establishment of a healthy city is essential for fostering a healthy China, a vital component in promoting new urbanization, and an important foundation for the contemporary patriotic health campaign (36, 37). The creation of a healthy city encompasses diverse public policies across numerous sectors and is segmented into several construction phases. This approach necessitates the extensive and multidisciplinary application of policy instruments and the collaboration of diverse social stakeholders. The development of Healthy China is progressively transitioning from a focus on environmental health management to an emphasis on holistic health promotion. The focus has transitioned from the initial emphasis on constructing a singular, localized health environment to a model of integrated social health management including the full spectrum of a healthy environment, society, health services, individuals, and culture (38–40).

5.3 Policies are specific and targeted

Multiple regions in China are advancing the initiative for a healthy China in alignment with the central government's guidance. The foundation for constructing healthy cities differs based on location and environment. Local governments should customize their strategies to local situations to avoid duplicating policies. Nonetheless, the current foundations and settings for healthy cities differ from one

location to another. Local governments should tailor their programs to specific conditions to prevent redundancy. Local governments must select among supply-oriented, environmental, and demand-oriented strategies to prioritize the five domains of healthy cities. While the national government prioritizes supply-side policies, it is crucial to stress environmental policies and formulate demand-side strategies at the local level. Simultaneously, it is vital to modify the application of particular policy instruments based on the type of policy. Support for talent development, land assistance, and information technology can be enhanced through supply-oriented policy instruments. The demand-driven policy instruments aggressively seek government procurement assistance, outsourcing services, forming offshore entities, offering consumption incentives, and encouraging social engagement. This fosters the development of synergies for creating healthy cities (41–43).

5.4 The system appraisal of the implementation of the healthy city construction policy should continue, with the results of this appraisal forming the basis for further improvements to the policy content

The Chinese patriotic health movement originated in the 1980s and has demonstrated a favorable response to the World Health Organization's Healthy City construction program since the beginning of this century. To illustrate, the city of Shanghai has augmented its investment in urban environmental construction, completed the construction of the urban park system, completed the tertiary hospital system, gradually popularized the family doctor system, and achieved a high degree of satisfaction with health services (44, 45). Furthermore, it has actively popularized health education, thereby realizing the Trinity of a Healthy City, healthy community, and healthy town (46). This provides an exemplar of healthy city construction activities. It is important to note that the efficacy of healthy city construction activities varies depending on the context. A comprehensive evaluation is essential to identify areas for improvement and to develop strategies to address these shortcomings (47, 48). Promoting the dissemination of health education, enhancing food safety supervision, strengthening public health emergency warning and prevention mechanisms, and improving the medical classification system are key areas for consideration (49). It is essential to advocate a problem-oriented approach and actively improve the policy tools and content of healthy cities, thereby further promoting the level and quality of our healthy city construction (50). This approach should be based on the local reality.

5.5 Constructing an indicator system for building healthy cities and strengthening policy synergy

Building a healthy city, setting up a healthy city indicator system, and carrying out an evaluation of its effectiveness are important paths to promote the construction of a healthy city (51, 52). Since the promotion of the Healthy Cities Project, some scholars have begun to research the Healthy Cities Indicator System (53–55). In

2018, the National Office of the Patriotic Health Movement in China conducted research and developed the National Healthy Cities Evaluation Indicator System. This system was designed to align closely with the objectives and tasks outlined in China's Healthy City construction initiative. It aims to guide cities in improving the natural environment, social environment, and health services, promoting the comprehensive popularization of healthy lifestyles, meeting the health needs of residents, and facilitating the coordinated development of city construction and people's health. The indicator system consists of 5 first-level indicators, 20 s-level indicators, and 42 third-level indicators, which can objectively reflect the overall progress of the construction of healthy cities in different regions. The indicator system also gives the definition, calculation method, caliber range, source department, and other information of each indicator to ensure that the data collection of healthy city evaluation can be carried out by uniform standards. Level 1 indicators correspond to the five areas of "Healthy Environment," "Healthy Society," "Healthy Services," "Healthy People" and "Healthy Culture," "Healthy Environment," "Healthy Society," "Healthy Services," "Healthy Population" and "Healthy Culture," while the secondary and tertiary indicators focus on the main health problems and their influencing factors in the development of Chinese cities (52, 56). Since 2018, the National Patriotic Health Campaign Office has engaged the services of a third-party professional institution to conduct annual evaluations of all national health cities across the country. The evaluations entail the analysis and assessment of the progress of healthy city construction in each city, the identification of areas for improvement, the promotion of continuous quality improvement in the work of healthy city construction, and the advancement of the positive development of healthy city construction (50, 57).

At the same time, it is important to pay attention to policy synergies in the process of formulating and implementing public policies for the development of healthy cities that are constantly being followed up. Firstly, it is important to note that local Healthy City construction is based on the Healthy China 2030 Planning Outline and the central Healthy City policy, and is aligned with the central policy (58). Secondly, it is essential to recognize the potential for synergy among local healthy cities, which may face different specific situations, factors affecting healthy cities, and progress in the construction of healthy cities. The model cannot be replicated, but there is an opportunity to learn from each other's advanced experiences, based on the local construction of healthy cities (59). Thirdly, there is a synergy between policy tools and policy content. The deployment of different policy instruments is associated with varying degrees of efficacy, and the timing of their utilization is crucial for optimizing the overall impact of policy implementation (8). Fourthly, the process of policy formulation should be aligned with the practical implementation of policies. Policies must evolve by the requirements of practice, while practice also informs the necessity for policy (60). The formulation of policy and the practice of policy should be developed in a coordinated manner to facilitate the comprehensive advancement of all areas and aspects of healthy city construction.

Of course, this study possesses limitations that necessitate additional inquiry. The classification of policy tool kinds was performed according to the software specifications of the coding unit to guarantee precision

and impartiality. Nonetheless, the understanding of the content and coding may be erroneous. This could result in code mistakes. The impact of precisely articulated policy recommendations on policy efficiency remains ambiguous. This necessitates more verification, which was omitted from this subject.

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

QW: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing. GH: Data curation, Formal analysis, Methodology, Validation, Visualization, Investigation, Writing – original draft, Writing – review & editing. LH: Funding acquisition, Investigation, Project administration, Resources, Software, Supervision, Writing – review & editing.

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Public perception of COVID-19 in Saudi Arabia during the Omicron wave: recommendations for policy improvement

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Background: The emergence of new SARS-CoV-2 variants makes it difficult to forecast potential epidemiological changes. This study investigates Saudi citizens' perceptions of COVID-19 during the Omicron wave.

Methods: We conducted a cross-sectional study using an online survey and a convenience sample of 746 participants. The survey included questions about demographics, anxiety levels, and perception of COVID-19 during the Omicron wave.

Results: Our findings revealed that 27.3% of the participants believed that COVID-19 cases would decrease, while 30.2% believed that cases would increase; the remaining 42.5% were uncertain. When asked about the primary reasons for expecting a rise in COVID-19 cases, the two most frequently cited causes were non-adherence to prevention measures (74.7%) and the high transmissibility of the virus (66.7%). Conversely, when asked about the primary reasons for expecting a decrease in COVID-19 cases, participants cited the availability of free vaccines (60.3%), government measures (59.9%), compliance with preventive measures (57.4%), and health awareness programs (44.1%). Multivariate logistic regression analysis indicated that anxiety about COVID-19 (AOR = 1.23, 95% CI: 1.15–1.32) and education level (AOR = 1.58, 95% CI: 1.11–2.25) were significant predictors of respondents' expectations of increases or decreases in COVID-19 cases ($p < 0.05$). Around 46.2% of participants were moderately to highly worried about the reinstatement of lockdowns, while 36.2% reported moderate to high levels of anxiety related to COVID-19. Ordinal logistic regression analysis showed that respondents who reported higher levels of worry about the reinstatement of lockdowns were 1.28 times more likely to experience higher levels of anxiety related to COVID-19 ($p < 0.05$). A few participants were hesitant to adhere to preventive measures because they had already been vaccinated or believed that COVID-19 was not real or severe. This hesitancy raises public health concerns, suggesting that some individuals may underestimate the risks associated with COVID-19 and future pandemics.

Conclusion: This study provides valuable insights into how Saudi citizens perceived COVID-19 during the Omicron wave. Understanding these perceptions can guide the development of public health policies, optimize

resource allocation, help control the potential transmission of viral variants, and enhance preparedness for future pandemics.

KEYWORDS

COVID-19, pandemics, public health, public perceptions, policy, Saudi Arabia

1 Introduction

The coronavirus disease 2019 (COVID-19) pandemic has posed a global threat since its emergence in December 2019. More than 775 million people have been infected with the virus to date, with more than 7.7 million fatalities (1). The World Health Organization (WHO) has issued several statements about the ongoing COVID-19 outbreak, with more than 40,000 COVID-19 cases reported between May 13 and June 4, 2024 (2). The pandemic impacted many aspects of daily life, including the global economy, public services, education, healthcare, and social activities.

Saudi Arabia was one of the first countries in the Middle East to be affected by the COVID-19 pandemic. Since August 19, 2023, there have been 841,469 reported cases of COVID-19 in the country as well as more than 9,646 deaths (3). The Saudi government implemented several measures to contain the spread of the virus, including lockdowns: these involved the closure of schools, public offices, and businesses; restrictions on travel; limits on Hajj and Umrah activities; and controls on the usage of mosques for prayer (4–7). The government also launched a mass vaccination campaign. As of June 4, 2024, a total of 68.53 million doses of the COVID-19 vaccine had been administered, with 46% of the total population receiving at least one booster dose (8).

The emergence of new variants of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), such as Omicron, along with its many lineages and new families, is an ongoing threat that requires collaborative partnerships to address (9, 10). For example, at least 30 SARS-CoV-2 genomes related to Omicron variants were reported in Saudi Arabia alone (11). The WHO raised the alarm about the Omicron variant on November 26, 2021, citing its high number of mutations and negative impact on COVID-19 epidemiology (12, 13) and highlighting its increased infectiousness compared to previous SARS-CoV-2 variants. The emergence of new variants makes it impossible to predict potential relevant epidemiological changes and it is possible that more hazardous variants could emerge in the future. These changes and uncertainties can affect people's mental health, heighten anxiety, and affect perceptions of diseases and preventive measures.

A global cross-sectional online survey was distributed to assess people's knowledge and perception of the Omicron variant of SARS-CoV-2 (14); the average knowledge score was found to be 3.18 out of 5, indicating that people had some knowledge of the variant though there was still room for improvement. In addition, perceptions of the fatality rate of Omicron varied from country to country ($p = 0.05$) (14). A study from the United States found that a majority of respondents were worried about the risk of contracting COVID-19 (15). However, the emergence of the Omicron variant led to an unexpected decline in negative perceptions and concerns among the general public while increasing them among individuals infected by COVID-19.

A cross-sectional study conducted in Jordan revealed a low average knowledge score about Omicron (4.19 ± 2.06 out of 8), suggesting that participants were relatively unaware of the variant (16). In addition, more than one-third of participants (38.6%) were unconcerned about

the Omicron variant, indicating that a majority of respondents were worried or unsure about their perception of the disease. Another survey conducted in Iraq revealed that over half of the participants (56.5%) believed that Omicron was more contagious than previous variants (17), and the vast majority (86.5%) also believed that following the recommended protective measures would be ineffective.

In the Saudi context, a study was conducted in Riyadh during the Omicron wave to evaluate anxiety, depression, and fear in individuals with and without diabetes (18). The results revealed that, compared to non-diabetic participants, people with diabetes exhibited significantly higher levels of nervousness and anxiety ($p = 0.001$), depression and hopelessness ($p = 0.004$), and COVID-19-related fear ($p = 0.037$). Another study surveyed the experience of healthcare workers in Saudi Arabia regarding the Omicron variant (19); the results revealed that participants were more worried about the Omicron variant than the original, Alpha, and Delta strains ($p < 0.001$). Furthermore, uncertain individuals were more likely to experience stress ($r = 0.326$, $p < 0.010$). However, those with higher levels of resilient coping ($r = -0.313$, $p < 0.010$) as well as those who followed preventive measures and obtained information from the WHO website were better able to cope with stress. The negative perception of Omicron may also be attributed to its speedy transmission. An observational study at an eye care center in Riyadh found that 7.6% of ordinary patients tested positive for COVID-19 during the Omicron outbreak, although they were asymptomatic when swabbed (20).

This study aims to understand how Saudi citizens perceived COVID-19 during the Omicron wave as well as identify the factors that influenced these perceptions. Understanding these influences can guide responses to future potential epidemics, reduce the burden on public health, and inform relevant decisions. We examined the participants' anxiety levels during the Omicron wave, their concerns about the possibility of another lockdown, their willingness to follow preventive measures, and whether they expected COVID-19 cases to increase or decrease. Evaluating concerns regarding potential future lockdowns creates an opportunity for adequate preparation, communication, and planning of necessary restrictions. Examining COVID-19-related anxiety also helps public health professionals to provide appropriate mental health support. Understanding people's willingness to comply with preventive measures and their expectations regarding COVID-19 waves can help predict their responses to future waves as well as guide the planning of related health services. Finally, examining factors that influence people's attitudes toward COVID-19 can assist in the development of targeted public health policies.

2 Materials and methods

2.1 Study design and sample

This study used a cross-sectional survey design. The minimum sample size of 385 was determined using Epi Info for Windows

(21), taking into consideration the survey population (21.7 million) (22), margin of error (5%), confidence interval (95%), and response distribution (50%). All completed questionnaires were analyzed, resulting in a convenience sample of 746 participants.

2.2 Questionnaire

The initial draft of the study questionnaire was developed by the first author and validated by a group of experts, including two bilingual public health professors and co-authors of this article. The validation process included content and face validity (23). Upon approval, the questionnaire was translated into Arabic and validated by the same experts. The Arabic version was used for data collection, while the English version was presented for publication. Two bilingual public health professors and co-authors of this article reviewed both versions of the questionnaire to ensure coherence, clarity, and accuracy. The clarity of the Arabic version was also verified by a subgroup of the survey population.

The survey included questions on demographics, anxiety levels, perception of COVID-19 during the Omicron wave, and an open-ended section. Demographics queried included age, gender, marital status, care for dependents, education level, and whether the respondent had contracted COVID-19. The section on anxiety included two questions scored on a continuous scale from 1 to 10. These questions examined the level of anxiety among participants related to Omicron as well as their concerns about the possibility of another lockdown. A higher score on the scale indicates greater COVID-19-related anxiety or increased worry about the reinstatement of lockdowns. The percentile cut-off points (25th, 50th, and 75th percentiles) were used to categorize the level of anxiety experienced by respondents related to the Omicron wave and/or concerns about the reinstatement of lockdowns, resulting in three categories: low (1–3.33), moderate (3.34–6.67), and high (6.68–10). The section on perception included two questions graded on a five-point Likert scale about the participants' willingness to follow preventive measures and whether they expected COVID-19 cases to increase or decrease. The responses ranged from "strongly disagree" to "strongly agree." The third question in this section was a multiple-answer question about the different factors that influenced their perceptions. More details on the survey can be found in [Supplementary material \(24\)](#).

2.3 Data collection

Data were collected during February and March 2022 using an online survey that took an average of 4 min to complete. The researchers shared the survey link to their Twitter (X) followers and WhatsApp contacts, encouraging participants to continue sharing it across their social media networks. Eligibility criteria for participation included being Saudi Arabian, aged 18 years or older, and residing in Saudi Arabia during the pandemic.

This study was approved by the Research Ethics Committee of Jazan University in Saudi Arabia. Participants were given clear instructions about data confidentiality and the survey completion process. They were informed that their participation was voluntary and that they could withdraw at any time before submitting the survey.

Participants were also asked to provide informed consent by answering a simple yes or no question.

2.4 Data analysis

The data were analyzed using the IBM SPSS statistics software, version 29. First, descriptive statistics were used to determine the characteristic demographics of the participants, whether they expected COVID-19 cases to increase or decrease during the Omicron wave, and the mean anxiety scores relating to Omicron and the reinstatement of lockdowns. Second, univariate and multivariate regression analyses were used to determine which factors were the strongest predictors of a respondent's expectation regarding an increase or decrease in COVID-19 cases, including age, gender, education level, care for dependents, whether they had contracted COVID-19, adherence to the prevention measures, level of anxiety about Omicron, and worries about the reinstatement of lockdowns. Finally, an ordinal logistic regression model was used to assess the impact of the abovementioned independent variables on the participants' anxiety about the Omicron variant. A p -value < 0.05 indicates statistical significance.

3 Results

3.1 Demographic description

There were 774 responses to the survey. After 28 incomplete questionnaires were excluded, only 746 responses were included in the final sample. The average age of the participants was 29.18 years, with a standard deviation of 9.27 and a range of 18–55 years. Most participants were male (59.5%), unmarried (58.3%), and had completed university or higher education (64.9%). About 54.3% of respondents did not care for a dependent, while 63.3% had not contracted COVID-19. For more details, refer to [Table 1](#).

3.2 Expectations regarding increases or decreases in COVID-19 cases during the omicron wave

Less than one-third of the participants ($n = 204$; 27.3%) disagreed or strongly disagreed that COVID-19 cases would increase, while 30.2% ($n = 225$) agreed or strongly agreed that cases would increase; the remaining 42.5% ($n = 317$) were unsure about their expectations. [Figures 1, 2](#) present the primary reasons provided for these expectations.

3.3 Intention to adhere to preventive measures

Although the vast majority of participants ($n = 711$; 95.3%) agreed or strongly agreed that they would voluntarily adhere to preventive measures against COVID-19, a small proportion ($n = 8$; 1%) disagreed or strongly disagreed, while 3.7% ($n = 27$) were hesitant. Several reasons were cited for rejecting adherence, including: "The disease is

TABLE 1 Participants characteristics.

Variables	N	%	Variables
Age	< 30 years	467	62.6
	30–40 years	169	22.7
	> 40 years	110	14.7
Gender	Female	302	40.5
	Male	444	59.5
Marital status	Unmarried	435	58.3
	Married	311	41.7
Education level	Pre-university	262	35.1
	University or higher	484	64.9
Care for dependents	No	405	54.3
	Yes	341	45.7
Contracted COVID-19	No	472	63.3
	Yes	274	36.7

no longer as risky as it used to be,” “COVID-19 is not a real disease,” “COVID-19 is a flu-like disease that poses no real threat,” and “I am protected with three vaccine doses.” Table 2 provides a more detailed breakdown of the responses to this question.

3.4 Regression analysis of expected increases in COVID-19 cases during the omicron wave

Table 3 presents the results of the univariate logistic regression analysis that examined the factors that predict the following dependent variable: the expectation of increased COVID-19 cases. The results showed that younger respondents were significantly more likely to expect an increase in COVID-19 cases (OR = 0.98; 95% CI: 0.96–0.99). Married respondents were 31% less likely to expect COVID-19 cases to increase. In addition, respondents with university degrees or higher were significantly more likely (1.54 times) to expect an increase in COVID-19 cases compared to those with pre-university educations. Finally, individuals who were more anxious about the Omicron variant (OR = 1.22; 95% CI: 1.15–1.30) or who were more worried about the reinstatement of lockdowns (OR = 1.10; 95% CI: 1.01–1.12) were more likely to expect an increase in COVID-19 cases.

A multivariate logistic regression model was also implemented to help predict respondents’ expectations of increased COVID-19 cases (Table 4). The model included five factors that showed a significant association with the dependent variable at a p -value <0.05 in the univariate logistics regression model: age, marital status, education level, anxiety about COVID-19, and worry about the reinstatement of lockdowns. The model demonstrated a non-significant p -value ($p > 0.05$) for the Hosmer–Lemeshow goodness-of-fit test statistic, indicating that the data was well-fit to the model. The results showed that two of the five factors in this multivariate model were significant predictors of the respondents’ expectations ($p < 0.05$). The odds ratios indicated that anxiety about COVID-19 (AOR = 1.23; 95% CI: 1.15–1.32) was the strongest predictor of respondents’ expectation of increasing COVID-19 cases, followed by education level (AOR = 1.58; 95% CI: 1.11–2.25).

3.5 Anxiety related to COVID-19 during the omicron wave and worries about the reinstatement of lockdowns

The mean anxiety score was 3.11, with a standard deviation of 2.40. About 36.1% of the participants reported moderate to high anxiety levels. Figure 3 shows the distribution of low, moderate, and high anxiety levels related to COVID-19 among participants during the Omicron wave.

The mean score associated with the respondents’ worry about the reinstatement of lockdown was 3.84, with a standard deviation of 3.02. About 46.2% of the participants reported moderate to high worry levels. Figure 4 shows the distribution of low, moderate, and high worry levels regarding the reinstatement of lockdowns.

Ordinal logistic regression analysis was performed, with anxiety levels (low–moderate–high) as the dependent variable and the participants’ characteristics as the predictor variables. The model was fitted to the data ($p < 0.05$) and exhibited a 7% improvement in the prediction of anxiety levels compared to the null model. However, none of the factors exhibited a significant association with anxiety levels except for worries related to the reinstatement of lockdowns. Table 5 shows that the respondents who were more worried about the reinstatement of lockdowns were 1.28 times more likely to have a high level of anxiety related to COVID-19.

4 Discussion

Understanding how people perceive and respond to pandemics is crucial for effective management. The COVID-19 pandemic has posed a significant threat to health over the past few years and has affected many aspects of daily life. In particular, the rapid spread of the Omicron variant led to a substantial increase in COVID-19 cases across many countries worldwide, including Saudi Arabia (25–30). Despite this, our study showed differences in people’s expectations regarding future COVID-19 trends. Over one-third of the participants thought that COVID-19 cases would increase, 27.3% believed that cases would decrease, and the remaining 42.5% were uncertain. Public concerns regarding the increasing number of COVID-19 cases caused by the Omicron variant in Saudi Arabia have been documented in research studies (26) and local media (31). How people perceive a disease’s severity and contagiousness will significantly impact their response behaviors to reduce susceptibility (32). When people perceive a threat to their health and believe that the benefits of a preventive behavior outweigh its potential downsides, they are more likely to adopt that behavior (33). Participants in this study identified several factors that influenced their expectation that COVID-19 cases were likely to increase, including people’s non-compliance with preventive measures and the virus’s high transmissibility.

Prior research has shown that non-compliance with COVID-19 preventive measures (34) and the rapid spread of the virus (35) increased the risk of both contracting and transmitting the disease. Reluctance to follow the recommended preventive measures was observed in many regions worldwide (36–40), including Saudi Arabia (41). Unexpectedly, our study revealed that a few participants were unwilling to adhere to preventive measures against COVID-19 because they believed that the virus was not real or risky or because they had already been vaccinated. Nearly 28% of the participants

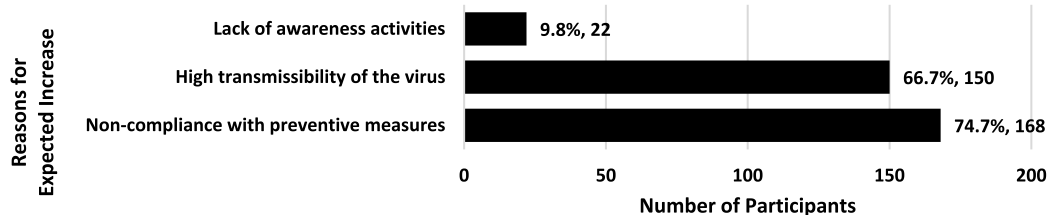


FIGURE 1

Primary reasons for expecting an increase in COVID-19 cases during the Omicron wave ($n = 225$). Percentage of those who expected an increase in COVID-19 cases. Participants were allowed to select multiple answers.

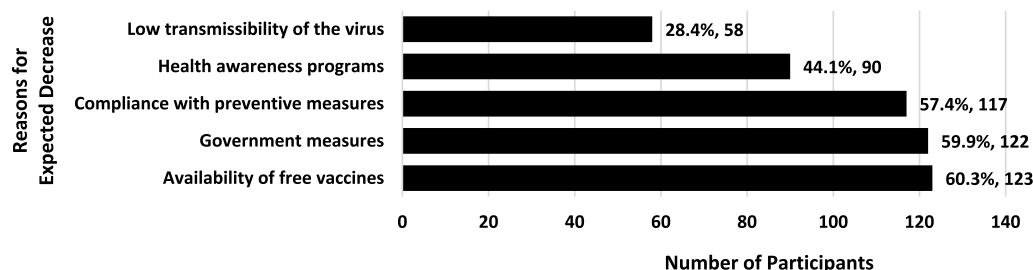


FIGURE 2

Primary reasons for expecting a decrease in COVID-19 cases during the Omicron wave ($n = 204$). Percentage of those who expected a decrease in COVID-19 cases. Participants were allowed to select multiple answers.

TABLE 2 Responses related to participants' intention to adhere to preventive measures.

(N = 746)	Responses	n	(%)
I will voluntarily adhere to the COVID-19 preventive measures recommended by the health authorities.	Strongly disagree	4	(0.5)
	Disagree	4	(0.5)
	Uncertain	27	(3.7)
	Agree	242	(32.4)
	Strongly agree	469	(62.9)

expected the spread of COVID-19 to be limited during the Omicron wave because they thought the virus was less transmissible than previous variants. This suggests that there is a concerning portion of the population that does not take COVID-19 seriously. Similar attitudes have been observed worldwide, with some people refusing to acknowledge the reality of COVID-19 (40, 42–44). Participants who did not believe in the existence of the virus had reduced perceptions of risk and did not adhere to risk-prevention behaviors (44). Constantinou, Kagialis and Karekla (42) found that as the strength of belief in conspiracy theories increases, the trust in COVID-19 science and willingness to adhere to preventive measures decreases significantly. This is consistent with a recent study from Spain, where young people who believed in conspiracy theories were less likely to follow COVID-19 preventive measures (39). Furthermore, a large-scale study found a decrease in people's anxiety levels following the emergence of the Omicron variant (15), suggesting that prolonged exposure to health risks may result in reduced levels of anxiety in some individuals. Some studies suggest that ongoing uncertainties linked to COVID-19 may result in “worry fatigue,” reducing the public's desire to adhere to preventive measures (45). Previous

research, including a study conducted in Saudi Arabia, have shown that anxiety and depressive symptoms tend to decrease after receiving the COVID-19 vaccine (46–48). Consequently, continuous efforts are essential to strengthening and enforcing preventive measures and policies aimed at controlling virus transmission during pandemics.

Participants of this study who believed that COVID-19 cases were likely to decrease cited factors such as compliance with preventive measures, accessibility of free vaccines, health education programs, and government policies and interventions. Many people were initially hesitant to get vaccinated against COVID-19, but the distribution of free vaccines in several countries, including Saudi Arabia, motivated individuals to prioritize their safety as well as that of their families, extending even to the broader community (49). Previous research has shown that people are more likely to adhere to preventive measures if they believe that the government and healthcare system are taking effective actions to control the spread of disease (50, 51). Conversely, mistrust in the government-led responses reduces adherence to COVID-19 preventive measures (40).

Our findings revealed that there was a significant association between the respondents' expectation of increased COVID-19 cases and both their education levels and their anxiety about the Omicron variant. Individuals with higher anxiety levels were more likely to expect a rise in COVID-19 cases than those with fewer concerns. Similarly, individuals who possessed university-level education or higher were 1.58 times more likely to expect a rise in COVID-19 cases compared to those who had only attained a pre-university qualification. These findings suggest that perceptions and expectations of the pandemic vary according to demographic factors such as educational background and general anxiety levels.

Anxiety is a common issue for many people during pandemics and health crises. According to the WHO, there was a 25% increase in the

TABLE 3 Univariate logistic regression for the different predictors of the expectation of increased COVID-19 cases during the Omicron wave (N = 746).

Variables		Perception of the anticipated increase vs. decrease in COVID-19 cases			
		B (SE)	OR (95% CI)	Wald	p-value
Age		−0.02 (0.01)	0.98 (0.96–0.99)	5.13	0.024*
Gender	Female		1		
	Male	−0.50 (0.16)	0.95 (0.69–1.31)	0.097	0.756
Marital status	Unmarried		1		
	Married	−0.37 (0.16)	0.69 (0.50–0.96)	4.96	0.026*
Care for dependents	No		1		
	Yes	−0.04 (0.16)	0.95 (0.69–1.31)	0.08	0.767
Education level	Pre-university		1		
	University or higher	0.43 (0.17)	1.54 (1.10–2.17)	6.26	0.012*
Contracted COVID-19	No		1		
	Yes	0.23 (0.16)	1.25 (0.91–1.73)	1.91	0.17
Adherence to prevention measures		−0.18 (0.12)	0.83 (0.66–1.06)	2.29	0.130
Anxiety about COVID-19		0.20 (0.03)	1.22 (1.15–1.30)	36.82	< 0.001*
Worry about the reinstatement of lockdowns		0.06 (0.03)	1.10 (1.01–1.12)	5.03	0.025*

B = coefficient for the constant, SE = standard error, OR = crude odds ratio, CI = 95% confidence interval, Wald = Wald chi-square test, 1 = the reference category for the variable,

* = statistically significant at p -value < 0.05.

TABLE 4 Multivariate logistic regression for the different predictors of the expectation of increased COVID-19 cases during the Omicron wave (N = 746).

Variables		Perception of the anticipated increase vs. decrease in COVID-19 cases			
		B (SE)	AOR (95%CI)	Wald	p-value
Age		−0.01 (0.01)	0.99 (0.96–1.02)	0.60	0.438
Marital status	Unmarried		1		
	Married	−0.17 (0.25)	0.84 (0.52–1.37)	0.47	0.493
Education level	Pre-university		1		
	University or higher	0.46 (0.18)	1.58 (1.11–2.25)	6.49	0.011*
Anxiety about COVID-19		0.21 (0.04)	1.23 (1.15–1.32)	32.82	< 0.001*
Worry about the reinstatement of lockdowns		−0.01 (0.03)	0.99 (0.94–1.05)	0.099	0.754

B = coefficient for the constant, SE = standard error, AOR = adjusted crude odds ratio, CI = 95% confidence interval, Wald = Wald chi-square test, 1 = the reference category for the variable,

* = statistically significant at p -value < 0.05.

worldwide occurrence of anxiety and depression during the first year of the COVID-19 pandemic (52). Increased anxiety can have negative impacts on an individual's overall health, their perspective on emerging health threats, and the extent to which they adhere to preventive measures. Several studies conducted in Saudi Arabia on the degree of anxiety experienced by individuals due to COVID-19 reported inconsistent results: some reported high or moderate levels of anxiety among participants (53–55) while others reported lower levels of anxiety (56, 57). A sentiment analysis of global tweets related to the Omicron variant revealed a high level of worry about the emergence of this strain (58). However, sentiment in Saudi Arabia was relatively neutral, with no significant concerns being observed (58). Nevertheless, over one-third of our study respondents exhibited moderate to high anxiety levels relating to COVID-19 and the Omicron variant.

Although the majority of participants were already familiar with COVID-19, some may have felt more uncertain about the new variant. Concerns about the reinstatement of lockdowns also significantly heightened anxiety levels related to COVID-19. However, the other examined demographic variables were found to be insignificant. These findings contrast with previous studies from Saudi Arabia, which found that personal factors, including age (57, 59, 60), gender (53, 59–61), level of education (60), and past infection with SARS-CoV-2 (61) were potential influencers of COVID-19-related anxiety.

In response to the COVID-19 pandemic, many countries, including Saudi Arabia, implemented lockdowns as a preventive measure (62). These lockdowns imposed various restrictions, such as isolating sick individuals, stay-at-home orders, curfews, and limits on commercial and service activities. While effective in limiting the spread of the

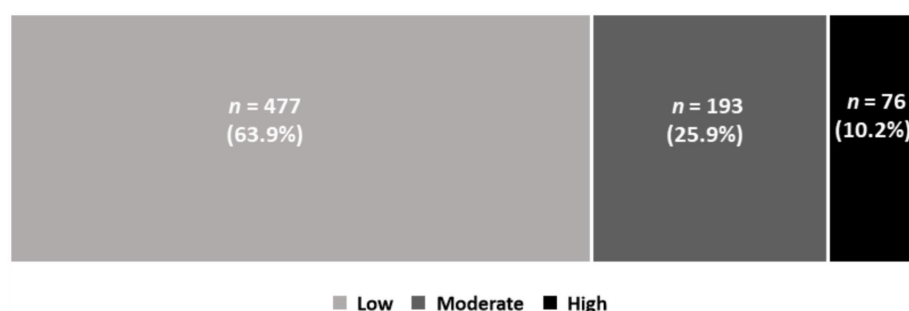


FIGURE 3
Anxiety levels related to COVID-19 during the Omicron wave.

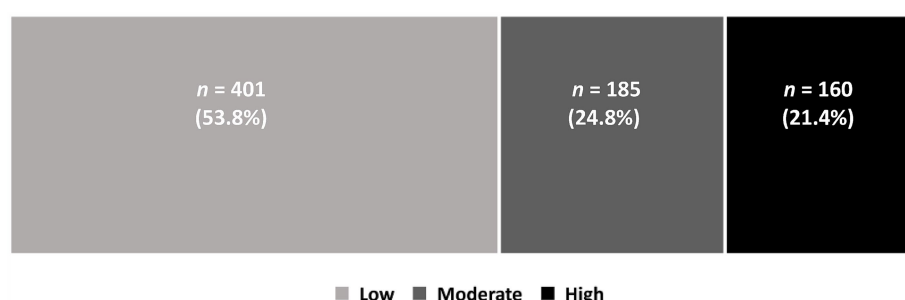


FIGURE 4
Worry levels related to the reinstatement of lockdown during the Omicron wave.

disease, the lockdowns significantly disrupted various aspects of daily life and contributed to psychological stress for many individuals (63–65). Approximately 46% of respondents in this study expressed moderate to high levels of concern about the possibility of a new lockdown. The results from previous research have revealed the negative role of lockdowns on people's mental health (66–69). Experts in mental health have warned that prolonged lockdowns, quarantine, and isolation could cause mental health issues and increased suicide rates due to physical inactivity, economic hardship, and social isolation (70).

Our study contributes to COVID-19 research in Saudi Arabia by shedding light on how the Saudi public viewed COVID-19 during the Omicron wave—one of the most prevalent and infectious variants. Understanding how people's perceptions evolve during pandemics is crucial for decision-makers in order to improve preventive plans and allocate resources effectively. However, our study has certain limitations. The main limitation is the use of a non-probability sampling technique due to COVID-19 constraints. In addition, the survey was conducted online, which limited its scope to educated people and those with Internet access. These limitations must be considered when interpreting the findings, as they may affect the generalizability of the results.

5 Recommendations for policy improvement

The findings of our study provide valuable insights into Saudi Arabia's response to the COVID-19 pandemic as well as public perception and policy development. Saudi Arabia implemented several policies, including containment and closure policies, health system measures,

vaccination, and economic policies (71). Containment and closure policies refer to the administrative measures used to limit people's mobility, such as closing workplaces and restricting travel, to reduce transmission within the population. Health system policies refer to public health measures such as testing, contact tracing, delivering vaccines, wearing facial masks, protecting older people, and strengthening the health system. Vaccination policies include plans that provide free vaccinations to the population. Priority was given to individuals most at risk of developing severe symptoms, such as senior citizens and people with chronic diseases, and those most at risk of infection, such as healthcare workers. In addition, people participating in indoor activities were required to receive vaccination. Economic policies refer to the policies implemented by the Saudi government to address the financial impact of COVID-19. These policies included financial support for job seekers, deferred financial obligations for households, incentives for economic spending, and financial aid to other nations (71, 72).

COVID-19 mitigation policies in Saudi Arabia varied throughout the pandemic. In the early waves of the pandemic, measures such as strict lockdowns and mandatory testing were implemented, but as the pandemic continued, the focus shifted toward localized restrictions and expanded vaccination efforts (73, 74). Despite the Saudi government's outstanding response to COVID-19, targeted improvements to specific zones could strengthen future preparedness.

Our study emphasized the importance of customizing communication strategies for different groups during pandemics. Educational background and anxiety levels played a significant role in influencing people's expectations about the trend in COVID-19 cases. There was also a high level of concern about the possibility of future lockdowns. It seems that the strict measures enforced during

TABLE 5 Predictors of anxiety level using ordinal logistic regression analysis.

Variables		Anxiety level			
		B (SE)	AOR (95%CI)	Wald	p-value
Age		0.01 (0.01)	1.01 (0.99–1.04)	0.57	0.452
Gender	Female	0.16 (0.16)	1.17 (0.86–1.61)	0.98	0.322
	Male		1		
Marital status	Unmarried	0.32 (0.24)	1.73 (0.85–2.21)	1.70	0.193
	Married		1		
Care for dependents	No	−0.09 (0.18)	0.92 (0.64–1.31)	0.228	0.633
	Yes		1		
Education level	Pre-university	0.12 (0.16)	1.12 (0.81–1.55)	0.49	0.483
	University or higher		1		
Contracted COVID-19	No	−0.14 (0.16)	0.87 (0.63–1.20)	0.72	0.398
	Yes		1		
Adherence to prevention measures		−0.13 (0.12)	0.88 (0.69–1.12)	1.12	0.290
Worry about the reinstatement of lockdowns		0.25 (0.03)	1.28 (1.21–1.35)	84.41	< 0.001*

B = coefficient for the constant, SE = standard error, AOR = adjusted crude odds ratio, CI = 95% confidence interval, Wald = Wald chi-square test, 1 = the reference category for the variable, * = statistically significant at p -value < 0.05.

the early waves of the pandemic had a significant psychological impact that may have had lasting adverse effects on the health of Saudi citizens (70, 75). The development of customized policies that target disadvantaged groups, address emerging challenges, and build trust in public health initiatives is essential to better manage future epidemiological outbreaks and pandemics.

Interestingly, a small percentage of participants in our study still doubted the existence and severity of the virus, highlighting gaps in communication and awareness efforts. Future public health responses could address this issue through prompt, targeted campaigns in response to specific concerns and misinformation. The public's positive perception of government measures, reflected in the expectation of declining cases, highlights the crucial role of effective leadership during a pandemic.

These points highlight the importance of investing in future pandemic preparedness as well as building long-term resilience. Establishing effective surveillance systems and early-warning mechanisms is essential for proactive policy development. Additionally, ensuring clear and timely communication about new variants can help prevent panic and reduce the spread of misinformation, especially during the early stages of the pandemic.

Overall, Saudi Arabia can reinforce its public health framework by drawing lessons from past achievements and challenges. Key areas for improvement include targeted communication initiatives, comprehensive preparedness plans, and effective early-alarm systems—all crucial to effectively handling future health crises.

6 Conclusion

Our findings revealed that most participants were uncertain about the trend of Omicron infections. Individuals with higher

levels of anxiety and those with higher education levels were more likely to expect an increase in COVID-19 cases. Individuals who were worried about the potential of further lockdowns or a rise in COVID-19 cases also exhibited higher levels of anxiety. The possibility of another lockdown caused moderate to high concern in less than half of the participants. Additionally, a small number of participants refused to follow preventive measures, either believing that the virus was not real or that it did not pose a significant risk. Some participants also believed they were fully protected after receiving three doses of the vaccine. Such misconceptions are concerning as they lead individuals to underestimate the risks associated with COVID-19 and future pandemics.

This study provides insights into how Saudi citizens perceived the Omicron wave of the COVID-19 pandemic and the factors that shaped their expectations of the disease trends. Given that COVID-19 is likely to continue to be a concern, we may face additional waves of infectious and potentially risky variants in the future. Thus, it would be interesting to explore how people's perceptions change as the virus evolves using a larger and more representative sample. It would also be helpful to assess the impact of different cultural factors on people's perceptions of SARS-CoV-2 variants. Finally, future studies should aim to include underrepresented groups, such as older people, illiterate individuals, immigrants, and those without Internet access.

Data availability statement

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

Ethics statement

The study was approved by the Research Ethics Committee of Jazan University, Saudi Arabia. Informed consent was obtained from all participants.

Author contributions

MA: Conceptualization, Formal analysis, Funding acquisition, Methodology, Project administration, Supervision, Visualization, Writing – original draft. AmA: Conceptualization, Formal analysis, Methodology, Resources, Validation, Writing – review & editing. AJ: Conceptualization, Formal analysis, Investigation, Writing – review & editing. AE: Methodology, Resources, Validation, Writing – original draft. WH: Conceptualization, Resources, Validation, Writing – review & editing. HA: Conceptualization, Resources, Validation, Writing – review & editing. HM: Conceptualization, Resources, Validation, Writing – review & editing. AhA: Conceptualization, Resources, Validation, Writing – review & editing. AnA: Project administration, Resources, Validation, Writing – review & editing, Visualization. SA: Conceptualization, Data curation, Project administration, Resources, Visualization, Writing – review & editing, Methodology, Software.

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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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