frontiers | Research Topics

Infodemic management in public health crises

Edited by
Dilek Aslan, Fatjona Kamberi and Selen Yeğenoğlu

Published in
Frontiers in Public Health

ISSN 1664-8714
ISBN 978-2-8325-5869-0
DOI 10.3389/978-2-8325-5869-0

About Frontiers

Frontiers is more than just an open access publisher of scholarly articles: it is a pioneering approach to the world of academia, radically improving the way scholarly research is managed. The grand vision of Frontiers is a world where all people have an equal opportunity to seek, share and generate knowledge. Frontiers provides immediate and permanent online open access to all its publications, but this alone is not enough to realize our grand goals.

Frontiers journal series

The Frontiers journal series is a multi-tier and interdisciplinary set of open-access, online journals, promising a paradigm shift from the current review, selection and dissemination processes in academic publishing. All Frontiers journals are driven by researchers for researchers; therefore, they constitute a service to the scholarly community. At the same time, the *Frontiers journal series* operates on a revolutionary invention, the tiered publishing system, initially addressing specific communities of scholars, and gradually climbing up to broader public understanding, thus serving the interests of the lay society, too.

Dedication to quality

Each Frontiers article is a landmark of the highest quality, thanks to genuinely collaborative interactions between authors and review editors, who include some of the world's best academicians. Research must be certified by peers before entering a stream of knowledge that may eventually reach the public - and shape society; therefore, Frontiers only applies the most rigorous and unbiased reviews. Frontiers revolutionizes research publishing by freely delivering the most outstanding research, evaluated with no bias from both the academic and social point of view. By applying the most advanced information technologies, Frontiers is catapulting scholarly publishing into a new generation.

What are Frontiers Research Topics?

Frontiers Research Topics are very popular trademarks of the *Frontiers journals series*: they are collections of at least ten articles, all centered on a particular subject. With their unique mix of varied contributions from Original Research to Review Articles, Frontiers Research Topics unify the most influential researchers, the latest key findings and historical advances in a hot research area.

Find out more on how to host your own Frontiers Research Topic or contribute to one as an author by contacting the Frontiers editorial office: frontiersin.org/about/contact

Infodemic management in public health crises

Topic editors

Dilek Aslan — Hacettepe University, Türkiye

Fatjona Kamberi — University of Vlorë, Albania

Selen Yeğenoğlu — Hacettepe University, Türkiye

Citation

Aslan, D., Kamberi, F., Yeğenoğlu, S., eds. (2025). *Infodemic management in public health crises*. Lausanne: Frontiers Media SA. doi: 10.3389/978-2-8325-5869-0

Table of contents

frontiers | Frontiers in Public Health

TYPE Editorial
PUBLISHED 17 December 2024
DOI 10.3389/fpubh.2024.1536378

OPEN ACCESS

EDITED AND REVIEWED BY
Christiane Stock,
Charité – Universitätsmedizin Berlin, Germany

*CORRESPONDENCE
Dilek Aslan
✉ diaslan.dr@gmail.com

RECEIVED 28 November 2024
ACCEPTED 30 November 2024
PUBLISHED 17 December 2024

CITATION
Aslan D, Kamberi F and Yegenoglu S (2024) Editorial: Infodemic management in public health crises. *Front. Public Health* 12:1536378. doi: 10.3389/fpubh.2024.1536378

Editorial: Infodemic management in public health crises

Dilek Aslan [1]*, Fatjona Kamberi [2] and Selen Yegenoglu [3]

[1]Department of Public Health, Faculty of Medicine, Hacettepe University, Ankara, Türkiye, [2]Scientific Research Centre for Public Health, University of Vlore "Ismail Qemali", Vlorë, Albania, [3]Department of Pharmacy Management, Faculty of Pharmacy, Hacettepe University, Ankara, Türkiye

KEYWORDS

infodemic, infodemic management, public health, crises, evidence

Editorial on the Research Topic
Infodemic management in public health crises

Infodemic, one of the major challenges of the 21st century, is defined as the information overload in digital and/or physical environments, including misinformation, disinformation, unchecked information, information voids, conspiracy theories, etc. *Infodemic* causes risk-taking behaviors that are harmful for health (1). *Infodemic* is not a new phenomenon, as human history has examples with different topics in different time periods (2, 3). On the other hand, public health crises make the communities more vulnerable to *infodemic* and this makes the situation more complex. A recent example has been the Coronavirus-2019 (COVID-19) pandemic. COVID-19 pandemic has shown us how a public health crisis might have crashed the systems of the countries. The world has experienced that it was not only the pandemic itself but also many determinants of health, like social, structural, economical, commercial, and digital, concurrently influenced the course of the pandemic. Thus, the information ecosystem has been one of the major drivers of the burden. *Infodemic* has been a priority to be managed. In this regard, *infodemic management* has been developed as a systematic approach. *Infodemic management* is based on four pillars, including listening to community concerns and questions, facilitating to understand the risk, promoting to understand the advice of the health professionals, maintaining the resilience of the communities, and succeeding to engage and empower them to take intended and positive actions against *infodemic*.

For translating *infodemic management* into future generations, its pillars should be supported with evidence-based science to understand the causes of *infodemic* and to propose sustainable solutions to overcome the problems of today. Such initiatives will be helpful for predicting future risks and taking sustainable, evidence-based measures. At this point, research articles, perspectives, reviews, and opinions might have the potential to contribute to proposing solutions for the current and future crises at the global level. Such evidence is believed to play a crucial role in shaping future perspectives of *infodemic management*. Current evidence will also highlight the need for research gaps and capacity building on the Research Topic. The context of public health and health promotion provides the interdisciplinary feature of *infodemic management*.

Under this Research Topic, different aspects of *infodemic* and *infodemic management* have been tackled from the inter- and transdisciplinary features based on eight original research articles, two perspective articles, one study protocol article, one review, and one opinion article (Figure 1).

FIGURE 1
Research Topic collection: *Infodemic management in public health crises*.

Let us briefly emphasize the importance of the articles contributions to the Research Topic. Factors associated with COVID-19 misinformation among college students have been investigated by Shan and Ji from China. Their study emphasized the importance of complexity, dynamics, and differences in online susceptibility of the college students. Devi et al. from Singapore investigated the general population's trust levels in different stakeholders in COVID-19 information from different sources. They showed us that perceived risk of infection is associated with the trust level. Alzahrani from Saudi Arabia studied the impact of health beliefs and trust in health information sources on vaccine uptake. He emphasized the crucial role of targeting health beliefs of the community. Choi from the Republic of Korea performed a concept analysis on the COVID-19 infodemic. The study results might be helpful for the governments and health professionals for building up a policy in order to prevent *infodemic*. Öntaş et al. from Türkiye investigated the internet news sites to assess the opinions of health communication actors. Feng from China did research on the three dimensions of social capital at the theoretical level and provided empirical evidence for specific practices like improving the health literacy of the social media users. *Infodemic* types, including rumors in public health emergencies, were studied by Wang et al. from China. Liu et al. from China shared their qualitative research results. Perspective articles of the Research Topic contributed to widening the view and the scope in infodemic management during public health crises. Ebola outbreak in Uganda and the role of inaccessibility of social media data for *infodemic management* from the European Union widen our vision. The opinion article of the Research Topic gave us different examples of different social media platforms. Such examples are extremely helpful to be prepared for the next pandemic(s). One study protocol article in its pilot study phase written by authors with different backgrounds and institutions in the Research Topic has been a good example of a worldwide network of websites that could be used for effective and good communication. The systematic review article in the content has been a very significant example of how a systematic review can be conducted in the *management* of *infodemic* in health crises.

In the light of the above we feel that more steps should be taken to solve the *infodemic* problem at the global level. We are sure that public health crises' complexity makes everything worse and difficult. In this regard, scientific evidence is recommended to be conducted compatible with the pillars of *infodemic management*. Thus, interdisciplinary and transdisciplinary research teams have to study together to define the challenges and to propose solutions to be prepared for the next public health crises.

Unfortunately, public health crises are today's reality. They are also hot topics of the current century. Therefore, practical, reliable, and objective solutions should meet the needs of the Community. Science and scientific evidence will be the leading tools as they were in the past.

In conclusion, the Research Topic on *Infodemic management in public health crises* hopefully will tackle the recent needs and open a new vision for the readers. It provides valuable insights into managing health information during outbreaks like COVID-19. It emphasizes the importance of addressing infodemic, to better control disease spread. The studies highlight the role of social media

platforms in shaping communication strategies for future crises including pandemics. By leveraging social capital, improving access to social media data, and learning from past health crises, the findings offer key strategies for enhancing infodemic management in future public health emergencies.

Author contributions

DA: Conceptualization, Writing – original draft, Writing – review & editing. FK: Writing – review & editing. SY: Writing – review & editing.

Acknowledgments

The Research Topic editors would like to thank all the authors for their contributions to the Research Topic. We express our gratitude to all the contributing authors and peer reviewers who made this Research Topic possible.

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.

Publisher's note

References

1. WHO. *Infodemic*. Available at: https://www.who.int/health-topics/infodemic#tab=tab_1 (accessed November 26, 2024).

2. Machado SH. 100 years later, little has changed in Brazil: disinformation and pandemic. *Afr Health Sci*. (2021) 21:1938–40. doi: 10.4314/ahs.v21i4.52

3. Bandara NA, Jhauj R, Fernando J, Mehrnoush V, Wijesinghe N. Overlapping public health crises during the coronavirus disease pandemic. *World J Emerg Med*. (2021) 12:151–3. doi: 10.5847/wjem.j.1920-8642.2021.02.011

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 17 November 2023
DOI 10.3389/fpubh.2023.1233414

OPEN ACCESS

EDITED BY
Dilek Aslan,
Hacettepe University, Türkiye

REVIEWED BY
Pinar Okyay,
Aydın Adnan Menderes University, Türkiye
Pier Luigi Sacco,
University of Studies G. d'Annunzio Chieti and Pescara, Italy

*CORRESPONDENCE
Meng Ji
✉ christine.ji@sydney.edu.au

RECEIVED 02 June 2023
ACCEPTED 27 October 2023
PUBLISHED 17 November 2023

CITATION
Shan Y and Ji M (2023) Factors associated with COVID-19 misinformation rebuttal among college students: a descriptive study. *Front. Public Health* 11:1233414. doi: 10.3389/fpubh.2023.1233414

Factors associated with COVID-19 misinformation rebuttal among college students: a descriptive study

Yi Shan[1] and Meng Ji[2]*

[1]School of Foreign Studies, Nantong University, Nantong, China, [2]School of Languages and Cultures, University of Sydney, Sydney, NSW, Australia

Background: The deluge of COVID-19 misinformation makes people confused, and acting on such misinformation can kill, leading to the tragic outcome of death. This makes it necessary to identify significant factors associated with college students' susceptibility.

Objective: This descriptive study sought to ascertain factors significantly associated with college students' susceptibility to online COVID-19 misinformation.

Methods: To assess college students' susceptibility to COVID-19 misinformation, we first chose as independent variables some demographic information, some well-developed, validated literacy tools, and the Patient Health Questionnaire-9 Items. Second, we selected as the dependent variable COVID-19 myths from some authoritative, official websites. Third, we integrated the independent and dependent variables into an online questionnaire. Fourth, we recruited students from Nantong University in China to participate in an online questionnaire survey. Finally, based on the data collected, we conducted quantitative and qualitative analyses to relate the independent variables to the dependent variable.

Results: Five hundred forty-six students participated in the survey voluntarily, and all questionnaires they answered were valid. The participants had an average of 2.32 (SD = 0.99) years of higher education. They have a mean age of 20.44 (SD = 1.52) years. 434 (79.5%) of the 546 participants were females. The frequency of their Internet use averaged 3.91 (SD = 0.41), indicating that they logged onto the Internet almost every day. Their self-reported Internet skill was rated 3.79 (SD = 1.07), indicating that the participants rated their Internet skills as basically "good." The mean scores of the sub-constructs in the AAHLS were 6.14 (SD = 1.37) for functional health literacy, 5.10 (SD = 1.65) for communicative health literacy, and 11.13 (SD = 2.65) for critical health literacy. These mean scores indicated that the participants needed help to read health-related materials "sometimes," the frequency that they knew how to communicate effectively with professional health providers was between "often" and "sometimes," and the frequency that they were critical about health information was between "often" and "sometimes," respectively. The sum of their scores for eHealth literacy averaged 28.29 (SD = 5.31), showing that they had a relatively high eHealth literacy level. The mean score for each question in the GHNT was determined at 1.31 (SD = 0.46), 1.36 (SD = 0.48), 1.41 (SD = 0.49), 1.77 (SD = 0.42), 1.51 (SD = 0.50), and 1.54 (SD = 0.50), respectively. These mean scores showed that a high percentage of the participants answered the 6 questions wrongly, especially Questions 4–6. Similarly, participants performed unsatisfactorily in answering the 3 questions in the CRT, with a mean score of 1.75 (SD = 0.43), 1.55 (SD = 0.50), and 1.59 (SD = 0.49) for each question, respectively. In the PHQ-9, the participants reported that they never

felt depressed or felt depressed only for 1–3 days in the past week. The mean score for myths 1–6 and 9–10 ranged from 1.15 (SD = 0.36) to 1.29 (SD = 0.46). This meant that the participants rated these myths false. However, most of the participants rated myths 7–8 true (1.54, SD = 0.50; 1.49, SD = 0.50), showing that they were highly susceptible to these 2 pieces of misinformation. Through data analysis via Logistic Regression (forward stepwise), we found that (1) at an average threshold of 0.5, Internet use frequency, functional health literacy, general health numeracy, reflective thinking tendency, and depression severity were significant predictors of susceptibility to misinformation for both male and female students, (2) at a higher threshold of 0.8, aggregated general health numeracy scores and functional health literacy scores, as well as depression severity were predictors of susceptibility to misinformation for both male and female students, (3) functional health literacy, general health literacy, and depression predicted resistance to misinformation for female students, and (4) internet use frequency and self-reported digital health literacy predicted resistance to misinformation for male students.

Conclusion: We revealed the complexity, dynamics, and differences in age, gender, education, Internet exposure, communicative health literacy, and cognitive skills concerning college students' susceptibility to online COVID-19 misinformation. Hopefully, this study can provide valuable implications for counteracting COVID-19 misinformation among Chinese college students.

KEYWORDS

factors, susceptibility, COVID-19, online misinformation, college students

Introduction

Background

Misinformation is false information that is shared by people with on intention to mislead others (1). Misinformation often prevails when information gaps or unsettled science motivate people to seek to reason, better understand, and fill in the gaps (1). Misinformation, conspiracy theories, and unverified information on COVID-19 have taken the form of fabricated content and true information that is presented in misleading ways (2–5). The deluge of misinformation makes people confused as to which sources of information are believable (6). Acting on misinformation can kill, leading to the tragic outcome of death (7). According to the statistics of WHO, during the first 3 months of 2020, about 6,000 people across the world were hospitalized and at least 800 died due to COVID-19 misinformation (7).

False information runs the gamut, including discrediting the threat of COVID-19, whether people can use public health measures (e.g., mask-wearing) to protect themselves, erroneous treatments and cures, conspiracy theories that vaccination can change human DNA, etc. (7). Social media platforms significantly contribute to the deluge of misinformation (8). In this context, health organizations across the world have endeavored to curb misinformation. For example, WHO has joined hands with the UK Government to launch an awareness campaign about the risks of misinformation about COVID-19 (9). Currently, WHO is promoting the global campaign "Stop The Spread" to raise people's awareness about the risks of misinformation on COVID-19, encourage them to double-check information with trusted sources such as WHO and national health authorities, address the infodemic of misinformation on COVID-19, and find and disclose myths about the spread, diagnosis, and treatment of the pandemic (9). WHO promotes infodemic management as the systematic use of risk- and evidence-based analysis and approaches to manage the infodemic and reduce its impact on health behaviors during health emergencies (10). Infodemic management aims to enable good health practices through 4 types of activities: listening to community concerns and questions; promoting understanding of risk and health expert advice; building resilience to misinformation; and engaging and empowering communities to take positive action (10).

In the context of more than 3 billion people using the Internet globally (11), information-seeking is one of the overriding reasons for Internet use, and online information supplements and even replaces data found through traditional sources (12). As reported in a previous study (13), more than 80% of people with a particular health problem have consulted online information about their condition in China. College students tend to be heavy media users (14). Therefore, online health information seeking is of great importance among Chinese college students. However, the digital age has magnified the adverse effects of the current online "infodemic" (15), making it difficult for the public to find trustworthy information among excessive online data (16). There is, therefore, a rampant deluge of incomplete, inaccurate, or false health information in the domain of medicine (17). The mixed quality of online information, easy access to misinformation, and adverse implications of misusing misinformation (12) all make it necessary

for us to evaluate the susceptibility to COVID-19 misinformation among Chinese college students.

Although the scientific community has carried out and provided unprecedented access to COVID-19-related studies (18), there is still the prevalence of misinformation on medical topics, which is easily accessible and frequently associated with differential health behaviors, for example, in terms of getting vaccinated, taking herbal supplements, etc. (19). Belief in misinformation on COVID-19 is likely to induce substantive, real-world consequences that make it not only an essential theoretical but also practical field of study (20). Belief in misinformation is not pathological at all, but worthy of being seriously taken as an independent area of scientific research (21). Previous studies have been conducted on factors related to belief in misinformation or conspiracy theories, producing varying and inconsistent findings (20). Belief in misinformation was found to be associated with various sociodemographic features, like low education (22), high education (23), social dynamics (24), age (25), etc. It has also been found to be related to political orientation (25–27). Cognitive sophistication was identified as an effective predictor of the endorsement of misinformation on COVID-19 (28, 29). Some studies also investigated the relationship between religion and endorsement or belief in misinformation (23, 30). Besides, other factors were also found to be contributors to susceptibility to online COVID-19 misinformation, including health-related knowledge, attitudes, and beliefs (17), occupation (31), objective health literacy (32), the efficacy of digital literacy (33), and some information competencies, including information literacy, science literacy, interpersonal trust, and trust in health authority (34). However, these studies did not exclusively investigate college students' vulnerability to COVID-19 misinformation, they did not examine the role of gender in influencing the study participants' susceptibility to misinformation, and they did not use some well-developed, validated health literacy tools to capture some of the informants' demographic characteristics that are supposedly more relevant to their susceptibility to misinformation.

Based on the analysis above and the research gaps identified in particular, we posed some research questions as follows:

Does college students' educational level influence their COVID-19 misinformation susceptibility?

Is college students' gender associated with their COVID-19 misinformation susceptibility?

What health literacy skills can help college students rebut COVID-19 misinformation?

Objective

This descriptive study sought to ascertain factors that were significantly associated with web-based COVID-19 misinformation susceptibility in the cohort of college students. Specifically, we first aimed to integrate into the informants' demographics some important data captured through some well-developed, validated health literacy tools (specified in the Methods section). The information thus captured was believed to be associated with the informants' objective health literacy which was found effective in counteracting online misinformation (32). Subsequently, we pinpointed the demographic information most likely contributing to informants' susceptibility to online COVID-19 misinformation.

Methods

Although there are several studies recently devoted to the topic, no specific conceptual framework has clearly been stated and used in these studies. Informed by a recent study that investigated susceptibility to breast cancer misinformation among Chinese patients (35), we incorporated into the questionnaire some validated scales, including the All Aspects of Health Literacy Scale (AAHLS) (36), the eHealth Literacy Scale (eHEALS) (37), the General Health Numeracy Test (GHNT-6) (38), the Cognitive Reflection Test (CRT) (39), and the Patient Health Questionnaire-9 Items (PHQ-9) (40). We also followed this study as a conceptual framework, since there was no better alternative, as we stated above. In the absence of an internationally standardized survey tool to assess one's ability to detect and appraise online misinformation about COVID-19, we adopted a gradient approach to define and quantify the level of misinformation rebuttal among the survey participants. It was achieved by adjusting the threshold of correct responses required for a student to be identified as able to detect general COVID-19 misinformation. Using the aforementioned scales as predictors and adopting Shan et al. (35) as a conceptual framework, this descriptive study sought to pinpoint factors significantly correlated with college students' susceptibility to Internet-mediated COVID-19 misinformation.

Questionnaire design

Four parts were included in the questionnaire designed for this study. Part 1 is related to the informants' age, gender, and education. Part 2 is concerned with the informants' self-reported Internet skills. Part 3, the highlight of the questionnaire, consists of 5 well-developed, validated health literacy tools (All Aspects of Health Literacy Scale (AAHLS) (36), the eHealth Literacy Scale (eHEALS) (37), the General Health Numeracy Test (GHNT-6) (38), the Cognitive Reflection Test (CRT) (39), and the Patient Health Questionnaire-9 Items (PHQ-9) (40)). Part 4 comprises 10 COVID-19 myths retrieved from some influential, official websites (41–44) of the Centers for Disease Control and Prevention, USA, the Johns Hopkins University School of Medicine, the World Health Organization, and the Australian Department of Health.

Although we submitted the English version of the questionnaire as Supplementary material for better understanding by international readers, the questionnaire was administered in Mandarin Chinese for accurate understanding by the study participants. The English-to-Chinese translation and cultural adaptation of the scales used in the questionnaire was based on a cognitive interview with a small group (10 male and 10 female) of Chinese university students. During the interview, students were invited to review and provide open feedback on the Chinese translation in terms of cultural relevance (whether the scales are relevant to your daily life) and linguistic understandability (whether the scales are comprehensible to you, and whether some terms or expressions are ambiguous to you). Based on the feedback, we improved the translated scales. After that, we repeated the cognitive interview to solicit feedback again. There were three rounds of such reviews and improvements before we finalized the translations.

The highlight, Part 3, was intended to solicit some information on the informants' objective health literacy, which has the potential to help people tell misinformation (32). The AAHLS (36) is designed

to evaluate functional, communicative, and critical health literacy. It identifies the health literacy support needs as well as the strengths and capabilities of an individual and assesses the influence of local patient education initiatives (45, 46). It provides healthcare practitioners with important information on users' health literacy needs and capabilities (46). The eHEALS (37) measures users' combined knowledge, comfort, and perceived skills in terms of finding, assessing, and applying electronic health information (47). Reliably and consistently capturing the eHealth literacy concept in repeated administrations, the eHEALS promises to help evaluate user comfort and skills in adopting information technology for health (47). The GHNT-6 (38) is a reliable and valid measure of general health numeracy (48, 49). The CRT (39, 50) has been verified to be an effective scale for assessing individual differences in thinking, judgments, and decisions. It shows substantial correlations with common biases in judgments and decisions (51). The PHQ-9 (40) is an instrument for diagnosing major depressive disorder among adults (52). It has been widely adopted as a screening and diagnostic scale in clinical and population-based research (53, 54) to gauge the severity of depression symptoms. This test was relevant to our investigation based on the clinical experience of 2 researchers (ZX and ZD), who reported an apparent association between patients' status of depression and their misinformation appraisal skills. Besides, a recent study revealed the association between misinformation exposure and psychological distress including anxiety, depression, and posttraumatic stress disorder symptoms (15). This was another consideration justifying our incorporation of the PHQ-9 into our questionnaire.

Selection of COVID-19 myths

The myths were selected from the websites of The Centers for Disease Control and Prevention, USA (41), the School of Medicine of Johns Hopkins University (42), the World Health Organization (43), and the Australian Federal Department of Health (44). The selection of these myths was based on the cultural relevance of the statements to everyday life circumstances of university students in China, and the cognitive discernability of myths through a focused group interview with students before we distributed the questionnaire at a larger scale. Myths that were easily detectable by all the students in the interview, such as "COVID-19 vaccines contain magnetic chips," "vaccines can make me infected," and "vaccines can change my DNA," were deleted. We compiled a list of ten myths in Appendix 1 in English from the above-mentioned sources based on our understanding that there were similar or culturally adapted versions of the myths on popular Chinese social media to ensure that the questionnaire was of cultural relevance to the survey participants.

Recruitment of informants and questionnaire survey

Both undergraduate and graduate students studying at the School of Foreign Studies, Nantong University, were recruited as informants. On the other hand, COVID-19 as a major life stressor impacts their mental well-being directly and indirectly (55). Direct impacts include students' emotional feelings about COVID-19, such as fear of being infected (56–58). The predefined inclusion criteria comprise (1) being aged 18 years or older and (2) voluntarily participating in the survey. On the one hand, they were heavy media users, like those university students studied by Rideout et al. (14). We made face-to-face contact with students in the form of class meetings to identify those who satisfied the inclusion criteria, explain the purpose of the survey, and ask them to participate in the web-based survey as scheduled. We identified 712 eligible students, who were invited to the project via a web-based link to the questionnaire and the consent form before the survey. They received written information on this study, including the study objective and steps, voluntary participation, and an option of withdrawal during any phase. They were assured of confidentiality and secure data storage.

We conducted a questionnaire survey administered via *wenjuanxing* (59), the most frequently used, influential web-based questionnaire platform in China. The students were asked via email and WeChat groups to answer the online questionnaire anonymously. This online survey lasted 4 days from July 21 to July 24, 2022. Each questionnaire with all questions answered was regarded as valid in this survey.

Data collection, coding, and analysis

On July 25, 2022, we downloaded the crude data collected through *wenjuanxing* in an Excel form. A total of 546 answered questionnaires were returned, with a response rate of 76.7% (546/712). We double-checked the returned questionnaires and found all of them to be valid. Afterward, we coded the valid data drawing on the predefined coding scheme, to convert text answers into digit answers (scores) for further logistic regression analyses. We then calculated the sums of the scores in the subsections of the AAHLS, and the total scores in the other health literacy tools (eHEALS, GHNT-6, CRT, and PHQ-9) and the 10 COVID-19 myths. Finally, we used Logistic Regression (forward stepwise) in SPSS (v.27) to identify statistically significant factors associated with the ability of Chinese college students to detect and rebut misinformation about COVID-19.

A recent study (35) set the cutoff score for breast cancer misinformation susceptibility at 5 correct answers to the 10 breast cancer-related myths. Informed by this study, we intended to set the cutoff score for COVID-19 misinformation susceptibility at 5 correct answers to the 10 myths about COVID-19. Specifically, if the study participants returned 5 or fewer correct answers to these 10 myths, they were regarded as being susceptible to breast cancer misinformation. Our consultation with health information experts and health educators from Qilu Hospital of Shandong University, China, confirmed the feasibility and rationality of this cutoff score. After identifying factors associated with COVID-19 misinformation susceptibility at this cutoff score, we intended to raise the cutoff score to 8 correct answers to the 10 myths about COVID-19 to further confirm whether we could ascertain the same or similar factors. This raised cutoff score was also deemed rational by the same health information experts and health educators from Qilu Hospital of Shandong University, China. Both authors of this study and all these experts believed that these two cutoff scores could provide a reference for future studies and health education and intervention.

Assessment of the student participants

We assessed the student participants' ability to rebut COVID-19 misinformation using logistic regression statistics. Specifically, we chose as independent variables some demographic information of the participants (i.e., age, gender, education, Internet use frequency, and self-reported Internet skills), some validated literacy tools (i.e., AAHLS, eHEALS, and GHNT-6), the Cognitive Reflection Test (CRT), and the Patient Health Questionnaire-9 Items (PHQ-9). We selected as the dependent variable COVID-19 myths from some authoritative, official websites. And then, we used logistic regression statistics to relate the independent variables to the dependent variable. In this way, we identified some essential factors from the independent variables which were statistically significant. These significant factors were used as important indicators of the participants' COVID-19 misinformation rebuttal ability. In the Results and Discussion sections, we focused on these indicators to assess the students.

Ethics approval

This study followed the tenets of the Declaration of Helsinki and was approved by the Academic Committee of the School of Foreign Studies, Nantong University, China. Written informed consent was obtained from all study participants who were assured that their responses would remain confidential and anonymous and be only used for academic purposes. We recruited students who were willing to support our research without compensation.

Results

Participant descriptive statistics

Participant descriptive statistics are presented in Appendix 2. 546 students participated in the survey voluntarily, and all of their answers were verified to be valid. The participants had an average of 2.32 (SD = 0.99) years of higher education. They have a mean age of 20.44 (SD = 1.52) years. 434 (79.5%) of the 546 participants were females. The frequency of their Internet use averaged 3.91 (SD = 0.41), indicating that they logged onto the Internet almost every day. Their self-reported Internet skill was rated 3.79 (SD = 1.07) according to a 5-point Likert scale (1 = poor, 2 = reasonable, 3 = average, 4 = good, and 5 = excellent), indicating that the participants rated their Internet skill basically "good." The mean scores of the sub-constructs in the AAHLS were 6.14 (SD = 1.37) for functional health literacy, 5.10 (SD = 1.65) for communicative health literacy, and 11.13 (SD = 2.65) for critical health literacy, in light of a 3-point Likert scale (1 = often, 2 = sometimes, and 3 = rarely). These mean scores indicated that the participants needed help to read health-related materials "sometimes," the frequency that they knew how to communicate effectively with professional health providers was between "often" and "sometimes," and the frequency that they were critical about health information was between "often" and "sometimes," respectively. The sum of their scores for eHealth literacy averaged 28.29 (SD = 5.31) based on a 5-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = undecided, 4 = agree, and 5 = strongly agree), showing that they had a relatively high eHealth literacy level. The mean score for each question in the GHNT was determined at 1.31 (SD = 0.46), 1.36 (SD = 0.48), 1.41 (SD = 0.49), 1.77 (SD = 0.42), 1.51 (SD = 0.50), and 1.54 (SD = 0.50), respectively, based on a 2-point Likert scale with 1 representing a right answer and 2 representing a wrong answer. These mean scores showed that a high percentage of the participants answered the 6 questions wrongly, especially Questions 4–6. Similarly, participants performed unsatisfactorily in answering the 3 questions in the CRT, with a mean score of 1.75 (SD = 0.43), 1.55 (SD = 0.50), and 1.59 (SD = 0.49) for each question respectively, based on a 2-point Likert scale with 1 representing a right answer and 2 representing a wrong answer. In the PHQ-9, the participants reported that they never felt depressed or felt depressed only for 1–3 days in the past week.

Statistics of student responses to the 10 myths about COVID-19

Multimedia Appendix 2 presents the statistics of student responses to the 10 myths about COVID-19. The mean score for myths 1–6 and 9–10 ranged from 1.15 (SD = 0.36) to 1.29 (SD = 0.46). This meant that the participants rated these myths false. However, most of the participants rated myths 7–8 true (1.54, SD = 0.50; 1.49, SD = 0.50), showing that they were highly susceptible to these 2 pieces of misinformation.

Multilinearity statistics of the 12 predictor variables in the regression model

Table 1 shows the multilinearity statistics of the 12 predictor variables in the regression model. It shows that all variables had a Variance Inflation Factor (VIF) under or slightly above 2, widely used as the threshold for acceptable multilinearity for regression in the literature (60, 61). Small VIFs are indicative of limited, tolerable

TABLE 1 Multilinearity statistics.

Predictor variables [a]	Tolerance	VIF
(Constant)		
Years of HE	0.71	1.4
Age	0.7	1.42
Gender	0.92	1.09
Internet use frequency	0.96	1.04
Self-assessed internet skill	0.93	1.07
FHL-SUM	0.7	1.43
COHL-SUM	0.48	2.09
CRHL-SUM	0.52	1.94
eHEALS-SUM	0.9	1.11
GHNT-SUM	0.58	1.72
CRT-SUM	0.61	1.65
PHQ9-SUM	0.97	1.04

[a] Years of HE, Years of Higher Education; FHL-SUM, functional health literacy sum scores; COHL-SUM, communicative health literacy sum scores; CRHL-SUM, critical health literacy sum scores; eHEALS-SUM, digital health literacy sum scores; GHNT-SUM, General Health Literacy Test sum scores; CRT-SUM, Cognitive Recognition Test sum scores; PHQ9-SUM, PHQ-9 Patient Depression Questionnaire sum scores.

TABLE 2 Factors associated with the ability to detect COVID-19 misinformation (Threshold = 0.5, Gender = Both).

Predictors	*B*	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
							Lower	Upper
Years of HE	0.43	0.16	7.14	1.00	0.01	1.54	1.12	2.11
Internet use			10.91	3.00	0.01			
Internet use (1)	−0.89	0.99	0.82	1.00	0.37	0.41	0.06	2.83
Internet use (2)	−1.94	1.02	3.60	1.00	0.06	0.14	0.02	1.07
Internet use (3)	−1.40	0.52	7.21	1.00	0.01	0.25	0.09	0.69
FHL1			6.89	2.00	0.03			
FHL1(1)	−1.11	0.43	6.68	1.00	0.01	0.33	0.14	0.77
FHL1(2)	−0.31	0.34	0.81	1.00	0.37	0.74	0.38	1.44
eHEALS-SUM	0.05	0.02	4.73	1.00	0.03	1.05	1.01	1.09
GHNT-SUM	−0.27	0.11	6.12	1.00	0.01	0.76	0.62	0.95
CRT-SUM	−0.70	0.23	9.04	1.00	0.00	0.50	0.32	0.79
PHQSUM	−0.05	0.02	3.98	1.00	0.05	0.95	0.91	1.00
Constant	6.77	1.44	22.19	1.00	0.00	873.84		

correlation among the pre-selected predictor variables (12 in total in our study) which are required to develop logistic regression models of higher generalisability and reliability.

Thresholds of COVID-19 misinformation rebuttal

In this subsection, we present the result of the logistic regression analyses (forward stepwise) of the internal and external factors associated with one's ability to rebut COVID-19 myths when the threshold increased from an average level of 0.5 (having 5 or more correct responses) to 0.8 (having 8 or more correct responses) to understand the complexity, variability, as well as gendered differences in discerning and invalidating online misinformation about the pandemic among Chinese university students.

Table 2 shows the factors associated with the ability to detect and rebut online COVID-19 misinformation when the threshold of correct responses to the 10 myths was set at 0.5. It means that a student needs to identify 5 or more myths to reach the qualifying threshold. Table 2 shows the regression model developed on the entire dataset including both genders. It shows that the number of years of university education (Years of HE) was a statistically significant factor (OR = 1.54, CI [1.12, 2.11], $p = 0.01$). With 1 year more university education, the odds of a student being able to reach the misinformation rebuttal threshold increased by 54%. Internet usage frequency was another significant indicator. The original questionnaire contained 4 ordinal levels for Internet Use Frequency (1 = rarely, 2 = once a week, 3 = a few days a week, and 4 = almost every day of the week). Table 2 shows that Internet Use (2) and (3) predicted statistically significant decreases in the odds of students being able to discern and rebut COVID-19 myths: Internet Use (2 = once a week) (OR = 0.14, CI [0.02, 1.07], $p = 0.06$), Internet Use (3 = a few days a week) (OR = 0.25, CI [0.09, 0.69], $p = 0.01$). This means that when the frequency of internet usage changed from 'almost every day' to 'a few days a week', or to 'once a week' the odds of a student being capable to detect COVID-19 myths on the social media dropped by 75 and 86%, respectively. It was revealing to notice that despite a large decrease of 56% in the odds of being capable of detecting online COVID-19 myths when the internet use profile of a student changed from 'almost every day' to 'rarely,' such difference was not statistically significant ($p = 0.37$). This seems to suggest that it was the infrequent, limited access to the Internet which constituted significant risks to online health myths differentiation among Chinese college students, rather than high-level exposure ('almost every day') or minimal exposure ('rarely') to the internet.

Functional health literacy refers to one's ability to seek and understand health information (62). It contains three questions: FHL1: How often do you need someone to help you when you are given information to read by your doctor, nurse, or pharmacist? FHL2 When you need help, can you easily get hold of someone to assist you? FHL3: Do you need help to fill in official documents? (46). Each question has three frequency levels which we coded as ordinal data in our study: 1 = often, 2 = sometimes, 3 = rarely. As a result, larger scores on each question imply more limited functional literacy required to identify and comprehend health information. Regression modeling in Table 2 shows that when the frequency of a student needing others' help to read and understand a piece of health information increased, the odds of the student being able to detect COVID-19 myths dropped significantly, especially when the frequency of seeking help to comprehend health information increased from 'rarely' to 'often': FHL1(1) (OR = 0.33, CI [0.14, 0.77], $p = 0.01$). However, when frequency increased from 'rarely' to 'sometimes,' the odds of the student being able to detect COVID-19 myths did not differ significantly from that of students rarely needing others' help to understand health information: FHL1(2) (OR = 0.74, CI [0.38, 1.44], $p = 0.37$).

Digital health literacy (eHEALS) proved another significant predictor of students' ability to detect and rebut COVID-19 myths. It contains 8 highly related questions that enable a reflective self-assessment of one's ability to seek, appraise, and utilize quality online health information (47). Each question of the eHEAL scale has five frequency levels which were coded in our study as 1 = highly disagree,

2 = disagree, 3 = not sure, 4 = agree, and 5 = highly agree. To generate the combined scores, we produced the sum of the 8 questions and coded the sum as eHEALS-SUM. Higher combined scores thus indicated greater digital health literacy, as the respondent showed higher levels of confidence in internet usage. Table 2 shows that eHEALS-SUM (OR = 1.05, CI [1.01, 1.09], $p = 0.03$) positively predicted the odds of a student being able to detect COVID-19 myths. With one unit increase in the eHEALS-SUM score, the odds of the student being able to detect COVID-19 myths from the list provided increased by 5%.

In our study, we used two scales to measure cognitive ability to process health and general information which were the General Health Numeracy Test (GHNT), and the Cognitive Recognition Test (CRT). The GHNT-6 was developed to estimate the overall health numeracy skills of patients to understand and act on numerical health information (48, 63). The short form of the test contains 6 questions related to simple calculations of health risks (GHNT1 and GHNT2 on seasonal influenza, GHNT3 heart rate during physical exercise, GHNT4 nutrition composition, GHNT5 relation between cholesterol medication and heart attack risks, and GHNT6 interpretation of positive breast cancer screening test results). In our study, we coded the responses from students as binary data: 1 = correct, and 2 = wrong. As a result, higher sum scores of GHNT are indicative of more reduced general health numeracy. Logistic regression modeling in Table 2 shows that the sum score of GHNT was a significant predictor of student's ability to detect and rebut myths about COVID-19: GHNT-SUM (OR = 0.76, CI [0.62, 0.95], $p = 0.01$). This means with the increase of one unit in the aggregated score of GHNT (having made one more mistake in the overall answers), the odds of the student being able to detect 5 or more misleading statements about COVID-19 in the list dropped by about a third, i.e., 34%. In other words, with one unit decrease in the overall GHNT score (having made one less mistake in the GHNT test), the odds of the student being able to successfully rebut 5 or more myths that we provided to him or her increased by 31.58%.

The Cognitive Recognition Test (CRT) was developed to estimate the cognitive tendency to engage in reflective, contemplative thinking, as opposed more intuitive, hasty thinking style of individuals to reach instinctive 'gut' responses. The test contains 3 short questions on the cost of sporting goods, production speed of widgets, and growth rate of lily pads. We coded the responses from students as binary data: 1 = correct and 2 = wrong. The result of the CRT was similar to that of the GHNT. Higher aggregated CRT scores suggest a greater tendency toward more intuitive or less reflective cognitive processing of numerical information. CRT-SUM proved a significant predictor of the student's capability to detect and rebut myths about COVID-19: CRT-SUM (OR = 0.5, CI [0.32, 0.79], $p < 0.001$). With the increase of one unit (having made one more mistake in the CRT test), the odds of the student being able to detect 5 or more COVID-19 myths decreased by 50%.

Tables 3, 4 show the gender differences in detecting and rebutting COVID-19 myths among the students. For Chinese female university students, significant predictors of capability to detect COVID-19 myths were Years of Higher Education (OR = 1.87, CI [1.25, 2.8], $p < 0.001$), FHL1- the first question of the functional health literacy scale of AAHLS (need to ask help to comprehend health information) (OR = 0.29, CI [0.10, 0.79], $p = 0.02$), the aggregated scores of the GHNT test (OR = 0.75, CI [0.58, 0.97], $p = 0.03$) and CRTSUM (OR = 0.36, CI [0.20, 0.65], $p < 0.001$). Specifically, regarding FHL1, when the frequency of seeking others' help to comprehend health information increased from 'rarely' to 'often', the odds of the student reaching the predefined threshold (0.5) of being capable of differentiating COVID-19 myths decreased by 71%. Lower cognitive skills as indicated by higher scores on the GHNT and the CRT scales also predicted significant decreases in the odds of students being able to detect popular COVID-19 myths. For example, with one unit increase (having made one more mistake) on the GHNT and the CRT tests, the odds of the student not being able to rebut 5 or more common COVID-19 myths from the list increased by 33 and 178%, respectively.

Another useful finding was that depression was another significant predictor of female students' performance on COVID-19 myth rebuttal. We estimated the mental health status of students using the PHQ-9 (Patient Depression Questionnaire-9). The scale has 9 correlated questions on self-reported depression severity (53). Each question has four levels of occurrence of depressive symptoms, which we coded as 0 = not at all, 1 = several days, 2 = more than half the days, and 3 = nearly every day. The result shows that with one unit increase in the aggregated score of PHQ9, which indicates a higher level of depression, the odds of the student being capable of successfully detecting 5 or more COVID-19 myths were reduced by 6%.

Factors influencing the performance of male Chinese university students in detecting COVID-19 myths were distinct from those of their female peers. Table 4 shows that limited internet use predicted

TABLE 3 Factors associated with the ability to detect COVID-19 misinformation (Threshold = 0.5, Female).

Predictors	*B*	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
							Lower	Upper
Years of HE	0.63	0.21	9.20	1.00	0.00	1.87	1.25	2.80
FHL1			5.81	2.00	0.06			
FHL1(1)	−1.25	0.52	5.77	1.00	0.02	0.29	0.10	0.79
FHL1(2)	−0.44	0.41	1.13	1.00	0.29	0.64	0.29	1.45
GHNTSUM	−0.29	0.13	4.79	1.00	0.03	0.75	0.58	0.97
CRTSUM	−1.02	0.30	11.48	1.00	0.00	0.36	0.20	0.65
PHQSUM	−0.06	0.03	4.33	1.00	0.04	0.94	0.88	1.00
Constant	9.79	1.81	29.38	1.00	0.00	17929.66		

TABLE 4 Factors associated with the ability to detect COVID-19 misinformation (Threshold = 0.5, Male).

	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
							Lower	Upper
Internet use (1)	−1.10	1.32	0.70	1.00	0.40	0.33	0.03	4.38
Internet use (2)	−3.16	1.03	9.39	1.00	0.00	0.04	0.01	0.32
Constant	1.55	0.50	9.52	1.00	0.00	4.73		

TABLE 5 Factors associated with the ability to detect COVID-19 misinformation (Threshold = 0.8, Both Genders).

	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
							Lower	Upper
FHLSUM	0.19	0.07	8.53	1.00	0.00	1.21	1.07	1.38
GHN3(1)	0.41	0.20	4.06	1.00	0.04	1.51	1.01	2.25
GHN5(1)	0.49	0.20	5.93	1.00	0.02	1.64	1.10	2.43
PHQSUM	−0.05	0.02	10.03	1.00	0.00	0.95	0.92	0.98
Constant	−1.06	0.44	5.69	1.00	0.02	0.35		

substantial decreases in the odds of Chinese male college students being able to detect COVID-19 myths. But statistically significant drops in the odds of pandemic myth rebuttal only occurred when the frequency of internet usage changed from 'almost every day' to 'a few days a week' Internet Use (2) (OR = 0.04, CI [0.01, 0.32], $p < 0.001$). This means that when a male student had access to the internet a few days a week rather than every day of the week, the odds of that male student being able to reach the myth discrimination threshold decreased by as large as 96%. By contrast, we were surprised to find out that the difference between male students who had daily access to the internet and those who used internet only once a week was not statistically significant: Internet Use (1) (OR = 0.33, CI [0.03, 4.38], $p = 0.4$). This finding prompted us to speculate that among Chinese male college students, it was limited access, rather than daily or sporadic access to the internet which constituted a leading risk of students' vulnerability to online pandemic myths.

When raising the threshold from the average of 0.5 to a higher level of 0.8, we identified a similar but reduced set of factors that were significant predictors of students' performance in detecting online pandemic myths. Table 5 shows that first, increases in the aggregated score of the functional health literacy scale (FHL-SUM) predicted greater odds of students being able to reach the higher threshold of 0.8, namely, having the capability to correctly detect, rebut 8 or more items about COVID-19 from the list of myths we provided to them: FHL-SUM (OR = 1.21, CI [1.07, 1.38], $p < 0.001$). Recalling that we coded the three-level frequency of the three component questions of FHL in this order: 1 = often, 2 = sometimes, 3 = rarely, a higher aggregated FHL score indicates that an individual is less dependent on others' help to understand health materials properly (FHL1), more efficient in soliciting support when in need (FHL2), and less reliant on others' help to complete official medical documents (FHL3). Table 5 shows that with one unit increase in the sum of FHL scores, the odds of a student being able to correctly identify 8 or more myths increased by 21%.

Greater general health numeracy as measured by the GHNT test predicts better performance in myths rebuttal. Two items on the GHNT scale emerged as significant predictors: GHNT3 (1 = correct response) (OR = 1.51, CI [1.01, 2.25], $p = 0.04$) and GHNT5 (1 = correct response) (OR = 1.64, CI [1.10, 2.43], $p = 0.02$). GHNT3 was formulated in the context of calculating the maximal heart rate of older adult females when doing physical exercises, and GHNT5 was related to estimating changes in the probability of heart attacks after taking cholesterol medications for 5 years. Results in Table 5 show that when a Chinese college student correctly answered GHNT3 and GHNT5, the odds of the student being capable of detecting 8 or more pandemic myths from the list increased by 51 and 64%, respectively.

Depression again proved a significant predictor of lower performance in rebutting pandemic myths: PHQ-SUM (OR = 0.95, CI [0.92, 0.98], $p < 0.001$). With one score increase in the aggregated PHQ scores, which is indicative of more severe depression, the odds of students being capable of detecting 8 or more myths decreased by 5%. In our study of Chinese college students, the significant negative impact of depression was confirmed in both scenarios of average and higher-level thresholds of online health myth rebuttal capability.

Tables 6, 7 show gendered differences in detecting pandemic myths among Chinese college students. Table 6 shows that among female students, greater functional health literacy (FHL-SUM) (OR = 1.22, CI [1.04, 1.44], $p = 0.02$), greater general health numeracy (GHNT-SUM) (OR = 0.83, CI [0.74, 0.92], $p < 0.001$) were significant predictors of increased odds of better performance of myth rebuttal, whereas more severe depression (PHQ-SUM) (OR = 0.94, CI [0.91, 0.98], $p < 0.001$) predicted worse outcomes in myths detection among Chinese female students. Specifically, with a unit increase in the aggregated FHL scores, the odds of female students being able to detect 8 or more pandemic myths out of the 10 myths provided increased by 22%. With the increase of one more mistake in the GHNT test, the odds of female students being able to reach the higher myth rebuttal threshold were reduced by 17%. Lastly, with a unit increase on the PHQ depression severity scale, the odds of female students falling under the threshold increased by 6.38%.

By contrast, among Chinese male students, it was their self-reported digital health literacy measured by the eHEALS scale that predicted the odds of male students being capable of reaching the

TABLE 6 Factors associated with the ability to detect COVID-19 misinformation (Threshold = 0.8, Female).

	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
							Lower	Upper
FHLSUM	0.20	0.08	5.92	1.00	0.02	1.22	1.04	1.44
GHNTSUM	−0.19	0.06	11.75	1.00	0.00	0.83	0.74	0.92
PHQSUM	−0.06	0.02	9.69	1.00	0.00	0.94	0.91	0.98
Constant	1.12	0.73	2.38	1.00	0.12	3.06		

TABLE 7 Factors associated with the ability to detect COVID-19 misinformation (Threshold = 0.8, Male).

	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
							Lower	Upper
eHEALS-SUM	0.06	0.03	5.11	1.00	0.02	1.06	1.01	1.12
Constant	−1.44	0.79	3.32	1.00	0.07	0.24		

higher pandemic myth rebuttal threshold: eHEALS-SUM (OR = 1.06, CI [1.01, 1.12], $p = 0.02$). The digital health literacy scale contains 8 correlated questions enabling a reflective self-assessment of seek, appraise, and utilize critically and effectively online health resources (46). Each question is associated with a 5-item Likert scale which we coded as 1 = strongly disagree, 2 = disagree, 3 = not sure, 4 = agree, and 5 = strongly agree. Higher aggregated eHEALS scores are indicative of greater confidence in internet use for health purposes. Table 7 shows that among Chinese male students, with one unit increase in their aggregated eHEALS scores, the odds of students being capable of successfully detecting 8 or more myths increased by 6%.

Discussion

Principal findings in comparison with related publications

Finding 1: Education, Internet Use Frequency, Functional Health Literacy, General Health Numeracy, Reflective Thinking Tendency, and Depression Severity Were Predictors of Susceptibility to Misinformation about COVID-19 for Both Male and Female Students.

At an average threshold of 0.5, for both genders, years of higher education, internet use frequency (one day a week and a few days a week), functional health literacy, particularly the first item of the FHL scale (often needing others' help to understand health materials), general health numeracy, reflective thinking tendency, and depression severity were significant predictors of the capability of detecting popular myths about the pandemic among Chinese college students.

We found that the number of years of university education was a statistically significant factor (OR = 1.54, CI [1.12, 2.11], $p = 0.01$). With 1 year more university education, the odds of a student being able to reach the misinformation rebuttal threshold increased by 54%. This is in tune with previous studies which identified the association between low and high education levels and belief in misinformation (22, 23). However, a recent study dismissed education levels as a predictor of susceptibility to misinformation (20). Therefore, the role of education level in predicting misinformation susceptibility needs to be further ascertained.

COVID-19 is accompanied by an "infodemic," an overabundance of valid and invalid COVID-19-related information (64, 65). Digital communication technologies, the Internet and social media in particular, allow the COVID-19 infodemic to spread faster than the coronavirus itself (66). As a result, frequent exposure to the Internet increases the possibility of Chinese college students' vulnerability to COVID-19 misinformation.

We found health literacy, including functional health literacy and general health numeracy, an important predictor of Chinese college students' rebuttal to COVID-19 misinformation. This finding confirms the findings reported by some previous studies. Health literacy, the ability to seek, comprehend, assess, and apply health information in daily health behaviors and decisions (67), is crucially significant during COVID-19 (68). It has become a core capacity that people need to have for navigating online information and health service environments in the context of COVID-19 and the associated infodemic (69). People with poor health literacy are most probably confused when facing massive amounts of information on the Internet or media (70).

Reflective thinking was found to be an effective factor in predicting 'students' capability to detect and rebut COVID-19 misinformation in our study. COVID-19 increasingly demands people to find relevant information, critically reflect on it, and apply it to daily life and practices (66). Cognitive reflection (39, 50) results in individual differences in reflective thinking, judgments, and resistance to making 'gut' decisions. It shows substantial correlations with common biases in judgments and decisions (51). Cognitive sophistication (e.g., analytic thinking, basic science knowledge) has been found to effectively predict the endorsement of misinformation on COVID-19 (28), with lower analytic thinking abilities closely associated with the failure to distinguish between true and false news (29).

To our knowledge, no previous studies have investigated the relationship between depression severity and susceptibility to misinformation. Although we identified depression severity as a predictor of Chinese college students' susceptibility to COVID-19 misinformation, we cannot compare this finding with the findings reported by related publications.

Finding 2: Aggregated General Health Numeracy Scores and Functional Health Literacy Scores, as well as Depression Severity, Were

Predictors of Susceptibility to Misinformation for Both Male and Female Students.

At a higher threshold of 0.8, for both genders, aggregated functional health literacy scores and general health numeracy scores, as well as depression severity were significant predictors of capability to detect popular myths about the pandemic among Chinese college students.

As an essential component of literacy, numeracy reflects the ability to understand and use quantitative health information in everyday life (63). It is less likely for people with limited health literacy or numeracy to utilize health services effectively (71, 72). It is more likely for people with low health numeracy to experience difficulties in acting on medical instructions (73) comprehending health information (74), and engaging in self-care activities (75, 76), and to experience worse health outcomes (46, 77).

Functional health literacy, including individuals' abilities to seek and comprehend health-related knowledge (17, 32, 34), was also found to be an effective predictor of students' capability to rebut online misinformation about the pandemic.

Finding 3: Functional Health Literacy, General Health Literacy, and Depression Predicted Resistance to Misinformation for Female Students.

For Chinese female college students, functional health literacy, general health literacy, as well as depression were significant predictors of female students' capability to detect popular myths about the pandemic.

Finding 4: Internet Use Frequency and Self-reported Digital Health Literacy Predicted Resistance to Misinformation for Male Students.

For Chinese male college students, it was their internet use frequency and self-reported digital health literacy that were significant predictors of male students' capability to detect popular myths about the pandemic. Digital health literacy applies health literacy (67) to digital contexts and environments (78). It is a vital necessity for heavy media users (14) to rebut online misinformation (33). People reported difficulties in dealing with health-related information due to limited digital health literacy (70, 79).

Implications

This descriptive study can add to the body of evidence supporting the necessity of investigating COVID-19 misinformation rebuttal. Important implications can be provided for clinical practice, health education, medical research, and public health policy-making. The 4 principal findings concerning the predictors of susceptibility to COVID-19 misinformation identified in the study could be used as important indicators for screening those susceptible to COVID-19 misinformation to deliver targeted education and interventions. Knowledge and skills related to the 4 predictors should be integrated into public health education about COVID-19 misinformation to improve the general public's ability to appraise and rebut COVID-19-related myths. Medical researchers may gain insights into the topic of the susceptibility to COVID-19 misinformation. As a result, they could verify the contributors to COVID-19 misinformation susceptibility ascertained in this study and identify more contributing factors in future studies. Public health policymakers can consider the results and findings of this study when making public health policies in the future.

In the digital age, the mixed quality of online information, easy access to misinformation, and adverse implications of using misinformation all make it essential to evaluate susceptibility to misinformation in the public. Such evaluations can contribute to more tailor-made and targeted infodemic management. As Dr. Tedros Adhanom Ghebreyesus, WHO Director-General, said, "Finding solutions to the infodemic is as vital for saving lives from COVID-19 as public health measures, like mask-wearing and hand hygiene, to equitable access to vaccines, treatments and diagnostics" (7). Given that effective and timely evaluation of COVID-19 misinformation susceptibility can be made in various populations, infodemic management is most likely to enable good health practices through such measures as listening to community concerns and questions, promoting understanding of risk and health expert advice, building resilience to misinformation, and engaging and empowering communities to take positive action (10).

Limitations

This study has some limitations. First and foremost, it is unclear to what extent a single university sample is representative in the Chinese context. Such representativeness needs to be further attested. The generalizability of the research findings based on such a sample also needs to be further tested. In future studies, we will involve more students from diverse universities across China to test the representativeness of the sample we used in this study and the generalizability of the research findings reported in this study. In this way, we can ascertain more diversified and more tailor-made factors specific to the Chinese college students sample. Second, female participants (79.5%) were far more than male participants in this cross-sectional survey. This may induce a certain level of gender bias, which most probably caused higher self-reported Internet access frequencies and more wrong answers to the question items on the GHNT and CRT scales. These gender bias-induced results may undermine the generalizability of the research findings to some extent. However, our sample reflected a population that is theoretically relevant to key literature on medical misinformation. In future studies, we will try to balance the proportions of male and female participants to minimize gender bias. Third, the assessment of students' capability of pandemic myth rebuttal was subject to the deliberate selection of thresholds that would suit the varying practical needs of the tool. When setting the threshold at different values, we obtained different findings, as evidenced by principal findings 1 and 2 above. Fourth, the absence of statistically significant differences in differentiating online pandemic myths between male students who had infrequent, limited access to the Internet and those who had high-level exposure ('almost every day') to the Internet warrants further research. In comparison, greater exposure to the Internet increased female students' susceptibility to misinformation about the pandemic. Whether this gender difference may apply to college students' vulnerability to other online misinformation needs to be ascertained in future studies. Finally, the cross-sectional nature of this study may cause some biases, including a non-response bias, a reporting bias, etc. According to established practice, a non-response rate of over 30% can cause a non-response bias in a questionnaire survey. The response rate (76.7%, 546/712) of the study participants indicates that our cross-sectional study was less

likely to be influenced by a non-response bias. However, in the PHQ-9, the participants reported that they never felt depressed or felt depressed only for 1–3 days in the past week. This self-reported depression level was likely to be influenced by a reporting bias because students, especially females, usually prefer not to acknowledge their depressive mood to others. In future studies, we would recruit more cohorts from more walks of life as participants to reduce cross-sectional study-induced biases.

Conclusion

In this descriptive study, we revealed the complexity and dynamics concerning Chinese college students' susceptibility to COVID-19 misinformation. Specifically, we found that (1) at an average threshold of 0.5, Internet use frequency, functional health literacy, general health numeracy, reflective thinking tendency, and depression severity were predictors of susceptibility to misinformation for both male and female students, (2) at a higher threshold of 0.8, aggregated general health numeracy scores and functional health literacy scores, as well as depression severity were predictors of susceptibility to misinformation for both male and female students, (3) functional health literacy, general health literacy, and depression predicted resistance to misinformation for female students, and (4) internet use frequency and self-reported digital health literacy predicted resistance to misinformation for male students. It was the first study that assessed Chinese college students' susceptibility to COVID-19 misinformation through a comprehensive survey of their various health and digital health literacy and skills. This study provided valuable insights into the mechanism of how Chinese students engage or disengage with COVID-19 misinformation We will perform similar studies to assess susceptibility to other health misinformation and disinformation among Chinese college students to identify more contributors to their vulnerability to online misinformation.

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 Academic Committee of the School of Foreign Studies, Nantong University, China. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

MJ and YS made the data analysis, and designed and wrote this article. YS conducted the survey and collected the data. All authors read and approved the final manuscript.

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.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2023.1233414/full#supplementary-material

References

1. WHO. Fighting misinformation in the time of COVID-19, one click at a time. (2021). Available at: https://www.who.int/news-room/feature-stories/detail/fighting-misinformation-in-the-time-of-covid-19-one-click-at-a-time (Accessed August 4, 2022)

2. Sunstein CR, Vermeule A. Conspiracy theories: causes and cures. *J Polit Philos*. (2009) 17:202–27. doi: 10.1111/j.1467-9760.2008.00325.x

3. Mian A, Khan S. Coronavirus: the spread of misinformation. *BMC Med*. (2020) 18:89. doi: 10.1186/s12916-020-01556-3

4. Kouzy R, Jaoude JA, Kraitem A, EI Alam MB. Coronavirus goes viral: quantifying the COVID-19 misinformation epidemic on Twitter. *Cureus*. (2020) 12:e7255. doi: 10.7759/cureus.7255

5. Brennen JS, Simon FM, Howard PN, Nielsen RK. Types, sources, and claims of COVID-19 misinformation: the Reuters institute for the Study of Journalism (2020). Available at: https://reutersinstitute.politics.ox.ac.uk/typessources-and-claims-covid-19-misinformation

6. Lima DL, Lopes MAAA, Brito AM. Social media: friend or foe in the COVID-19 pandemic? *Clinics*. (2020) 75:e1953. doi: 10.6061/clinics/2020/e1953

7. CDC. How to address COVID-19 vaccine misinformation. (2021). Available at: https://www.cdc.gov/vaccines/covid-19/health-departments/addressing-vaccine-misinformation.html (Accessed August 4, 2022)

8. The President and Fellows of Harvard College Fighting the spread of COVID-19 misinformation. (2021). Available at: https://www.hsph.harvard.edu/news/features/fighting-the-spread-of-covid-19-misinformation/ (Accessed August 4, 2022)

9. WHO Countering misinformation about COVID-19. (2020). Available at: https://www.who.int/news-room/feature-stories/detail/countering-misinformation-about-covid-19 (Accessed August 4, 2022)

10. World Health Organization. Infodemic. (2023). Available at: https://www.who.int/health-topics/infodemic#tab=tab_1 (Accessed October 14 2023

11. International Telecommunication Union. ITU releases 2015 ICT figures: statistics confirm ICT revolution of the past 15 years. (2015). Available at: http://www.itu.int/net/pressoffice/press_releases/2015/17.aspx#.VsSsE_krK71 (Accessed July 26, 2022)

12. Morahan-Martin J, Anderson CD. Information and misinformation online: recommendations for facilitating accurate mental health information retrieval and evaluation. *Cyberpsychol Behav*. (2000) 3:731–46. doi: 10.1089/10949310050191737

13. Liu J, Liu Z, Zhang Z, Dong S, Zhen Z, Man L, et al. Internet usage for health information by patients with epilepsy in China. *Seizure*. (2013) 22:787–90. doi: 10.1016/j.seizure.2013.06.007

14. Rideout VJ, Foehr UG, Roberts DFEducation Resources Information Center. (2010). Generation M2: media in the Lives of 8- to 18-Year-Olds Available at: https://eric.ed.gov/?id=ED527859 (Accessed July 26, 2022)

15. Lee JJ, Kang KA, Wang MP, Zhao SZ, Wong JYH, O'Connor S, et al. Associations between COVID-19 misinformation exposure and belief with COVID-19 knowledge and preventive behaviors: cross-sectional online study. *J Med Internet Res*. (2020) 22:e22205. doi: 10.2196/22205

16. World Health Organization *Coronavirus disease 2019 (COVID-19) situation report 86*. Available at: https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200415-sitrep-86-covid-19.pdf?sfvrsn=c615ea20_6 (Accessed July 26, 2022)

17. Chou WS, Oh A, Klein WMP. Addressing health-related misinformation on social media. *JAMA*. (2018) 320:2417–8. doi: 10.1001/jama.2018.16865

18. Lake MA. What we know so far: COVID-19 current clinical knowledge and research. *Clin Med*. (2020) 20:124–7. doi: 10.7861/clinmed.2019-coron

19. Oliver JE, Wood T. Medical conspiracy theories and health behaviors in the United States. *JAMA Intern Med*. (2014) 174:817–8. doi: 10.1001/jamainternmed.2014.190

20. Agley J, Xiao Y. Misinformation about COVID-19: evidence for differential latent profiles and a strong association with trust in science. *BMC Public Health*. (2021) 21:89. doi: 10.1186/s12889-020-10103-x

21. Hagen K. Should academics debunk conspiracy theories? *Soc Epistemol*. (2020) 34:423–39. doi: 10.1080/02691728.2020.1747118

22. Freeman D, Bentall RP. The concomitants of conspiracy concerns. *Soc Psychiatry Psychiatr Epidemiol*. (2017) 52:595–604. doi: 10.1007/s00127-017-1354-4

23. Galliford N, Furnham A. Individual difference factors and beliefs in medical and political conspiracy theories. *Scand J Psychol*. (2017) 58:422–8. doi: 10.1111/sjop.12382

24. Douglas KM, Uscinski JE, Sutton RM, Cichocka A, Nefes T, Ang CS, et al. Understanding conspiracy theories. *Polit Psychol*. (2019) 40:3–35. doi: 10.1111/pops.12568

25. Guess A, Nagler J, Trucker J. Less than you think: prevalence and predictors of fake news dissemination on Facebook. *Sci Adv*. (2020) 5:eeau4586. doi: 10.1126/sciadv.aau4586

26. Sutton RM, Douglas KM. Conspiracy theories and the conspiracy mindset: implications for political ideology. *Curr Opin Behav Sci*. (2020) 34:118–22. doi: 10.1016/j.cobeha.2020.02.015

27. Miller JM, Saunders KL, Farhart CE. Conspiracy endorsement as motivated reasoning: the moderating roles of political knowledge and trust. *Am J Polit Sci*. (2015) 60:824–44. doi: 10.1111/ajps.12234

28. Pennycook G, McPhetres J, Bago B, Rand DG. Predictors of attitudes and misperceptions about COVID-19 in Canada, the U.K., and the U.S.A. *PsyArxiv*. (2020). doi: 10.31234/osf.io/zhjkp

29. Pennycook G, Rand DG. Who falls for fake news? The roles of bullshit receptivity, overclaiming, familiarity, and analytic thinking. *J Pers*. (2020) 88:185–200. doi: 10.1111/jopy.12476

30. Jasinskaja-Lahti I, Jetten J. Unpacking the relationship between religiosity and conspiracy beliefs in Australia. *Br J Soc Psychol*. (2019) 58:938–54. doi: 10.1111/bjso.12314

31. Bapaye JA, Bapaye HA. Demographic factors influencing the impact of coronavirus-related misinformation on WhatsApp: cross-sectional questionnaire study. *JMIR Public Health Surveill*. (2021) 7:e19858. doi: 10.2196/19858

32. Schulz PJ, Pessina A, Hartung U, Petrocchi S. Effects of objective and subjective health literacy on patients' accurate judgment of health information and decision-making ability: survey study. *J Med Internet Res*. (2021) 23:e20457. doi: 10.2196/20457

33. Blakemore LM, Meek SEM, Marks LK. Equipping learners to evaluate online health care resources: longitudinal study of learning design strategies in a health care massive open online course. *J Med Internet Res*. (2020) 22:e15177. doi: 10.2196/15177

34. Keselman A, Arnott Smith C, Leroy G, Kaufman DR. Factors influencing willingness to share health misinformation videos on the internet: web-based survey. *J Med Internet Res*. (2021) 23:e30323. doi: 10.2196/30323

35. Shan Y, Ji M, Xing Z, Dong Z, Xu X. Susceptibility to breast Cancer misinformation among Chinese patients: cross-sectional study. *JMIR Form Res*. (2023) 7:e42782. doi: 10.2196/42782

36. All aspects of health literacy scale (AAHLS). (2010). Available at: https://healthliteracy.bu.edu/documents/34/AAHLS%20Tool.pdf (Accessed June 26, 2022)

37. Koo M, Norman C, Chang HM. Psychometric evaluation of a Chinese version of the eHealth literacy scale (eHEALS) in school age children. *Int J Health Educ*. (2012) 15:29–36.

38. The General Health Numeracy Test (GHNT-6). (2011). Available at: https://healthliteracy.bu.edu/documents/36/GHNT_6%20.pdf (Accessed June 26, 2022)

39. Frederick S. Cognitive reflection and decision making. *J Econ Perspect*. (2005) 19:25–42. doi: 10.1257/089533005775196732

40. The Psychological Health Questionnaire (PHQ-9). (2020). Available at: https://m.medsci.cn/scale/show.do?id=291e1050f3 (Accessed June 26, 2022)

41. CDC Myths and Facts about COVID-19 Vaccines. (2022). Available at: https://www.cdc.gov/coronavirus/2019-ncov/vaccines/facts.html (Accessed August 1, 2022)

42. The Johns Hopkins University COVID-19-Myth Versus Fact. (2021). Available at: https://www.hopkinsmedicine.org/health/conditions-and-diseases/coronavirus/2019-novel-coronavirus-myth-versus-fact (Accessed August 1, 2022)

43. WHO Coronavirus disease (COVID-19) advice for the public: Mythbusters. (2022). Available at: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/advice-for-public/myth-busters (Accessed August 1, 2022)

44. Is it true? Get the facts on COVID-19 vaccines. (2021). Available at: https://www.health.gov.au/initiatives-and-programs/covid-19-vaccines/is-it-true (Accessed August 1, 2022)

45. Guzys D, Kenny A, Dickson-Swift V, Threlkeld G. A critical review of population health literacy assessment. *BMC Public Health*. (2015) 15:215. doi: 10.1186/s12889-015-1551-6

46. Chinn D, McCarthy C. All Aspects of Health Literacy Scale (AAHLS): developing a tool to measure functional, communicative and critical health literacy in primary healthcare settings. *Patient Educ Couns*. (2013) 90:247–53. doi: 10.1016/j.pec.2012.10.019

47. Norman CD, Skinner HA. eHEALS: the eHealth literacy scale. *J Med Internet Res*. (2006) 8:e27. doi: 10.2196/jmir.8.4.e27

48. Osborn CY, Wallston KA, Shpigel A, Cavanaugh K, Kripalani S, Rothman RL. Development and validation of the General Health Numeracy Test (GHNT). *Patient Educ Couns*. (2013) 91:350–6. doi: 10.1016/j.pec.2013.01.001

49. Dorst MT, Anders SH, Chennupati S, Chen Q, Purcell JG. Health information technologies in the support systems of pregnant women and their caregivers: mixed-methods study. *J Med Internet Res*. (2019) 21:e10865. doi: 10.2196/10865

50. Bialek M, Pennycook G. The cognitive reflection test is robust to multiple exposures. *Behav Res*. (2018) 50:1953–9. doi: 10.3758/s13428-017-0963-x

51. Toplak ME, Stanovich KE. The domain specificity and generality of disjunctive reasoning: searching for a generalizable critical thinking skill. *J Educ Psych*. (2002) 94:197–209. doi: 10.1037/0022-0663.94.1.197

52. Gelaye B, Williams MA, Lemma S, Deyessa N, Bahretibeb Y, Shibre T, et al. Validity of the patient health questionnaire-9 for depression screening and diagnosis in East Africa. *Psychiatry Res*. (2013) 210:653–61. doi: 10.1016/j.psychres.2013.07.015

53. Kroenke K, Spitzer RL, Williams JB. The PHQ-9: validity of a brief depression severity measure. *J Gen Intern Med*. (2001) 16:606–13. doi: 10.1046/j.1525-1497.2001.016009606.x

54. Spitzer RL, Williams JB, Kroenke K, Hornyak R, McMurray J. Validity and utility of the PRIME-MD patient health questionnaire in assessment of 3000 obstetric-gynecologic patients: the PRIME-MD Patient Health Questionnaire Obstetrics-Gynecology study. *Am J Obstet Gynecol*. (2000) 183:759–69. doi: 10.1067/mob.2000.106580

55. Pramukti I, Strong C, Sitthimongkol Y, Setiawan A, Pandin MGR, Yen CF, et al. Anxiety and suicidal thoughts during the COVID-19 pandemic: cross-country comparative study among Indonesian, Taiwanese, and Thai university students. *J Med Internet Res*. (2020) 22:e24487. doi: 10.2196/24487

56. Akdeniz G, Kavakci M, Gozugok M, Yalcinkaya S, Kucukay A, Sahutogullari B. A survey of attitudes, anxiety status, and protective behaviors of the university students during the COVID-19 outbreak in Turkey. *Front Psych*. (2020) 11:695. doi: 10.3389/fpsyt.2020.00695

57. Cao W, Fang Z, Hou G, Han M, Xu X, Dong J, et al. The psychological impact of the COVID-19 epidemic on college students in China. *Psychiatry Res*. (2020) 287:112934. doi: 10.1016/j.psychres.2020.112934

58. Zhai Y, Du X. Addressing collegiate mental health amid COVID-19 pandemic. *Psychiatry Res*. (2020) 288:113003. doi: 10.1016/j.psychres.2020.113003

59. Wenjuanxing. Available at: https://www.wjx.cn/newwjx/manage/myquestionnaires.aspx?randomt=1646223058

60. O'brien RM. A caution regarding rules of thumb for variance inflation factors. *Qual Quant*. (2007) 41:673–90. doi: 10.1007/s11135-006-9018-6

61. Menard S. *Applied logistic regression analysis: Sage University series on quantitative applications in the social sciences*. Thousand Oaks, CA: Sage (1995).

62. Parker RM, Baker DW, Williams MV, Nurss JR. The test of functional health literacy in adults. *J Gen Intern Med*. (1995) 10:537–41. doi: 10.1007/BF02640361

63. Rothman RL, Montori VM, Cherrington A, Pignone MP. Perspective: the role of numeracy in health care. *J Health Commun*. (2008) 13:583–95. doi: 10.1080/10810730802281791

64. Hua J, Shaw R. Corona virus (COVID-19) "Infodemic" and emerging issues through a data Lens: the case of China. *Int J Environ Res Public Health*. (2020) 17:2309. doi: 10.3390/ijerph17072309

65. Zarocostas J. How to fight an infodemic. *Lancet*. (2020) 395:676. doi: 10.1016/S0140-6736(20)30461-X

66. Dadaczynski K, Okan O, Messer M, Leung AYM, Rosário R, Darlington E, et al. Digital health literacy and web-based information-seeking behaviors of university students in Germany during the COVID-19 pandemic: cross-sectional survey study. *J Med Internet Res*. (2021) 23:e24097. doi: 10.2196/24097

67. Sørensen K, Van den Broucke S, Fullam J, Doyle G, Pelikan J, Slonska Z, et al. Health literacy and public health: a systematic review and integration of definitions and models. *BMC Public Health*. (2012) 12:80. doi: 10.1186/1471-2458-12-80

68. Paakkari L, Okan O. COVID-19: health literacy is an underestimated problem. *Lancet Public Health*. (2020) 5:e249–50. doi: 10.1016/S2468-2667(20)30086-4

69. Sørensen K. Covid-19: digital health literacy is a key to saving time, costs and lives. *ICT Health*. (2020). Available at: https://www.ictandhealth.com/news/covid-19-digital-health-literacy-is-a-key-to-saving-time-costs-and-lives (Accessed August 6, 2022)

70. Okan O, Bollweg TM, Berens E, Hurrelmann K, Bauer U, Schaeffer D. Coronavirus-related health literacy: a cross-sectional study in adults during the COVID-19 Infodemic in Germany. *Int J Environ Res Public Health*. (2020) 17:5503. doi: 10.3390/ijerph17155503

71. Ciampa PJ, Osborn CY, Peterson NB, Rothman RL. Patient numeracy, perceptions of provider communication, and colorectal cancer screening utilization. *J Health Commun*. (2010) 15:157–68. doi: 10.1080/10810730.2010.522699

72. Sudore RL, Mehta KM, Simonsick EM, Harris TB, Newman AB, Satterfield S, et al. Limited literacy in older people and disparities in health and healthcare access. *J Am Geriatr Soc*. (2006) 54:770–6. doi: 10.1111/j.1532-5415.2006.00691.x

73. Kumar D, Sanders L, Perrin EM, Lokker N, Patterson B, Gunn V, et al. Parental understanding of infant health information: health literacy, numeracy, and the Parental Health Literacy Activities Test (PHLAT). *Acad Pediatr*. (2010) 10:309–16. doi: 10.1016/j.acap.2010.06.007

74. Rothman RL, Housam R, Weiss H, Davis D, Gregory R, Gebretsadik T, et al. Patient understanding of food labels: the role of literacy and numeracy. *Am J Prev Med*. (2006) 31:391–8. doi: 10.1016/j.amepre.2015.04.010

75. Kripalani S, Henderson LE, Chiu EY, Robertson R, Kolm P, Jacobson TA. Predictors of medication self-management skill in a low-literacy population. *J Gen Intern Med*. (2006) 21:852–6. doi: 10.1111/j.1525-1497.2006.00536.x

76. Huizinga MM, Carlisle AJ, Cavanaugh KL, Davis DL, Gregory RP, Schlundt DG, et al. Literacy, numeracy, and portion-size estimation skills. *Am J Prev Med*. (2009) 36:324–8. doi: 10.1016/j.amepre.2008.11.012

77. Wolf MS, Gazmararian JA, Baker DW. Health literacy and functional health status among older adults. *Arch Intern Med*. (2005) 165:1946–52. doi: 10.1001/archinte.165.17.1946

78. van der Vaart R, Drossaert C. Development of the digital health literacy instrument: measuring a broad Spectrum of health 1.0 and health 2.0 skills. *J Med Internet Res*. (2017) 19:e27. doi: 10.2196/jmir.6709

79. Schaeffer D, Berens E, Vogt D. Health literacy in the German population. *Dtsch Arztebl Int*. (2017) 114:53–60. doi: 10.3238/arztebl.2017.0053

Glossary

AAHLS	the All Aspects of Health Literacy Scale
eHEALS	the eHealth Literacy Scale
GHNT-6	the General Health Numeracy Test
CRT	the Cognitive Reflection Test
PHQ-9	the Psychological Health Questionnaire-9 Items
HE	higher education
FHL	functional health literacy
CRHL	critical health literacy
COHL	communicative health literacy
FHL-SUM	sum of the functional health literacy scale of the All Aspects of Health Literacy Scale (AAHLS)
CRHL-SUM	sum of the critical health literacy scale of the AAHLS
COHL-SUM	sum of the communicative health literacy scale of the AAHLS
eHL-SUM	sum of the digital health literacy scale
GHNT-SUM	sum of the general health numeracy scale
CRT-SUM	sum of the cognitive recognition test
PHQ-SUM	sum of the Patient Health Questionnaire-9 (PHQ9)

frontiers | Frontiers in Public Health

TYPE Study Protocol
PUBLISHED 07 December 2023
DOI 10.3389/fpubh.2023.1248949

OPEN ACCESS

EDITED BY
Fatjona Kamberi,
University of Vlorë, Albania

REVIEWED BY
Rezarta Lalo,
University of Vlorë, Albania
Franklin Apfel,
World Health Communication Associates, United Kingdom
Naveen Thacker,
International Pediatric Association, India

*CORRESPONDENCE
Lucie Marisa Bucci
✉ lmbucci@bhhealthservices.com

†These authors have contributed equally to this work and share first authorship

RECEIVED 27 June 2023
ACCEPTED 06 November 2023
PUBLISHED 07 December 2023

CITATION
Bucci LM, Lamprianou S, Gesualdo F, Tozzi AE, Ghalayini T, Sahinovic I and Pal S (2023) A social media intervention for communicating vaccine safety in low- and middle-income countries: protocol for a pilot study. *Front. Public Health* 11:1248949. doi: 10.3389/fpubh.2023.1248949

A social media intervention for communicating vaccine safety in low- and middle-income countries: protocol for a pilot study

Lucie Marisa Bucci[1*†], Smaragda Lamprianou[2†], Francesco Gesualdo[3], Alberto E. Tozzi[3], Tala Ghalayini[4], Isabelle Sahinovic[2] and Shanthi Pal[2†]

[1]Bucci-Hepworth Health Services, Pincourt, QC, Canada, [2]World Health Organization, Geneva, Switzerland, [3]Predictive and Preventive Research Unit, Bambino Gesù Children's Hospital, Rome, Italy, [4]Accenture Health and Public Service, London, United Kingdom

Vaccine safety is a concern that continues to drive hesitancy and refusal in populations in low-and-middle income countries (LMICs). Communicating about vaccine safety is a strategy that can successfully change personal and community perceptions and behaviors toward vaccination. The COVID-19 infodemic emergency with the rapid rollout of new vaccines and new technology, demonstrated the need for good and effective vaccine safety communication. The Vaccine Safety Net (VSN), a WHO-led global network of websites that provide reliable information on vaccine safety offers the ideal environment for gathering web and social media analytics for measuring impact of vaccine safety messages. Its members work with a wide range of populations, in different geographic locations and at many levels including national, regional, and local. We propose to undertake a pilot study to evaluate the feasibility of implementing COVID-19 vaccine safety communications with VSN members working in LMICs and to assess the impact of communications on public knowledge, attitudes, and perceptions.

KEYWORDS

COVID-19, vaccine safety, communication, social media, surveillance, LMIC

Introduction

Vaccines remain effective public health interventions for reducing significant morbidity and mortality caused by communicable diseases in populations globally (1, 2). Despite the success of vaccines, populations continue to be hesitant and either delay or refuse vaccines. There is a myriad of complex interrelated factors that contribute to vaccine refusal (3), but the most cited concern is vaccine safety (4). The risk of harm is considered a driver of refusal particularly in low- and middle-income countries (LMICs) (5).

The perception of risk vs. benefit plays a pivotal role in individual and community decision-making about vaccination (6–8). In our digital world, perceptions about vaccines are commonly shaped by religion, culture, and politics through influencers found in a range of networks that are simultaneously offline and online (e.g., social networks) (9). While these social networks have indeed increased population awareness, they have also facilitated the confluence and

circulation of inaccurate and misleading information that may cause harm to population health (10). Vaccine safety communication, which entails the fostering of vaccine confidence through a range of strategies (i.e., collecting analytical data through social media listening tools, diagnosing and identifying concerns as they arise, creation of common messaging), is widely recognized by experts globally as an effective intervention for addressing population concerns and for filling information voids caused by the spread of misinformation (11).

Providing people with risk–benefit information in comprehensible ways is a strategy for reducing doubt in vaccines and building resilience against misinformation. The rejection of misinformation requires mindfulness to critically assess what is falsely presented as fact (12). Most misinformation appeals to negative emotions, which has been shown to reinforce false beliefs, or any state of doubt along the vaccine hesitancy spectrum (3) as defined by the World Health Organization (WHO) Strategic Advisory Group of Experts (SAGE) in 2015. Vaccine hesitancy is also very context-specific and variable across time, places, and vaccines (3).

The 3C's of vaccine hesitancy (complacency, confidence, and convenience), a mainstay conceptual model in vaccine demand and acceptance research, is a useful model for identifying and evaluating factors that lead to personal or community unwillingness to be vaccinated (13). This model was recently expanded by the WHO Behavioral and Social Drivers of Vaccination (BeSD) Working Group to include two more categories: rational calculation and collective responsibility, which provide additional explanations for vaccination decision-making (7). The value of the model is that it helps frame vaccine hesitancy issues. It is also understood by SAGE that this model should continue to be expanded upon through new learnings, tools, and best practices.

The Vaccine Safety Net (VSN) was created by the World Health Organization (WHO) in 2003 to promote vaccine safety communication by facilitating access to trustworthy information on accredited websites who meet the WHO's good information practices criteria (14, 15). The VSN network currently includes 104 websites in all WHO regions that adhere to the Global Advisory Committee on Vaccine Safety (GACVS) good information practices criteria. In fact, to become a VSN member, mandatory criteria in terms of the credibility of the website, the quality and quantity of the content (i.e., vaccine safety related information), as well as the design and accessibility of the website should be met. VSN membership is accountable for ensuring quality content online and facilitating the access of internet users to science-based and reliable vaccine safety information. Members benefit from guidance on how to optimize search engine rankings. They also have access to tips for best practices in vaccine safety communication, how to improve web linking and web analytics gathering (16) to facilitate public access to evidence-based and trustworthy information through collaborations, webinars and projects organized by the WHO. Additionally, since its creation, the network has become a knowledge base for all members seeking to achieve more effective ways to communicate about vaccine safety. VSN-led research expanded to meet this need through web and social media analytics gathering practices within the network to measure the reach of the members' communication efforts, and impact on population behavior. WHO contracted a social listening platform that supported VSN members to evaluate the outreach of their messaging and communication strategies through their respective social media accounts by monitoring particular parameters such as numbers of shares, likes, trends, retweets, comments, replies, and sentiments using their tools. The messages were used in local contexts such as vaccination campaigns, or during global events such as World Immunization Week (WIW).

The COVID-19 infodemic emergency demonstrated the need for effective and good communication because of the rapid global rollout of new vaccines and new technologies intended for different groups of users (in terms of age and underlining health factors such as chronic disease). The VSN provides an ideal environment for gathering unique web and social media analytics for measuring the impact of vaccine safety communications. The VSN is unique in terms of its richness of knowledge and expertise ranging from epidemiologists, clinical pharmacists, pediatricians, nurses, midwives, IT specialists and others. In addition, members come from different settings and often experience different cultural or public health contexts and issues. Its members work at many levels including national, regional, and local. Since the height of the COVID-19 pandemic, VSN members have reported diverging experiences with vaccine acceptance, confidence and even the spread of misinformation, which has posed challenges never experienced before. There has been pressing concern to address the continuous onslaught of information, ever changing, from a multitude of untrusted sources. In addition, circulating conspiracies about the side effects of COVID-19 vaccines have affected public confidence in vaccination (17). This is not a new issue; many recent immunization programs have suffered setbacks from misinformation and inadequate communication, such as the "HPV scare in Japan" (18–20).

The primary objective of this protocol is to call for the running of a pilot study with VSN members working in LMICs, where COVID-19 vaccine safety messaging customized to local settings will be disseminated through web and social media platforms. The second objective is to evaluate the feasibility of the pilot study by gathering feedback from VSN members. This is the first pilot study of its kind to be implemented in collaboration with VSN members from LMICs. To our knowledge, there are only a few projects comparable to this pilot study (21).

Methods and analysis

The pilot study will be implemented in four phases: (1) intelligence gathering; (2) vaccine safety message development; (3) implementation and monitoring; and (4) evaluation. This comprehensive framework is depicted in Figure 1.

VSN recruitment

A call for participation will be sent to the Network. Eligible members will be VSN members coming from LMICs with limited resources or members located in countries with very low vaccine coverage. All other members will be excluded from the study, but they can participate in the "Research Committee" that will provide support in terms of data analysis, social media intelligence, communication expertise, statistical analysis and social behavior

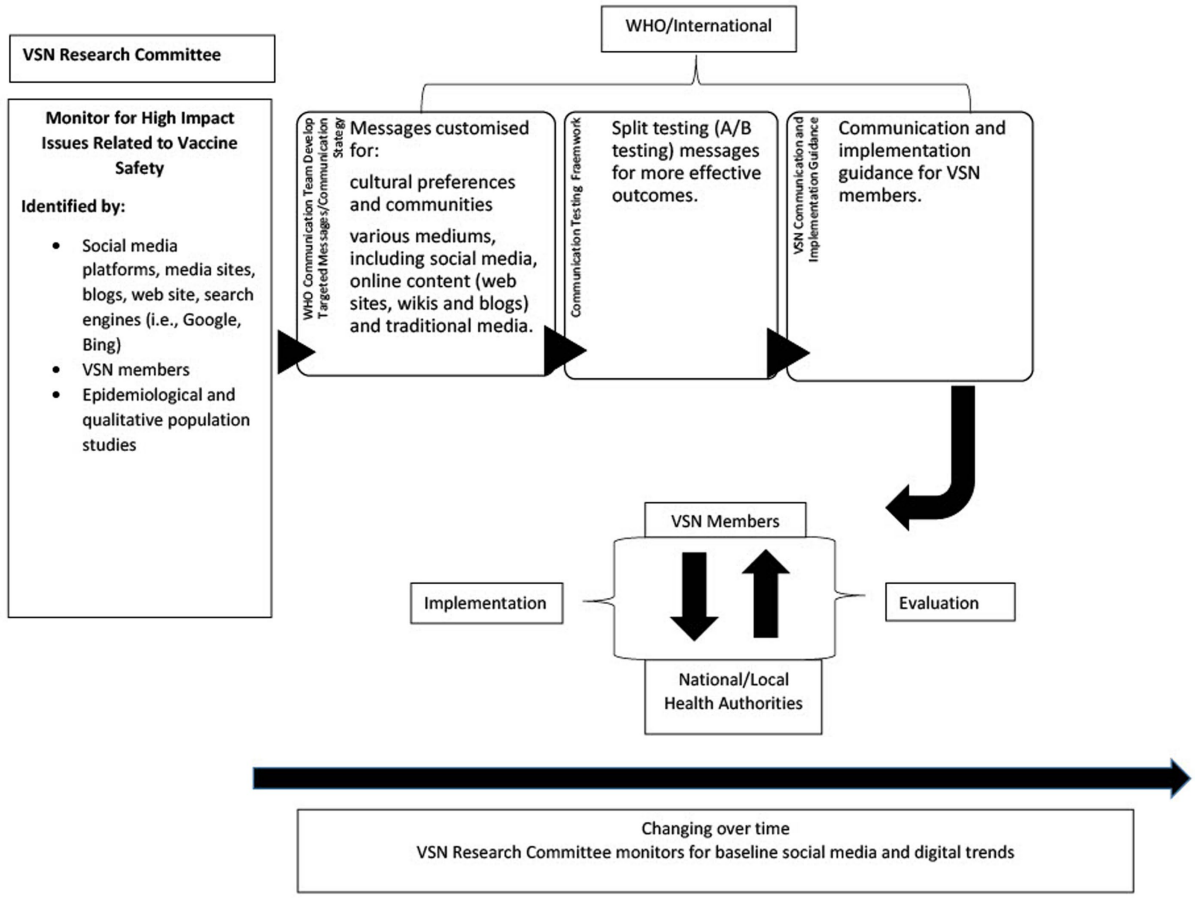


FIGURE 1
VSN social media framework.

analysis. The Research Committee will be composed of VSN members participating and not participating in the study, WHO representatives, a representative from the social listening platform and other stakeholders as needed.

Intelligence gathering

A triangulation approach (22) will be used for collecting data that will be used to understand the epidemiological, socio-cultural, religious, and political views that would affect vaccine confidence. VSN members participating in the pilot study will collect baseline intelligence in their respective countries and settings. The study team will use multiple sources of information such as local media, disease surveillance, post-marketing pharmacovigilance reports, websites, and social media platforms to capture public perceptions. Data gathering using triangulation is a recognized approach in health research monitoring and evaluation (23) to understanding local contexts, improves credibility and validity of findings, and is therefore appropriate for this study.

In addition to the data collected in their settings, VSN members will be asked to respond to a short questionnaire that will prompt intelligence sharing on populations at high risk of severe disease and negative health outcomes. These will provide a context that will help to understand the setting-specific events. They will include items concerning:

- *Traditionally vaccine hesitant and under immunized communities*; understanding the drivers of hesitancy often translates to understand the concerns of people regarding the safety of vaccines.
- *Age-specific and chronically ill behaviors toward vaccination*.
- *Active community leaders/influencers*; understanding vaccination perception of community leaders and influencers will inform on the community sentiment toward vaccination and immunization campaigns. In addition, establishing relations and involving influential people of the community in the survey, will support responsiveness.
- *Events that impact public perception of vaccine safety*; particular events that occurred in a setting might influence people's perception about vaccines. A poorly managed event will erode trust of the community for immunization programs, public health services and in general vaccination.
- *Research information* (i.e., *country specific research information in peer reviewed published literature; presentations*); this part will help understand the current communication strategies and the drivers for using particular methods and procedures.
- *Social media, online and news media reporting*; depending on the setting and the country people use radio, microphone calling in the streets or other means to disseminate information. It is very important to understand what is used, where and by whom, so that the modified messages will successfully reach different groups of people.

Development of vaccine safety messages

Baseline intelligence will be shared with the Research Committee following analysis by VSN members. Based on this analysis messaging will be customized to address concerns of different audiences and if required to be adapted to different events and specific needs of end-users. A manual (24) with GACVS guidance for vaccine safety communication on COVID-19 will be adapted to develop tailored messages for use on VSN members' social media profiles, taking into consideration local languages, as well as sociocultural norms, beliefs and concerns of each setting and for other vaccines if needed. All campaign key messages will be developed by the Research Committee and VSN members in local languages and reviewed by a team of communication experts in collaboration with the WHO. Moreover, material and tools will adapted to follow the 5 steps guide of the cultural adaptation of health communication. Key messages will be provided to the VSN members for feedback and customization prior to implementation. Vaccine safety messages will be pre-tested by VSN members to obtain additional feedback from target audiences. We recognize that VSN members may be unable to split test messages due to limited resources. Therefore, further testing can be performed by the Research Committee upon request by VSN members before an immunization campaign or global event, such as HPV Awareness Day, World Immunization Week (WIW) or other health related event.

Implementation, monitoring, and evaluation

The protocol will need to be submitted to the WHO Ethics Review Committee to seek clearance before performing the study. An implementation and evaluation guide will be supplied to VSN members, including data collection instructions. Data for this pilot will be collected using: (1) a post-communication campaign qualitative survey with target audiences; (2) social media monitoring; and (3) interviews with VSN members.

The post-campaign survey will provide insights into the knowledge, attitudes, and vaccine safety perceptions of target audiences following exposure to customized COVID-19 vaccine safety messages used by VSN members. Surveys will be designed by the Research Committee and will incorporate Larson et al. survey tool for measuring vaccine hesitancy with context specific adaptations (e.g., population, historical, socio-cultural values, politics) informed by VSN members (25). We will target a convenience sample of 150 men and women from each participating VSN member country. Recruitment strategy and inclusion criteria will be determined by VSN members. Meeting the convenience sample target will depend upon the outreach area and capacity of each VSN member. For example, a VSN member from Brazil may have fewer inhibitors to recruiting participants using social media than a member from Sudan where access to social media is more limited. Surveys and data collection will be administered by VSN members using a cloud-based platform. Data will be shared with the Research Committee for analysis and results will be shared with VSN members to discuss failure or success of messages and campaigns.

Additionally, social media monitoring of VSN member social media accounts such as Twitter or Facebook will be done by the Research Committee through social listening platforms. Key performance indicators (KPIs) (26) using a social media and web analytics curator will be monitored to provide additional data on impact of VSN messages and campaigns. Data such as conversion rate, reach, shares, likes, trends, retweets, comments, replies, and sentiments will be used to quantitatively assess messaging and implement changes to improve communication effectiveness and outreach. A social listening platform is currently available to all VSN members and provides the ability to measure social media performance across plugged social media channels and websites, as well as real-time content tracking and deep audience segmentation insights. For the purpose of the pilot study, a dashboard will be created to collect at the same time points as the public surveys KPIs, social media analytics data.

A list of candidate vaccine safety keywords will also be pooled in collaboration with VSN members. Candidate keywords will be selected based on language of VSN member countries and applied to a custom filter that will triage keywords for relevance. Keywords will be applied to Boolean searches in social listening platforms to collect additional data on vaccine safety social conversations beyond the campaign.

Interviewer-administered interviews with VSN members will be also performed by the Research Committee following the roll out of the vaccine safety communications. These interviews will be completed online. Interviews will take place over software that enables video/audio communication and recording. All interviews will be facilitated by a trained individual using a semi-structured interview guide. Participants will be deidentified by code name/study numbers. Transcripts of interviews will be recorded for analysis.

Qualitative data from the post-communication campaign survey will be coded using a deductive approach incorporating the expanded vaccine hesitancy conceptual model. VSN member interviews will be coded using an inductive approach. Thematic analyses will be performed by the Research Committee. Results of the surveys and interviews will complete the monitoring of messaging and will support the analysis of data received to better understand why communication was unsatisfactory or successful.

Results

Most social media listening projects focus on collecting big data to identify and predict misinformation before they go viral. Messages are tracked using open source software or social listening platforms, and quantitative data is collected, aggregated, and analyzed over time (27). The primary outcomes of this study also involves the collection and analysis of social media KPIs on vaccine safety messages. We expect to obtain new knowledge on public attitudes and perceptions in LMICs as they are known to vary over time.

VSN members will also provide feedback on whether the pilot study process was feasible for them. Their feedback will provide new insight into their experience with the pilot project. For example, we will ask them if participant recruitment and data collection processes were burdensome. Another outcome of interest is whether they felt VSN educational resources on web and social media listening

best practices adequately prepared them for the pilot study. Digital literacy and experience with social listening platforms may vary despite resources offered by the VSN. We also anticipate that not all VSN members have ample experience with pilot studies.

Discussion

This pilot study is a unique and timely opportunity for the VSN to work with its LMICs members to improve and contribute to the ongoing development of vaccine safety communication standards. It will support understanding of the concerns and the important parameters to improve outreach of specific audiences. VSN members are highly valuable as they have local perspectives and insights into cultural, socio-economic, religious, and political factors that influence public perceptions on vaccine safety. Although the Network is heterogenous, it is a safe space gathering a lot of expertise and knowledge that favors collaboration establishment and mutual support. Collaboration with fellow VSN members that are fact checkers will enable less resourced VSN members to easily recognize misinformation that circulates not only from digital sources but local influencers. Through this study, VSN members can leverage all the advantages of global resources that facilitate social media surveillance, pharmacovigilance, and evidence-based guidance in the fight against the COVID-19 infodemic. New knowledge gained through this pilot study will be used to improve and further test the framework. Future applications of the framework will be explored to other communication campaigns aimed at promoting the safety of vaccines for routine vaccinations (e.g., measles, HPV, influenza, pneumococcus, polio, etc.).

Ethics and dissemination

Concerns about the breach of personal privacy and confidentiality in the use of social media information as intelligence has been raised by experts (28). Social media analytics collected in this pilot study through the social listening platform as well as the interviews will be used in a broader analysis as methods to disseminate credible, accurate information on COVID-19 vaccination safety and changing personal views and behavior toward COVID-19 vaccination. Furthermore, social media data collected will only be sought from public spaces on platforms and stored on a password protect dashboard only accessible to the Research Committee. There will be no attempt to identify social media users and any information that can identify a user will be removed.

Limitations

A possible limitation of this pilot study is the unintentional exclusion of target populations in LMICs that may have limited or no access to the Internet. Inclusivity will be an issue that we will address directly with VSN members. Mitigation strategies may include the use of alternate communication approaches to web sites and social media, such as radio ads, posters and pamphlets when required. Also, we will work with VSN members to ensure that local languages and terminologies for describing and communicating about vaccine safety are used in all aspects of this study.

The information collected will be used in a broader context involving the use of social media platforms as methods to disseminate credible, accurate information on vaccine safety not only for COVID-19 vaccine but also in view of new vaccines that are expected to be rolled out soon such as the Respiratory Syncytial Virus (RSV) or the Group B Streptococcus (GBS) vaccine in LMICs. Impact of this improved safety communication strategy can be measured by vaccine coverage before and after communication release and assess change in personal views and vaccine uptake. This information may enhance use of best practices in social media marketing by public health.

Author contributions

LB contributed to conception and design of study and wrote the first draft of the manuscript. AT and FG contributed to conception and design of study. All authors contributed to the article and approved the submitted version.

Acknowledgments

The authors want to thank the VSN research working group, Kristen De Graaf, Eve Dubé, Tina Purnat, and Elisabeth Wilhelm, for their contribution to the development of the implementation and evaluation framework and to the VSN Secretariat, Brian Yau, and Cécile Macé, for their support.

Conflict of interest

LB was employed by Bucci-Hepworth Health Services. TG was employed by Accenture Health and Public Service.

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

Publisher's note

References

1. Plotkin S. History of vaccination. *Proc Natl Acad Sci U S A*. (2014) 111:12283–7. doi: 10.1073/pnas.1400472111

2. Greenwood B. The contribution of vaccination to global health: past, present and future. *Phil R Soc B Biol Sci*. (2014) 369:20130433. doi: 10.1098/rstb.2013.0433

3. MacDonald NE. SAGE working group on vaccine hesitancy. Vaccine hesitancy: definition, scope and determinants. *Vaccine*. (2015) 33:4161–4. doi: 10.1016/j.vaccine.2015.04.036

4. Guignard A, Praet N, Jusot V, Bakker M, Baril L. Introducing new vaccines in low-and-middle-income countries: challenges and approaches. *Expert Rev Vaccines*. (2019) 18:119–31. doi: 10.1080/14760584.2019.1574224

5. Cobos Muñoz D, Monzón Llamas L, Bosch-Capblanch X. Exposing concerns about vaccination in low- and middle-income countries: a systematic review. *Int J Public Health*. (2015) 60:767–80. doi: 10.1007/s00038-015-0715-6

6. Karlsson LC, Soveri A, Lewandowsky S, Karlsson L, Karlsson H, Nolvi S, et al. Fearing the disease or the vaccine: the case of COVID-19. *Pers Individ Differ*. (2021) 172:110590. doi: 10.1016/j.paid.2020.110590

7. World Health Organization (WHO). Understanding the behavioural and social drivers of vaccine uptake: WHO position paper. *Wkly Epidemiol Rec*. (2022) 97:209–24.

8. Viswanath K, Bekalu M, Dhawan D, Pinnamaneni R, Lang J, McLoud R. Individual and social determinants of COVID-19 vaccine uptake. *BMC Public Health*. (2021) 21:818. doi: 10.1186/s12889-021-10862-1

9. Briand SC, Cinelli M, Nguyen T, Lewis R, Prybylski D, Valensise CM, et al. Infodemics: a new challenge for public health. *Cells*. (2021) 184:6010–4. doi: 10.1016/j.cell.2021.10.031

10. Wilson SL, Wiysonge C. Social media and vaccine hesitancy. *BMJ Glob Health*. (2020) 5:e004206. doi: 10.1136/bmjgh-2020-004206

11. Germani F, Biller-Andorno N. How to counter the anti-vaccine rhetoric: filling information voids and building resilience. *Hum Vaccin Immunother*. (2022) 18:825. doi: 10.1080/21645515.2022.2095825

12. Jones K, Libert K, Tynski K. The emotional combinations that make stories go viral. Harvard Business Review. Available at: https://hbr.org/2016/05/research-the-link-between-feeling-in-control-and-viral-content (2016). (Accessed 10 September 2023).

13. Oduwole EO, Pienaar ED, Mahomed H, Wiysonge CS. Overview of tools and measures investigating vaccine hesitancy in a ten year period: a scoping review. *Vaccine*. (2022) 10:1198. doi: 10.3390/vaccines10081198

14. Vaccine Safety Net Available at: https://vaccinesafetynet.org/ (Accessed 1 March 2023). (2023).

15. World Health Organization. Criteria for assessing websites with vaccine safety content, Available at: https://www.who.int/groups/global-advisory-committee-on-vaccine-safety/topics/vaccine-safety-information/criteria (Accessed 20 March 2023). (2023).

16. Gesualdo F, Marino F, Mantero J, Spadoni A, Sambucini QG, Rizzo C, et al. The use of web analytics combined with other data streams for tailoring online vaccine safety information at global level: the vaccine safety Net's web analytics project. *Vaccine*. (2020) 38:6418–26. doi: 10.1016/j.vaccine.2020.07.070

17. Garett R, Young SD. Online misinformation and vaccine hesitancy. *Transl Behav Med*. (2021) 11:2194–9. doi: 10.1093/tbm/ibab128

18. Hanley SJ, Yoshioka E, Ito Y, Kishi R. HPV vaccination crisis in Japan. *Lancet*. (2015) 385:2571. doi: 10.1016/S0140-6736(15)61152-7

19. Konnon R. Expert meeting aiming at convulsion of cervical cancer. Survey report on cervical cancer prevention vaccine public expenditure promotion initiative, Available at: http://www.cczeropro.jp/assets/files/report/2012/2012wakutin.pdf; (2012) (Accessed 9 September 2023).

20. Simms KT, Hanley SJB, Smith MA, Keane A, Canfell K. Impact of HPV vaccine hesitancy on cervical cancer in Japan: a modelling study. *Lancet Public Health*. (2020) 5:e223–34. doi: 10.1016/S2468-2667(20)30010-4

21. Project VCTR. (2023). Available at: https://projectvctr.com/ (Accessed 10 September 2023).

22. Carter N, Bryant-Lukosius D, DiCenso A, Blythe J, Neville AJ. The use of triangulation in qualitative research. *Oncol Nurs Forum*. (2014) 41:545–7. doi: 10.1188/14.ONF.545-547

23. UNAIDS. An introduction to triangulation. Available at: https://www.unaids.org/sites/default/files/sub_landing/files/10_4-Intro-to-triangulation-MEF.pdf; (Accessed 8 September 2023). (2023).

24. World Health Organization. Covid-19 vaccines: safety surveillance manual, Available at: https://cdn.who.int/media/docs/default-source/covid-19-vaccines-safety-surveillance-manual/covid19vaccines_manual_communication.pdf?sfvrsn=7a418c0d_1&download=true; (2020) (Accessed 20 March 2023).

25. Larson HJ, Jarrett C, Schulz WS, Chaudhuri M, Zhou Y, Dube E, et al. Measuring vaccine hesitancy: the development of a survey tool. *Vaccine*. (2015) 33:4165–75. doi: 10.1016/j.vaccine.2015.04.037

26. Tran HTT, Lu S, Tran HTT, Nguyen BV. Social media insights during the COVID-19 pandemic: Infodemiology study using big data. *JMIR Med Inform*. (2021) 9:e27116. doi: 10.2196/27116

27. Bonnevie E, Goldbarg J, Gallegos-Jeffrey AK, Rosenberg SD, Wartella E, Smyser J. Content themes and influential voices within vaccine opposition on twitter. *Am J Public Health*. (2019) 110:S326–30. doi: 10.2105/ajph.2020.305901

28. Pagoto S, Nebeker C. How scientists can take the lead in establishing ethical practices for social media research. *J Am Med Inform Assoc*. (2019) 26:311–3. doi: 10.1093/jamia/ocy174

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 08 January 2024
DOI 10.3389/fpubh.2023.1290841

OPEN ACCESS

EDITED BY
Fatjona Kamberi,
University of Vlorë, Albania

REVIEWED BY
Inna Romānova,
University of Latvia, Latvia
Junxiang Chen,
Indiana University, United States

*CORRESPONDENCE
Liping Qi
✉ qiliping22@mails.ucas.ac.cn
Shaoshuo Cai
✉ css223@hunnu.edu.cn

RECEIVED 08 September 2023
ACCEPTED 07 December 2023
PUBLISHED 08 January 2024

CITATION
Wang Y, Qi L and Cai S (2024) How can the collaborative participation of regulators, whistleblowers, and parties effectively promote rumor management in public health emergencies?
Front. Public Health 11:1290841.
doi: 10.3389/fpubh.2023.1290841

How can the collaborative participation of regulators, whistleblowers, and parties effectively promote rumor management in public health emergencies?

Yalin Wang[1], Liping Qi[2]* and Shaoshuo Cai[3]*

[1]Guangzhou Huashang College, Guangzhou, China, [2]School of Humanities, University of Chinese Academy of Sciences, Beijing, China, [3]School of Journalism and Communication, Hunan Normal University, Changsha, China

To effectively address the mental health risks associated with public health emergencies, it is crucial to actively manage rumors. This study explores the dynamic evolutionary process of rumor diffusion and its collaborative governance in public health emergencies. A game-theoretic model is constructed, involving three main actors: regulators, parties involved in public health emergencies (PIPHE), and whistle-blowers. The behaviors and game outcomes of each party are analyzed, and the effectiveness and feasibility of the model are validated through numerical simulations. The findings of this study reveal that various factors, such as regulatory costs, penalty income, reputation damage for regulators; image loss, reputation enhancement, penalty expenditure for PIPHE; and time costs, social responsibility, and reward income for whistle-blowers, all influence the behavioral choices and game equilibrium of each party. Optimization strategies for rumor governance are proposed in this study, including enhancing the sense of responsibility and capability among regulators, increasing transparency and credibility among PIPHE, and encouraging and protecting the participation of whistle-blowers. This study provides a comprehensive analytical framework for rumor governance in public health emergencies, contributing to improving the governance of public health emergencies and maintaining online public health orders for social sustainability.

KEYWORDS

public health emergencies, rumor management, collaborative governance, social sustainability, evolutionary games

1 Introduction

In 2020, the emergence of a novel coronavirus (COVID-19) and its rapid global dissemination posed a significant test to the worldwide public health infrastructure. Similarly, a spectrum of public health incidents, ranging in similarities to COVID-19, such as climate change, health disparities, digital health, food safety, and mental health,

due to their abrupt, uncertain, and hazardous nature, frequently engender public discourse and societal risks (1), particularly in the emergence and dissemination of rumors. The escalating ubiquity of social media platforms serves as a principal conduit for the dissemination of rumors, thereby amplifying the impact of such misinformation and instigating heightened and more frequent instances of societal discourse crisis (2). An illustrative example is the COVID-19 pandemic in 2020, wherein the initial rumor proposing that the Chinese medicine "Shuanghuanglian" could inhibit the novel coronavirus triggered a significant increase in purchases among Chinese citizens (3). These rumors further intensified social instability stemming from a crisis event.

In recent years, researchers have conducted numerous studies on how to manage rumors (4, 5). Rothkopf (6) first proposed the concept of "information epidemics," arguing that rumors can affect a country's economy, politics and national security, and ultimately the whole world. In circumstances marked by a dearth of authoritative information, rumors can cause more serious damage and credit crisis, thereby potentially culminating in disarray and augmenting the complexity of conflict resolution (7). As unverified information is iteratively presented and propagated, initially dubious rumors may progressively gain credibility during dissemination, leading to an amplification of risks and rendering individuals susceptible to the sway of collective emotions. This phenomenon exacerbates conflicts within the context of public health incidents (8), with panic-mongering rumors being the most socially damaging (9). Therefore, the governance of rumors is of great concern in all countries and regions and is an important area of social governance.

In current practice, rumor management of public health emergencies mainly starts with regulators and media, using traditional means such as deleting posts, dispelling rumors and media guidance (8). And the public often tends to search for more information to reduce uncertainty in a chaotic environment, which leads to the great spread of rumors (10, 11). Numerous studies have indicated the pronounced significance of stakeholder-oriented governance concerning rumors within the domain of public health incidents (12). Regulatory oversight, notably characterized by judicious legal and regulatory frameworks as well as administrative supervisory measures, emerges as a pivotal means for effectively preventing and dismantling the propagation of misinformation (2, 13).

In the process of rumor spreading and dissemination, parties involved in public health emergencies (PIPHE) play a crucial role (14), they have the responsibility to provide accurate and reliable information to dispel the rumors, and their timely response plays an important role in helping the regulatory authorities to prevent and intervene in large-scale rumor spreading (15). However, the reality is that many parties do not have this motivation and they may hide the facts for their own unilateral and short-sighted interests. In contrast, individuals and elites (whistle-blowers), emerge as the principal forces in countering rumors (16), adeptly accessing public health emergencies through social channels. Anchored upon evidence-based debunking strategies, their interventions exhibit considerable persuasiveness, and their oversight effectively contributes to the governance of rumors surrounding public health emergencies.

Risk communication strategies and health promotion among government, community, media, and patients, such as those adopted in the late stages of the Ebola epidemic in Africa, play an important role in preventing and responding to public health emergencies (17). The process also involves the participation of stakeholders such as social organizations, the public and the media (15, 18, 19). While an increasing body of research focuses on the governance of public health event rumors based on multi-agent dynamic analysis, significant variations persist in the study of key factors. Consequently, there is a lack of a comprehensive framework to analyze the spread of rumors during sudden public health events and formulate collaborative governance efforts between regulatory authorities and society. Nevertheless, such an integrated framework is of paramount importance for advancing the governance of rumors surrounding public health incidents.

According to our investigation of COVID-19-related health rumors, the very core stakeholders in the spread of online rumors during public health emergencies include regulators, PIPHE, whistle-blowers and the public. The attitudes and behaviors of regulators, parties, and whistle-blowers exert a significant influence on the public. To narrow the scope of inquiry, we designate the public as an exogenous participatory entity, with particular emphasis on the strategic interactions among the triadic entities: regulators, PIPHE, and whistle-blowers. This study centers on the dissemination of rumors regarding public health emergencies on social media and their collaborative governance.

Evolutionary game theory effectively describes a wide range of complex strategic interactions and decision-making processes in the real world (20, 21). Constructing mathematical models, allows for the formal analysis of different strategies and their interactions, aiding our understanding and explanation of behavioral phenomena in human society. The extensive application of this theory in various domains, such as industrial policy (22, 23), technology policy (21, 24), and environmental policy (25, 26), has provided valuable insights and inspiration to my work. Leveraging the framework of evolutionary game theory, we construct a dynamic game model encompassing regulators, PIPHE, and whistle-blowers. Within this construct, we analyze the behavioral strategies of each party in the context of rumor propagation, exploring gaming results. Furthermore, the model's efficacy and feasibility are substantiated through numerical simulations. Subsequently, we delve into an exploration of the influential factors underpinning rumor dissemination, and we propose optimization strategies for collaborative governance involving regulatory entities and media outlets.

The primary objective of this study is to delve into the intricate dynamics of rumor spreading and dissemination, with a particular emphasis on the pivotal roles and interactions of key stakeholders during public health emergencies. The ultimate goal is to construct a framework based on evolutionary game that enables the thorough analysis of rumor propagation and facilitates the formulation of effective collaborative governance strategies between regulatory authorities and society. The innovations of this paper are (1) Adopting an evolutionary game-theoretic perspective, this study elucidates the intrinsic mechanisms underpinning the dissemination of rumors within the domain of public health emergencies, accounting for the rational choices and adaptive learning of all parties involved, as well as acknowledging the temporal dynamics and inherent uncertainty characterizing the propagation of rumors. (2) From the perspectives of regulators, PIPHE, and whistle-blowers, we analyze the process and results of the game of rumor propagation, as well as the interests and influence of each party, which provides the basis for the development of effective governance strategies. Particularly the analysis of

whistle-blowers' participation in rumor governance makes up for the shortcomings of existing studies.

2 Model design

2.1 Description of the problem

During public health emergencies, the spread of online rumors on social media poses a threat to citizens' emotions and social stability, becoming a significant challenge in the field of public health (27). The regulation of rumors poses a systemic challenge that requires collaboration among regulators, PIPHE, and whistleblowers. The primary goal of regulators is to safeguard the public interest, which includes ensuring access to reliable information and maintaining social stability. Achieving this objective necessitates taking active measures to prevent the spread of misinformation and promptly disclosing relevant facts (28, 29). PIPHE may seek to gain public support and trust or protect their own interests. They should openly disclose information related to the events to alleviate public concerns and distrust (30). Whistleblowers may aim to expose the truth, assist regulatory agencies in detecting problems in a timely manner, and promote the implementation of effective governance measures. They can actively participate in controlling the proliferation of rumors (31).

However, both relevant literature (32, 33) and the facts we have investigated suggest that due to cost and benefit considerations, different stakeholders may not always adopt optimal strategies in a given situation. For example, in the early stages of the COVID-19 outbreak, there were instances of passive regulatory behavior among local authorities, PIPHE, and whistleblowers. However, as the situation developed, people became increasingly aware of the severity of the pandemic and adjusted their strategies accordingly. Moreover, in public health emergencies, there are complex interrelationships and interactions among these stakeholders. Regulators may face political pressure or be swayed by public opinion and opt for passive regulatory approaches. PIPHE stakeholders may use rumors to divert attention or enhance their reputation, leading them to conceal or delay information disclosure in an attempt to protect their standing. Whistleblowers may face legal risks or social ostracism and decide to remain silent or retract their claims.

Therefore, to effectively regulate online rumors, it is necessary to establish a regulation model based on their triadic interactions. Such an approach has the potential to increase the efficiency of online rumor regulation, thereby promoting the robust development of digital public health within the online domain. Based on real-world problems and existing literature (28, 30, 31), we have attempted to construct this analytical framework. Figure 1 illustrates the triadic subject interaction of network rumor regulation, providing a visual representation of our approach.

2.2 Model assumptions

Based on the above analysis and the facts we have investigated, the following modeling assumptions can be made (Table 1).

Assumption 1: In the game model, the probability that the regulator opts for a proactive regulatory strategy is denoted as x $(0 \le x \le 1)$, while the probability of selecting a passive regulatory strategy is $1 - x$. The probability that the parties involved in public health incidents choose an open disclosure strategy is represented as y $(0 \le y \le 1)$, whereas the probability of opting for a strategy of concealing facts is $1 - y$. whistle-blowers exhibit a probability z $(0 \le z \le 1)$ of actively engaging in regulatory oversight of online rumor regulation, and a probability of $1 - z$ for passive engagement. Similarly to the related research (25, 26), the variables x, y, and z vary over time, while the other variables remain constant.

Assumption 2: When the regulator opts for a proactive regulatory strategy, the regulatory cost C incurred consists of fixed costs and variable costs, where $C = C_o + H\ g$. Here, C_o and H are constants; C_o represents the fixed costs, denoting the initial capital investment required by the regulators at the outset of supervision. This includes resource allocation for hardware, software, and personnel. H represents the variable costs, signifying the incremental costs that escalate in tandem with the augmentation of regulatory tasks undertaken by the regulators. Conversely, in the scenario where the regulator selects a passive regulatory strategy, its reputation loss is denoted as T. Additionally, the regulator is exposed to a loss in the network's public health order, indicated as $g\ U$. When the PIPHE opt for a strategy of disseminating false information, and if exposed, the regulator imposes a fine denoted as R.

Assumption 3: The party involved in the public health incident needs to bear the image loss caused by the public health incident, denoted as D. When the party involved in the public health incident chooses the strategy of disclosing the facts, the reputation loss is represented as B. When the party involved in the public health emergencies chooses the strategy of covering up the facts and the regulator chooses the strategy of regulating the facts, the probability of the party involved in the public health incident's covering up the facts being exposed with the participation of the netizens is denoted as $u = m + n$. This encompasses the probability of the regulator exposing parties in public health incidents (m) and the probability of whistle-blowers exposing parties (n).

Assumption 4: The extent of rumor propagation is denoted as g, and its magnitude is directly correlated with the level of active engagement by whistle-blowers, thereby influencing the strategic behaviors of the triadic entities. We postulate that the extent of rumor propagation is a function of the proportion of active engagement by whistle-blowers, i.e., $g = k\left(1 - z\right)$. When whistle-blowers opt for active engagement, they experience an augmentation of social responsibility and civic awareness denoted as U, while simultaneously incurring certain temporal and effort costs denoted as E. Additionally, engaging in whistle-blowing activities entitles whistle-blowers to a certain reward denoted as A from regulator.

A three-dimensional matrix to represent the payment matrix of the tripartite evolutionary game of collaborative governance among regulators, parties involved in public health emergencies and whistle-blowers in rumor dissemination of public health emergencies can be shown in the following Table 2.

3 Model analysis

3.1 Analysis of replication dynamics

Based on the above payment matrix, the equilibrium strategies of the regulator, PIPHE and whistle-blowers are further analyzed according to evolutionary game theory. Let the expected payoff of the regulator choosing the regulatory strategy be U_{11}, the expected payoff

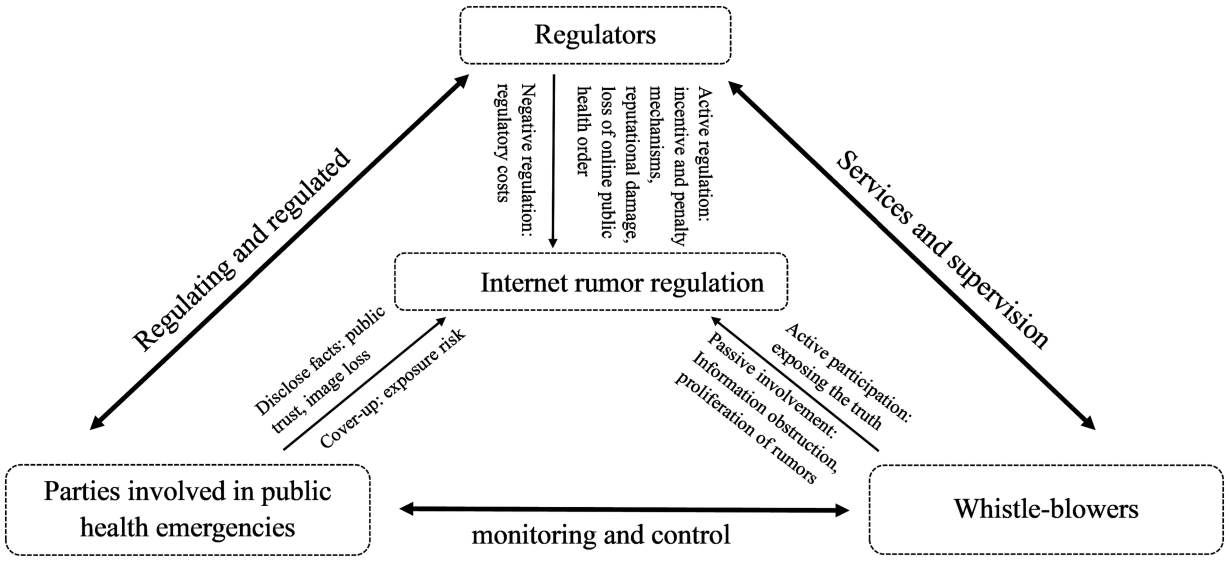


FIGURE 1
Evolutionary gaming system for rumor management of public health emergencies.

of the regulator choosing the non-regulatory strategy be U_{12}, and the average payoff be U_1, then there is Eq. 1.

$$\begin{cases} U_{11} = y\left(\left(-C_o - gHk\right)\left(1-z\right) + \left(-C_o - gHk\right)z\right) + \\ \left(1-y\right)\begin{pmatrix}\left(-C_o - gHk + mR\right)\left(1-z\right) + \\ \left(-C_o - gHk - An + \left(m+n\right)R\right)z\end{pmatrix} \\ U_{12} = y\left(-gkT\left(1-z\right) - gkTz\right) + \left(1-y\right) \\ \left(-gkT\left(1-z\right) + \left(nR - gkT\right)z\right) \\ U_1 = xU_{11} + \left(1-x\right)U_{12} \end{cases} \tag{1}$$

Drawing from relevant research, the replicated dynamic equation for the regulator's selection of a supportive strategy can be derived based on the principles of the Malthusian dynamic equation, as denoted by Eq. 2.

$$F\left(x\right) = \frac{dx}{dt} = x\left(U_{11} - U_1\right) = \left(-1+x\right)x\begin{pmatrix} C_o + gk\left(H-T\right) \\ +\left(-1+y\right) \\ \left(mR - Anz\right)\end{pmatrix} \tag{2}$$

Let the expected payoff of the PIPHE choosing the disclose facts strategy be U_{21}, the expected payoff of the PIPHE choosing the cover-up strategy be U_{22}, and the average payoff be U_2, then there is Eq. 3.

$$\begin{cases} U_{21} = (1-x)\left(-Dk\left(1-z\right) - Dkz\right) + x\left(-Dk\left(1-z\right) - Dkz\right) \\ U_{22} = x\left(\left(-Bgk - mR\right)\left(1-z\right) + \left(-Bgk + \left(-m-n\right)R\right)z\right) + \\ \left(1-x\right)\ \left(-Bgk\left(1-z\right) + \left(-Bgk - nR\right)z\right) \\ U_2 = yU_{21} + \left(1-y\right)U_{22} \end{cases} \tag{3}$$

The replicated dynamic equation for the PIPHE choosing the disclose facts strategy is Eq. 4.

$$F\left(y\right) = \frac{dy}{dt} = y\left(U_{21} - U_2\right) = -\left(-1+y\right)y\begin{pmatrix} -Dk + Bgk \\ +mRx + nRz\end{pmatrix} \tag{4}$$

Let the expected payoff of the whistle-blowers choosing the active participation strategy be U_{31}, the expected payoff of the whistle-blowers choosing the negative participation strategy be U_{32}, and the average payoff be U_3, then there is Eq. 5.

$$\begin{cases} U_{31} = \left(\left(-E - gkU\right)\left(1-x\right) + \left(-E + Agn + gkU\right)x\right)\left(1-y\right) + \\ \left(\left(-E + gkU\right)\left(1-x\right) + \left(-E + gkU\right)x\right)y \\ U_{32} = 0 \\ U_3 = zU_{31} + \left(1-z\right)U_{32} \end{cases} \tag{5}$$

The replicated dynamic equation for the whistle-blowers choosing the active participation strategy is Eq. 6.

$$\begin{aligned} F\left(z\right) = \frac{dz}{dt} = z\left(U_{31} - U_3\right) = \left(-1+z\right) \\ z\left(E - gkU + Agnx\left(-1+y\right)\right) \end{aligned} \tag{6}$$

3.2 Stable equilibrium analysis

The coupling of Eqs. 2, 4, 6 yields a three-dimensional dynamical system (I), i.e., Eq. 7.

10.3389/fpubh.2023.1290841

TABLE 1 Parameters and their meanings.

Parameter	Meaning
x	Probability that the regulator chooses an active regulatory strategy
y	Probability that PIPHE chooses a strategy of disclosing facts
z	Probability that a whistle-blower chooses to actively participate in the regulator's online rumor regulation
C	Regulatory costs paid by the regulator
C_o	Fixed costs, the amount of money that the regulator needs to invest in the initial period of regulation
H	Variable costs, indicating the increase in costs as the regulatory mandate of the regulator increases
T	Reputation loss incurred by the regulator in the absence of regulation.
R	Fines imposed by the regulator on PIPHE
D	Image damage borne by PIPHE when they choose to disclose the facts strategy
B	Reputational damage when parties to a public health incident choose a cover-up strategy
u	Probability that PIPHE will be exposed for a cover-up
m	Probability that the regulator will expose the party involved in a public health emergencies
n	Probability that a whistle-blower will expose a party involved in a public health emergencies
g	Extent of the rumor spread
k	Hazard level of a public health emergencies
U	The elevation of social responsibility and civic awareness acquired by whistle-blowers upon choosing an active engagement
E	Costs of time and effort borne by whistle-blowers choosing to be actively involved
A	Regulatory rewards received by whistle-blowers for reporting rumors

$$\begin{cases} F(x) = (-1+x)x\left(C_o + gk(H-T) + (-1+y)(mR - Anz)\right) \\ F(y) = -(-1+y)y(-Dk + Bgk + mRx + nRz) \\ F(z) = (-1+z)z\left(E - gkU + Agnx(-1+y)\right) \end{cases} \tag{7}$$

Let$\left(F(x),F(y),F(z)\right) = \left(\frac{dx}{dt},\frac{dy}{dt},\frac{dz}{dt}\right) = (0,0,0)$, we can get E_1 (0,0,0), E_2 (1,0,0), E_3 (0,1,0), E_4 (0,0,1), E_5 (1,1,0), E_6 (1,0,1), E_7 (0,1,1), E_8 (1,1,1), and E_9 (x^*,y^*,z^*). E_9 is meaningful under certain conditions; it is not a pure strategy equilibrium. If the equilibrium of the three-party evolutionary game is an asymptotically stable state, the equilibrium must be a strict Nash equilibrium, which is a pure strategy equilibrium. Therefore, the asymptotic stability of the three-party evolutionary game only needs to discuss the asymptotic stability of the pure strategy equilibrium point in the replication dynamic equation, that is, discuss the asymptotic stability of E_1~E_8 (34–36). The aforementioned equilibrium points may not necessarily constitute evolutionary stable strategies (ESS) within the evolutionary game system. Therefore, it is essential to further examine whether these stable points indeed represent stable strategies and to identify the conditions under which they qualify as stable strategies.

First, the asymptotic stability of the above eight equilibrium is further discriminated by the local stability of the Jacobi matrix. The Jacobi matrix of the game equations is obtained by taking the first-order partial derivatives of $F(x)$, $F(y)$, and $F(z)$ concerning x, y, and z, then there is Eq. 8.

$$J = \begin{bmatrix} F_x(x) & F_y(x) & F_z(x) \\ F_y(y) & F_y(y) & F_y(y) \\ F_z(z) & F_z(z) & F_z(z) \end{bmatrix} \tag{8}$$

According to the Lyapunov theory, when all eigenvalues of the Jacobian matrix, denoted as λ, are less than zero, the point is asymptotically stable. Conversely, when all eigenvalues of the Jacobian matrix are greater than zero, the point is unstable. When the eigenvalues of the Jacobian matrix exhibit a mix of positive and negative values, the equilibrium point is unstable, referred to as a saddle point. The asymptotic stability analysis of equilibrium points is presented in Table 3. Under specific conditions, each of the eight stable points possesses asymptotic evolutionary stability. These conditions are as follows:

Scenario 1: E_1 (0,0,0) is the stable equilibrium when $-C_o + mR - gk(H-T) < 0$, $-Dk + Bgk < 0$, and $-E + gkU < 0$. At this point, the regulatory cost of the regulator is higher than its reputation loss and penalty income, and the image loss of the PIPHE is higher than its reputation enhancement and penalty expenditure, and the cost of the whistle-blower's time and effort is higher than his or her social responsibility and reward income. In such a scenario, this equilibrium is detrimental to the prompt detection and management of public health incidents, as well as to the safeguarding of public awareness and a sense of security. Rumors may spread widely on the Internet, resulting in social instability and panic. Therefore, there is a need to break this equilibrium through measures such as improving the accountability and capacity of the regulator, increasing the transparency and integrity of the PIPHE, and encouraging increased participation and protection for whistle-blowers.

Scenario 2: E_2 (1,0,0) is a stable equilibrium when $C_o - mR + gk(H-T) < 0$, $-Dk + Bgk + mR < 0$, and $-E + Agn + gkU < 0$. At this point, the cost of regulation to the regulator is lower than its reputation loss and penalty income, the image loss of the PIPHE is lower than its reputation enhancement and penalty expenditure, and the cost of the whistle-blower's time and effort is higher than its social responsibility and reward income. In this scenario, this equilibrium favors the functioning of the regulator, yet it also presents certain issues. On the one hand, if the regulatory capacity of the regulator is inadequate or subject to interference, the parties involved in a public health incident may evade punishment for concealing facts, leading to the spread of rumors and social distrust. On the other hand, insufficient engagement of whistle-blowers could result in regulatory authorities lacking effective information sources and social support, thereby diminishing regulatory efficacy. Therefore, there is a need to improve this balance through measures such as increasing the legal responsibility of the PIPHE and the penalties for moral hazard and increasing the incentivization mechanisms and safeguards for whistle-blowers.

TABLE 2 Payment matrix.

	Active regulation by regulators (x)		Negative regulation by regulators ($1-x$)	
	Disclose facts by PIPHE (y)	Cover-up by PIPHE ($1-y$)	Disclose facts by PIPHE (y)	Cover-up by PIPHE ($1-y$)
Active participation of whistle-blowers (z)	$-C_o - Hgk$	$-C_o - Hgk + (m+n)R - nA$	$-gkT$	$-gkT + nR$
	$-Dk$	$-(m+n)R - gkB$	$-Dk$	$-nR - gkB$
	$gkU - E$	$gkU - E + ngA$	$gkU - E$	$gkU - E$
Negative participation by whistle-blowers ($1-z$)	$-C_o - Hgk$	$-C_o - Hgk + mR$	$-gkT$	$-gkT$
	$-Dk$	$-mR - gkB$	$-Dk$	$-gkB$
	0	0	0	0

Scenario 3: E_3 (0,1,0) is a stable equilibrium when $-C_o - gk(H-T) < 0$, $Dk - Bgk < 0$, and $-E + gkU < 0$. At this point, the regulatory cost of the regulator is higher than its reputation loss and penalty income, the image loss of the person involved in the public health incident is lower than its reputation enhancement and penalty expenditure, and the cost of the whistle-blower's time and effort is higher than its social responsibility and reward income. The equilibrium in this scenario is favorable to the PIPHE demonstrating its integrity and transparency, but there are some risks. On the one hand, if the public health emergency party's disclosure of facts is incomplete or untrue, then negative regulation by the regulator may lead to the generation and spread of rumors, affecting the trust and safety of the community. On the other hand, inadequate engagement of whistle-blowers might result in a lack of effective validation and feedback for the disclosed facts by the PIPHE, thereby causing distortion and misinformation of information. Hence, it is necessary to optimize this equilibrium through certain measures, such as enhancing the sense of responsibility and capacity of regulators, and augmenting incentivization mechanisms and safeguards for whistle-blowers.

Scenario 4: E_4 (0,0,1) is a stable equilibrium when $-C_o - An + mR - gk(H-T) < 0$, $-Dk + Bgk + nR < 0$, and $E - gkU < 0$. At this point, the regulatory cost of the regulator is higher than its reputation loss and penalty income; the image loss of the PIPHE is higher than its reputation enhancement and penalty expenditure; the cost of the whistle-blower's time and effort is lower than its social responsibility and reward income. In this scenario, the equilibrium is conducive to the role of whistle-blowers; however, it also presents certain challenges. On one hand, if regulators' passive oversight leads to untimely and ineffective handling of whistle-blowers' reports, the participation of whistle-blowers could be hindered and discouraged, potentially fostering the spread of rumors and societal distrust. On the other hand, if the concealment of facts by the PIPHE results in insufficient and authentic evidence for whistle-blowers' reports, the involvement of whistle-blowers may face scrutiny and backlash, causing distortion and misguidance of information. Therefore, measures need to be implemented to enhance this equilibrium, such as reinforcing the sense of responsibility and capacity of regulatory authorities, enhancing transparency and integrity of the PIPHE, and safeguarding the rights and security of whistle-blowers.

Scenario 5: E_5 (1,1,0) is a stable equilibrium when $C_o + gk(H-T) < 0$, $Dk - Bgk - mR < 0$, and $-E + gkU < 0$. At this point, the cost of regulation to the regulator is lower than its reputation loss and penalty income, the image loss of the PIPHE is higher than its reputation enhancement and penalty expenditure, and the cost of the whistle-blower's time and effort is higher than its social responsibility and reward income. The equilibrium in this scenario is favorable for regulators and PIPHE to demonstrate their integrity and transparency, yet it also presents certain limitations. On the one hand, if the regulator's supervisory capacity is insufficient or interfered with, then the public facts of PIPHE may lack effective verification and feedback, leading to distortion and misdirection of information. On the other hand, if the participation level of whistle-blowers is too low, then the public facts of the regulatory authorities and the parties involved in the public health incident may lack effective sources of information and social support, leading to the generation and dissemination of rumors. Therefore, there is a need to optimize this equilibrium through various measures, such as enhancing the sense of responsibility and capacity of the regulator, and implementing incentive mechanisms and safeguards for whistle-blowers, among others.

Scenario 6: E_6 (1,0,1) is a stable equilibrium when $C_o + An - mR + gk(H-T) < 0$, $-Dk + Bgk + (m+n)R < 0$, and $E - AgN - gkU < 0$. At this point, the cost of regulation to the regulator is lower than its reputation loss and penalty income, the image loss of the PIPHE is lower than its reputation enhancement and penalty expenditure, and the cost of the whistle blower's time and effort is lower than its social responsibility and reward income. The equilibrium in this scenario is favorable for regulators and whistle-blowers to perform their roles, but there are some challenges. On the one hand, if the regulator's regulatory capacity is insufficient or interfered with, whistle-blowers' reports may not be dealt with in a timely and effective manner, leading to the spread of rumors and social distrust. On the other hand, if the cover-up by the parties involved in public health emergencies results in whistle-blowers' reports not being supported by sufficient and truthful evidence, then whistle-blowers' participation may be challenged and attacked, leading to distorted and misleading information. Therefore, it is imperative to enhance this equilibrium through various measures, such as enhancing the accountability and capacity of the regulatory authorities, increasing transparency and integrity of the PIPHE, and protecting the rights and security of whistle-blowers.

Scenario 7: E_7 (0,1,1) is a stable equilibrium when $-C_o - gk(H-T) < 0$, $Dk - Bgk - nR < 0$, and $E - gkU < 0$. At this point, the regulatory cost of the regulator is higher than its

TABLE 3 Asymptotic stability analysis of local equilibrium points.

Equilibrium	Eigenvalue (math.)	In the end
(0,0,0)	$\lambda_1 = -C_o + mR - gk(H-T)$	Stable point when $-C_o + mR - gk(H-T) < 0$, $-Dk + Bgk < 0$, and $-E + gkU < 0$, otherwise saddle point or unstable point
	$\lambda_2 = -Dk + Bgk$	
	$\lambda_3 = -E + gkU$	
(1,0,0)	$\lambda_1 = C_o - mR + gk(H-T)$	Stable point when $C_o - mR + gk(H-T) < 0$, $-Dk + Bgk + mR < 0$, and $-E + Agn + gkU < 0$, otherwise saddle or unstable point
	$\lambda_2 = -Dk + Bgk + mR$	
	$\lambda_3 = -E + Agn + gkU$	
(0,1,0)	$\lambda_1 = -C_o - gk(H-T)$	Stable point when $-C_o - gk(H-T) < 0$, $Dk - Bgk < 0$, and $-E + gkU < 0$, otherwise saddle or unstable point
	$\lambda_2 = Dk - Bgk$	
	$\lambda_3 = -E + gkU$	
(0,0,1)	$\lambda_1 = -C_o - An + mR - gk(H-T)$	Stable point when $-C_o - An + mR - gk(H-T) < 0$, $-Dk + Bgk + nR < 0$, and $E - gkU < 0$ otherwise saddle point or unstable point
	$\lambda_2 = -Dk + Bgk + nR$	
	$\lambda_3 = E - gkU$	
(1,1,0)	$\lambda_1 = C_o + gk(H-T)$	Stable point when $C_o + gk(H-T) < 0$, $Dk - Bgk - mR < 0$, and $-E + gkU < 0$ otherwise saddle point or unstable point
	$\lambda_2 = Dk - Bgk - mR$	
	$\lambda_3 = -E + gkU$	
(1,0,1)	$\lambda_1 = C_o + An - mR + gk(H-T)$	Stable point when $C_o + An - mR + gk(H-T) < 0$, $-Dk + Bgk + (m+n)R < 0$, and $E - Agn - gkU < 0$, otherwise saddle point or unstable point
	$\lambda_2 = -Dk + Bgk + (m+n)R$	
	$\lambda_3 = E - Agn - gkU$	
(0,1,1)	$\lambda_1 = -C_o - gk(H-T)$	Stable point when $-C_o - gk(H-T) < 0$, $Dk - Bgk - nR < 0$, and $E - gkU < 0$ otherwise saddle point or unstable point
	$\lambda_2 = Dk - Bgk - nR$	
	$\lambda_3 = E - gkU$	
(1,1,1)	$\lambda_1 = C_o + gk(H-T)$	Stable point when $C_o + gk(H-T) < 0$, $Dk - Bgk - (m+n)R < 0$, and $E - gkU < 0$, otherwise saddle or unstable point
	$\lambda_2 = Dk - Bgk - (m+n)R$	
	$\lambda_3 = E - gkU$	

reputation loss and penalty income, the image loss of the PIPHE is lower than its reputation enhancement and penalty expenditure, and the cost of the whistle-blower's time and effort is lower than its social responsibility and reward income. The equilibrium in this scenario is conducive to the PIPHE and whistle-blowers demonstrating their integrity and transparency, but there are some limitations. On one hand, if passive regulatory oversight by the regulator results in a lack of effective validation and feedback for the public disclosures made by the PIPHE, distortions and misinterpretations of information may lead to the generation and dissemination of rumors. On the other hand, if the engagement level of whistle-blowers remains insufficient, the publicly disclosed facts by both the PIPHE and regulator might lack robust sources of information and societal support, potentially giving rise to uncontrolled public opinion and conflicts. Therefore, it becomes necessary to optimize this equilibrium through various measures, such as enhancing the sense of responsibility and capacity of the regulator, introducing incentives and protective mechanisms for whistle-blowers, and other strategies.

Scenario 8: E_8 (1,1,1) is a stable equilibrium when $C_o + gk(H-T) < 0$, $Dk - Bgk - (m+n)R < 0$, and $E - gkU < 0$. At this point, the cost of regulation to the regulator is lower than its reputation loss and penalty income, the image loss of the PIPHE is higher than its reputation enhancement and penalty expenditure, and the cost of the whistle blower's time and effort is lower than its social responsibility and reward income. The equilibrium in this scenario is favorable for regulators, the PIPHE and whistle-blowers to perform their roles, but there are some challenges. On the one hand, if the regulator's regulatory capacity is insufficient or interfered with, the public facts of the PIPHE and the whistle-blower's report may not be dealt with in a timely and effective manner, leading to the spread of rumors and social distrust. On the other hand, if the public facts of the parties involved in public health emergencies and the whistle-blower's report cannot be fully and truthfully substantiated, then the behavior

of the regulator and the whistle-blower may be questioned and attacked, leading to distorted and misleading information. Therefore, there is a need to improve this equilibrium through several measures, such as improving the accountability and capacity of the regulator, increasing the transparency and integrity of the PIPHE, and protecting the rights and security of whistle-blowers.

4 Numerical modeling

To further verify the correctness of the model derivation and the reasonableness of the discussion, dynamic evolutionary simulations of the gaming system were conducted using Matlab. Based on the above evolutionary game analysis, it can be found that active regulation by the regulator, active disclosure of facts by the PIPHE, and active participation by the whistle-blowers are the most realistic ideal ESS. Based on the assumptions, numerical simulations were performed using the ideal ESS as a benchmark scenario. In this context, it is necessary to satisfy the conditions $C_o + gk\left(H - T\right) < 0$, $Dk - B\,gk - \left(m + n\right)R < 0$, and $E - gkU < 0$, so the parameters can be set as follows: $Co = 4$; $H = \mathbf{3}$; $T = 5$; $R = 4$; $D = 4$; $B = 4$; $u = 0.6$; $m = 0.4$; $n = 0.4$; $g = 0.8$; $k = 3$; $U = 2$; $E = 4$; $A = 3$; $x = 0.6$, $y = 0.5$, and $z = 0.7$, and the simulation period t *is* set to 10.

4.1 Impact of regulator's behavior

As shown in Figures 2A–C, the higher the regulatory cost paid by the regulator, the lower the willingness of the regulator to actively regulate, and the cost of regulation inhibits the regulator's motivation. When the cost becomes excessively high, the regulator may become disinclined to engage in regulation. The willingness of the parties involved in public health emergencies to disclose the facts decreases, and the enthusiasm of whistle-blowers for active supervision diminished. As illustrated in Figure 2D, an increase in the penalty imposed on PIPHE by the regulator enhances the willingness of PIPHE to disclose factual information. This finding suggests that higher penalties serve to amplify the motivation of parties involved in public health emergencies to disclose information, thereby stimulating proactive regulatory actions. In Figure 2E, a greater reward offered by regulators to whistle-blowers for reporting leads to an increased inclination of whistle-blowers to participate actively in rumor management. This observation underscores the incentivizing effect of rewards in motivating whistle-blowers to engage more actively in rumor control efforts. As in Figure 2F, a higher probability of the regulator exposing parties involved in public health emergencies corresponds to an elevated willingness of PIPHE to disclose facts. This outcome signifies that the proactive nature and capabilities of the regulator can encourage parties involved in public health emergencies to choose behavior that involves disclosing facts.

4.2 The impact of the behavior of those involved in a public health incident

As illustrated in Figure 3A, a higher degree of image loss incurred by parties involved in public health emergencies due to disclosing facts is associated with a reduced willingness to disclose facts. This observation suggests that the potential for image loss acts as a deterrent to the integrity-driven behavior of parties involved in public health emergencies. In this scenario, there is an increased inclination of regulators to engage in regulation, and correspondingly, a heightened willingness of whistle-blowers to participate in supervision efforts. In Figure 3B, an increase in the reputation gain acquired by PIPHE through the disclosure of facts corresponds to an augmented motivation for PIPHE to exhibit greater transparency and candor. This outcome implies that the prospect of reputation enhancement serves as an incentive for parties involved in public health emergencies to be more forthcoming and transparent. Given the intrinsic good self-discipline of stakeholders in public health incidents, wherein instances of concealing facts are infrequent or minimal, the safeguarding of the public's right to be informed is effectively ensured. Consequently, in such instances, the willingness of regulators to engage in regulation tends to decrease, while the willingness of whistle-blowers to participate in supervision efforts tends to increase.

4.3 Impact of whistle-blower's behavior

As depicted in Figure 4A, a higher magnitude of psychological gain derived by whistle-blowers from an increased sense of social responsibility and civic awareness, resulting from their act of reporting, corresponds to an elevated willingness of whistle-blowers to engage in supervision. This observation underscores that the enhancement of social responsibility and civic awareness serves as a motivating factor for whistle-blowers to proactively participate in the management of rumors. In this scenario, the inclination of the regulator toward proactive regulation is reduced, while the willingness of parties involved in public health emergencies to disclose facts is heightened. In Figure 4B, an increase in the time and effort costs borne by whistle-blowers because of their reporting activities corresponds to a diminished inclination of whistle-blowers to engage in supervision. This finding indicates that the time and effort costs exert a dampening effect on the enthusiasm of whistle-blowers. Consequently, the willingness of regulators to engage in proactive regulation increases, while the willingness of parties involved in public health emergencies to disclose facts diminishes. In Figure 4C, a higher probability of whistle-blowers exposing parties involved in public health emergencies corresponds to an augmented willingness of parties involved in public health emergencies to disclose facts. This outcome highlights that the initiative and capability of whistle-blowers can ensure effective social oversight, thereby driving regulators and parties involved in public health emergencies toward greater integrity and transparency through the revelation of truths.

4.4 Impact of other exogenous factors

As shown in Figure 5A, a higher magnitude of rumor propagation extent corresponds to an increased number of concealed facts perpetuated by the rumor, resulting in escalated reputational risks. At this time, the regulator, PIPHE and the whistle-blowers all have a stronger willingness to participate in the rumor management of the public health emergencies, i.e., the regulator's willingness to actively regulate is stronger, and the willingness of PIPHE to disclose the facts is stronger, and the whistle-blower's willingness to participate in the supervision is more advanced.

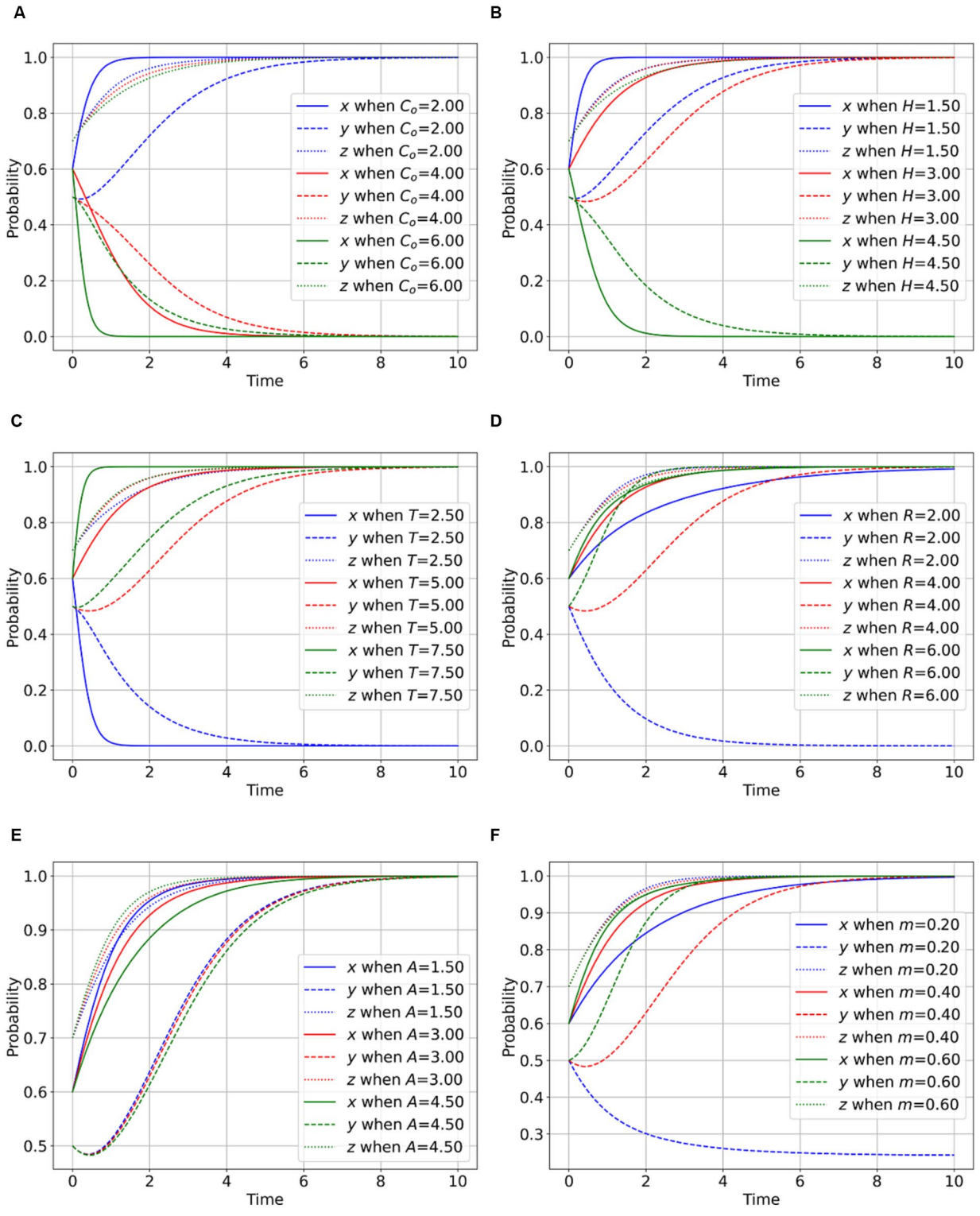


FIGURE 2
Impact of the regulator's behavioral parameters on the evolutionary game. **(A)** Impact of C_o on the player behavior. **(B)** Impact of H on the player behavior. **(C)** Impact of T on the player behavior. **(D)** Impact of R on the player behavior. **(E)** Impact of A on the player behavior. **(F)** Impact of m on the player behavior.

As shown in Figure 5B, a higher level of severity denoted by parameter in public health incidents corresponds to greater societal losses caused by the propagation of rumors. In such circumstances, regulators, PIPHE, and whistle-blowers all exhibit a more pronounced willingness to engage in the management of rumors associated with public health incidents.

5 Discussion

The results of the model analysis in this paper show that rumor spreading and its collaborative governance in public health emergencies is a dynamic evolutionary process, which is affected by a

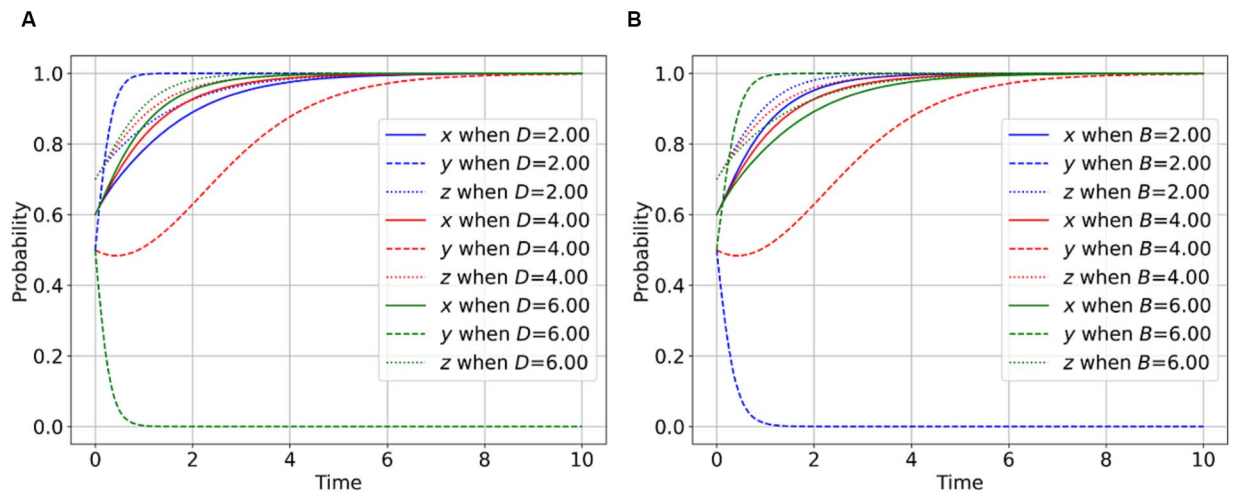


FIGURE 3
Effect of behavioral parameters of PIPHE on the evolutionary game. **(A)** Impact of *D* on the player behavior. **(B)** Impact of *B* on the player behavior.

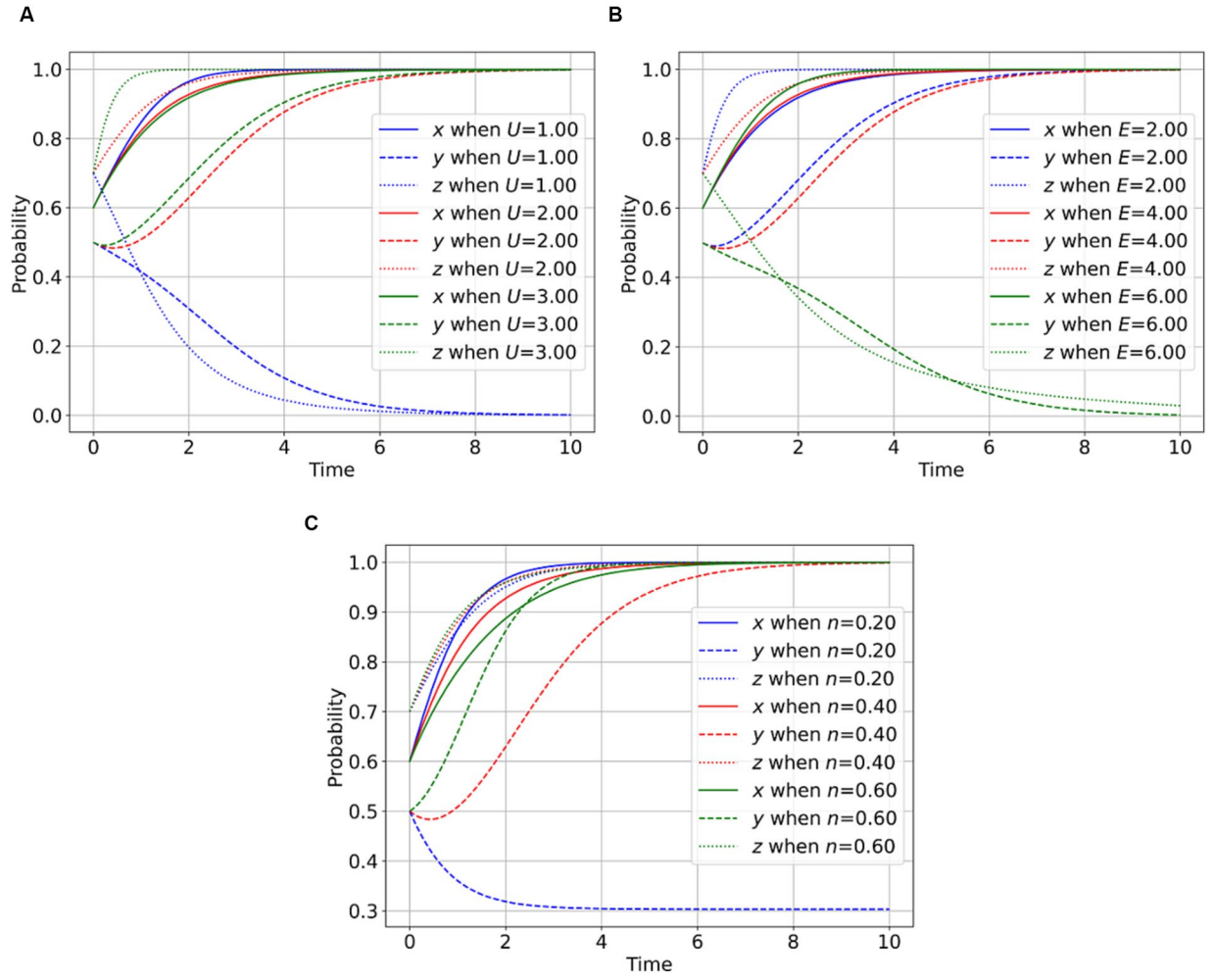


FIGURE 4
Effect of whistle blower's behavioral parameters on the evolutionary game. **(A)** Impact of *U* on the player behavior. **(B)** Impact of *E* on the player behavior. **(C)** Impact of n on the player behavior.

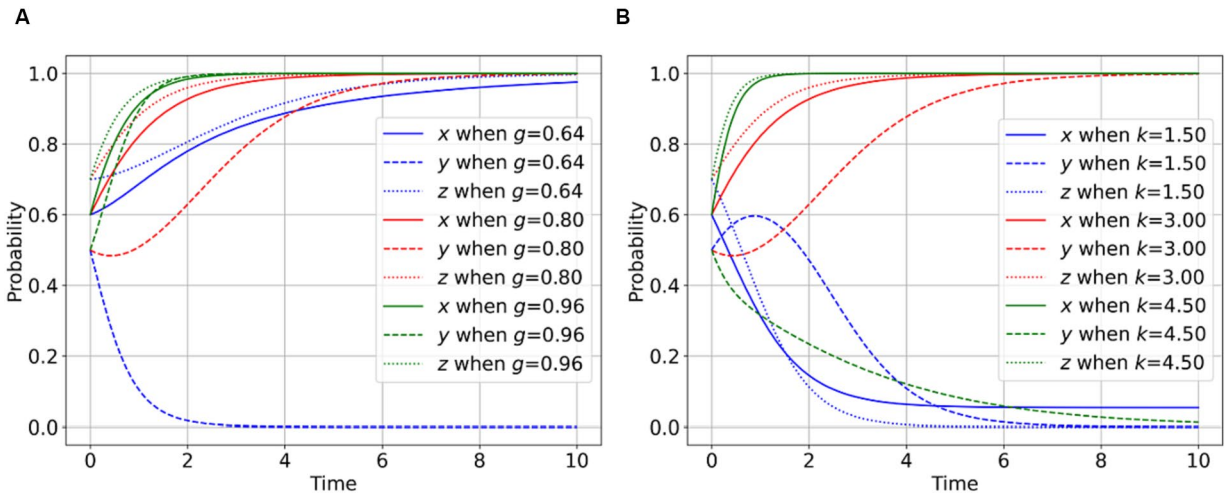


FIGURE 5
Impact of other exogenous factors on the evolutionary game. **(A)** Impact of *g* on the player behavior. **(B)** Impact of *k* on the player behavior.

variety of factors, such as regulatory costs, fines, incentives, image loss, credibility enhancement, and exposure probability. These factors affect the behavioral strategies and game results of all parties. The findings of the model analysis in this study exhibit a degree of congruence with empirical cases, for example:

In the Fukushima nuclear leak incident in 2011, as the Japanese government and TEPCO did not disclose the truth and impact of the accident promptly, various rumors appeared on the Internet, such as "iodized salt can protect against radiation," "Fukushima nuclear leak will contaminate seawater and lead to an increase in the price of sea salt," etc., triggering a "salt rush." and so on, which triggered the "salt rush." This is consistent with the results of the model analysis conducted in this paper, wherein it is demonstrated that the adoption of the strategy by PIPHE to conceal facts contributes to the proliferation of rumors and the instigation of societal panic.

In the 2015 Tianjin Port explosion incident, due to the delayed dissemination of official information, the public's eager anticipation for the latest updates prompted them to seek alternative sources of information, thereby creating opportunities for the propagation of online rumors. During that time, rumors circulated on the internet suggesting that harmful substances might be blown toward Beijing, that there were numerous casualties at the scene, and a significant leakage of sodium chloride could result in widespread casualties. Additionally, some netizens speculated that the explosion in Tanggu was related to terrorists and that the responsible individual was the son of a deputy mayor. These instances align with the findings of the present study's model analysis, which demonstrates that the adoption of a passive regulatory strategy by regulators can lead to the proliferation of rumors and societal instability.

In the 2020 COVID-19 pandemic, the outbreak and spread of the virus led to various rumors circulating on the internet regarding its origin, transmission pathways, prevention, and treatment methods. Examples of such rumors included claims that the novel coronavirus was artificially created, that it could be transmitted through mosquitoes, and that consuming alcohol could kill the virus. These rumors caused public panic and misinformation. In this process, there are some healthcare workers and scientists who act as whistle-blowers and expose the truth of the epidemic to the regulators or the media promptly, such as Dr. Li Wenliang and Academician Zhong Nanshan, etc. Their whistleblowing behaviors promote the active regulation of the regulator and the disclosure of the facts by the PIPHE, which effectively curbed the dissemination of the rumors. These findings align with the outcomes of the current study's model analysis, affirming that whistle-blowers opting for active supervisory strategies can enhance the synergistic effectiveness of rumor control.

These cases show that in the governance of public opinion on ecological public health public opinion events, the tripartite subjects of the regulators, PIPHE, and the whistle-blowers play distinct roles and functions, each facing unique challenges and dilemmas. Coordinating the relationship between the three main parties, striking a balance between information disclosure and the demands of social stability, is conducive to advancing the management of rumors in public health incidents, and holds significant implications for addressing rumors of other types. This also, on the other hand, validates the significance of this study.

Compared to general rumor propagation, rumors in public health incidents exhibit certain distinct characteristics. On the one hand, public health emergencies involve people's life safety, physical health, ecological public health and other important areas, once false information or rumors appear, it may trigger social panic, medical squeeze and other undesirable consequences to the people's health and risk management with serious consequences (3), and even lead to social unrest and public order chaos. Therefore, public health emergency rumor governance requires a more timely, accurate and authoritative release of the truth mitigating information voids and misguidance. On the other hand, public health emergency rumors are usually related to people's health and safety (37), making public health emergency rumors more likely to trigger emotional responses from the public (38), and more difficult to be identified and verified. Simultaneously, public health emergency rumors are also influenced and manipulated by multi-interested subjects, such as regulators, enterprises, media, and the public. These entities may report, comment on, or propagate public health emergencies for varying motivations and objectives, leading to the distortion or

misrepresentation of information. For example, a series of coupling problems such as uncontrolled rumors and public psychological imbalance will always occur on social media, which brings great interference to crisis disposal (39). And the endogenous demand for health information generated by the public due to the lack of scientific knowledge of health information stimulates the dissemination of health information by mass media, and at the same time provides rumor mongers with the opportunity to publish and disseminate online rumors (19).

Difficulties in the governance of rumors about public health emergencies mainly involve information asymmetry, multiple interests and social trust. Firstly, information asymmetry is the main problem in the governance of public health emergencies because the complexity and multidimensionality of public health issues make it difficult for the public to obtain accurate and comprehensive information (40), and there may be biases and misunderstandings during the process of information acquisition, translation, and dissemination, which may promote the dissemination and spread of rumors. Second, multiple interests are the main reason for the differences and conflicts among stakeholders in public health emergency governance (41). Stakeholders such as regulators, enterprises, the public, and the media usually have different goals, priorities, and positions, and these factors may affect their perceptions, attitudes, and actions toward public health emergencies, thus increasing the difficulty of investigating, verifying, and handling the news. Third, the significant challenge to societal trust has emerged as a crucial impediment in the governance of public event rumors. With the application of generative AI tools, unverified, false or misleading information has reached unprecedented levels (42), and audiences have difficulty in identifying true and false viral content, resulting in social trust challenges that will continue to increase (43). Consequently, addressing the propagation of rumors in public health emergencies necessitates collaborative efforts among stakeholders such as regulators, parties, and the public. The convergence of social consensus and collaborative actions is essential to drive effective governance of public health concerns (41).

This study elucidates the collaborative behaviors of regulators, PIPHE, and whistle-blowers in the governance of rumors in public health emergencies. Several valuable insights have been derived: rumor spreading is a complex problem, which requires the participation of multiple parties, including regulators, PIPHE, whistle-blowers, and the media. Regulators should actively supervise, disclose information promptly (44), stop the spread of rumors and guide the public to take rational actions (45). The parties involved in public health emergencies should disclose the facts and fully disclose relevant information to win public recognition and trust. Whistle blowers should actively participate in supervision, expose the truth in time and avoid the spread of rumors. The media should guide public opinion, publish true information, dispel rumors to clarify misinformation and expose unfavorable rumors. Therefore, regulators should flexibly adjust their regulatory strategies according to different situations and stages, and reasonably set up incentives such as costs, fines and rewards to promote cooperation and coordination among all parties. At the same time, regulators should also pay attention to collecting and analyzing behavioral data and feedback from all parties to promptly identify problems and enhance methodologies.

Based on the above analysis, we can derive the following recommendations for rumor management in public health emergencies. Firstly, it is recommended to establish effective collaborative mechanisms among regulators, stakeholders in public health emergencies, and informants, such as information sharing, building trust, and incentivizing protection, in order to enhance the efficiency and effectiveness of rumor management. Secondly, it is advised to enhance the legal regulations and social norms pertaining to public health emergencies, including the formulation and enforcement of laws and regulations related to rumors, strengthening supervision and punishment of parties involved in public health emergencies, and protecting the legitimate rights and safety of informants, to enhance the legitimacy and credibility of rumor management. Lastly, it is suggested to utilize social media and digital technology to enhance the capability and level of rumor management, such as using big data and artificial intelligence for rumor detection and refutation, leveraging social media and online communities for rumor dissemination and supervision, and utilizing mobile applications and cloud services for rumor management and collaboration, in order to improve the timeliness and inclusiveness of rumor management.

6 Conclusion

This paper focuses on the dissemination of rumors related to public health emergencies on social media and their collaborative governance. By employing evolutionary game theory, a dynamic game model involving regulators, parties involved in public health emergencies, and whistle-blowers is constructed. This model is utilized to analyze the behavioral strategies and game outcomes of each party during the rumor propagation process. The effectiveness and feasibility of the model are verified through numerical simulations. Subsequently, the study explores the influencing factors of rumor propagation and proposes optimization strategies for collaborative governance involving regulators and the media. Based on the model analysis and numerical simulation, this paper draws the following conclusions:

1 There are a variety of possible equilibrium strategies between regulators, PIPHE and whistle-blowers. Among these, the most practically significant is the ideal Evolutionarily Stable Strategy (ESS) characterized by proactive regulation by regulatory authorities, truthful disclosure by public health stakeholders, and active engagement by whistle-blowers. To achieve this equilibrium, certain conditions need to be met, i.e., the parameters of regulatory costs, image loss, credibility enhancement, penalties, and incentives need to be within a reasonable range.
2 The higher the regulatory costs paid by the regulator, the lower the willingness of the regulator to actively regulate. Similarly, an increase in the fines imposed on PIPHE by regulators corresponds to a higher willingness on the part of PIPHE to disclose accurate information. Furthermore, greater rewards provided by regulators to whistle-blowers for reporting lead to a heightened willingness on the part of whistle-blowers to actively participate in oversight. Moreover, an elevated probability of the regulator exposing PIPHE's actions results in a greater inclination of PIPHE to disclose truthful information.
3 The higher the image loss borne by the party involved in the public health incident due to disclosure of the facts, the lower the willingness of the party involved in the public health incident to disclose the facts; conversely, the higher the credibility enhancement gained by the party involved in the public health emergencies due to disclosure of the facts, the

higher the willingness of the party involved in the public health incident to disclose the facts. Additionally, as the time and effort costs increase for whistle-blowers who actively engage, their willingness to participate in oversight decreases.

4 The degree of rumor spreading is directly correlated to the degree of active participation by whistle-blowers; as the extent of rumor propagation increases, the willingness of whistle-blowers to engage in oversight decreases, and vice versa. The degree of rumor propagation is influenced by factors such as the severity of public health risks associated with the event and the number of whistle-blowers involved.

This study addresses the deficiencies in existing literature and further enriches the network rumor regulation system, offering significant theoretical value. However, this study also has certain limitations. On the one hand, the model assumes that the three parties' behavioral strategies are binary, that is, either positive or negative. In reality, a broader range of strategy options and combinations may exist. For instance, regulatory agencies may adopt different monitoring measures and intensities, stakeholders in public health events may utilize various information disclosure and crisis management techniques, and whistleblowers may use different reporting channels and methods. Therefore, future research could consider introducing more strategy variables and parameters to improve the model's fit with real-world situations. On the other hand, the model only considers the impact of rumor propagation on the three parties' behavioral choices and does not take into account the impact on the public and other stakeholders, such as media and digital platforms. Hence, future research could incorporate other relevant actors to provide a more comprehensive model.

Data availability statement

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

Author contributions

YW designed the research framework and methodology. YW and LQ constructed the game model and simulation analyses. YW and SC was responsible for the literature analysis and strategy research. YW and LQ edited the manuscript. All authors contributed to the article and approved the submitted version.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This research was funded by the National Social Science Funds of China, grant number 22&ZD192.

Acknowledgments

The authors thank the journal editor and reviewers.

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.

Publisher's note

References

1. Zhang Y, Fan H, Liu Q, Yu X, Yang S. How a short-lived rumor of residential redevelopment disturbs a local housing market: evidence from Hangzhou, China. *Land*. (2023) 12:518. doi: 10.3390/land12020518

2. Qi K, Yang Z, Zhang Z-M, Liu Y. Analysis on the evolutionary game of public opinion guidance mechanism of internet users under the participation of government. *Inf Sci*. (2017) 35:47–52. doi: 10.13833/j.cnki.is.2017.03.009

3. Zhang L, Chen K, Jiang H, Zhao J. How the health rumor misleads People's perception in a public health emergency: lessons from a purchase craze during the COVID-19 outbreak in China. *Int J Environ Res Public Health*. (2020) 17:7213. doi: 10.3390/ijerph17197213

4. Yao H, Zou Y. Research on rumor spreading model with time delay and control effect. *J Syst Sci Inform*. (2019) 7:373–89. doi: 10.21078/JSSI-2019-373-17

5. Zhao C, Li L, Sun H, Yang H. Multi-scenario evolutionary game of rumor-affected enterprises under demand disruption. *Sustainability*. (2021) 13:360. doi: 10.3390/su13010360

6. Rothkopf DJ. When the buzz bites back. *Wash Post*. (2003) 11:B1–5.

7. Chen S. Environmental disputes in China: a case study of media coverage of the 2012 Ningbo anti-PX protest. *Glob Media China*. (2017) 2:303–16. doi: 10.1177/2059436417753705

8. Zeng J, Chan C-H, Fu K-W. How social media construct "truth" around crisis events: Weibo's rumor management strategies after the 2015 Tianjin blasts. *Policy Internet*. (2017) 9:297–320. doi: 10.1002/poi3.155

9. Lv W, Zhou W, Gao B, Han Y, Fang H. New insights into the social rumor characteristics during the COVID-19 pandemic in China. *Front Public Health*. (2022) 10:4955. doi: 10.3389/fpubh.2022.864955

10. Fu C, Liao L, Xie H, Zhou X. How can we implement targeted policies of rumor governance? An empirical study based on survey experiment of COVID-19. *Chin Public Admin Rev*. (2023) 14:120–31. doi: 10.1177/15396754221139446

11. Ge P, Liu J, Han X, Wei S-T, He X-Z, Tang Y, et al. Systematic evaluation of COVID-19 related internet health rumors during the breaking out period of COVID-19 in China. *Health Promot Perspect*. (2021) 11:288–98. doi: 10.34172/hpp.2021.37

12. Hu G, Qiu W. From guidance to practice: promoting risk communication and community engagement for prevention and control of coronavirus disease (COVID-19) outbreak in China. *J Evid Based Med*. (2020) 13:168–72. doi: 10.1111/jebm.12387

13. Jain A, Dhar J, Gupta V. Rumor model on homogeneous social network incorporating delay in expert intervention and government action. *Commun Nonlinear Sci Numer Simul*. (2020) 84:105189. doi: 10.1016/j.cnsns.2020.105189

14. Liu Y, Wang Y. The generating and evolution of "secondary public sentiment" in public crisis: based on the focus on "8· 12 Tianjin port explosion". *Chin J Journ Commun*. (2017) 9:116–33. doi: 10.13495/j.cnki.cjjc.2017.09.008

15. Huo L, Dong Y. Analyzing the dynamics of a stochastic rumor propagation model incorporating media coverage. *Maths Methods Appl Sci*. (2020) 43:6903–20. doi: 10.1002/mma.6436

16. Wang D, Zhou Y, Qian Y, Liu Y. The echo chamber effect of rumor rebuttal behavior of users in the early stage of COVID-19 epidemic in China. *Comput Hum Behav*. (2022) 128:107088. doi: 10.1016/j.chb.2021.107088

17. Sumo J, George G, Weah V, Skrip L, Rude JM, Clement P, et al. Risk communication during disease outbreak response in post-Ebola Liberia: experiences in Sinoe and Grand Kru counties. *Pan Afr Med J*. (2019) 33:4. doi: 10.11604/pamj.supp.2019.33.2.16877

18. Fard AE, Verma T. "A Comprehensive Review on Countering Rumours in the Age of Online Social Media Platforms." In: Qureshi I, Bhatt B, Gupta S, Tiwari AA editors. *Causes and Symptoms of Socio-Cultural Polarization*. Springer, Singapore (2022).

19. Wang X, Li Y, Li J, Liu Y, Qiu C. A rumor reversal model of online health information during the Covid-19 epidemic. *Inf Process Manag*. (2021) 58:102731. doi: 10.1016/j.ipm.2021.102731

20. Abapour S, Nazari-Heris M, Mohammadi-Ivatloo B, Tarafdar Hagh M. Game theory approaches for the solution of power system problems: a comprehensive review. *Arch Comput Methods Engineer*. (2020) 27:81–103. doi: 10.1007/s11831-018-9299-7

21. Sun Y, Liu BY, Sun ZR, Yang R. Inter-regional cooperation in the transfers of energy-intensive industry: an evolutionary game approach. *Energy*. (2023) 282:128313. doi: 10.1016/j.energy.2023.128313

22. Liu H. The tripartite evolutionary game of green agro-product supply in an agricultural industrialization consortium. *Sustain For*. (2022) 14:1582. doi: 10.3390/su141811582

23. Sun Y, Yu R, Cheng TCE. Incentives for promoting climate change adaptation technologies in agriculture: an evolutionary game approach. *Environ Sci Pollut Res Int*. (2023) 30:97025–39. doi: 10.1007/s11356-023-28896-w

24. Wu F, Ma JH. Evolution dynamics of agricultural internet of things technology promotion and adoption in China. *Discret Dyn Nat Soc*. (2020) 2020:1–18. doi: 10.1155/2020/1854193

25. He QZ, Sun Y, Yi MA. Evolutionary game of pesticide reduction Management for Sustainable Agriculture: an analysis based on local governments, farmers, and consumers. *Sustain For*. (2023) 15:173. doi: 10.3390/su15129173

26. Teng Y, Chen X, Yu Z, Wei J. Research on the evolutionary decision-making behavior among the government, farmers, and consumers: based on the quality and safety of agricultural products. *IEEE Access*. (2021) 9:73747–56. doi: 10.1109/access.2021.3078561

27. McKee M, van Schalkwyk MCI, Stuckler D. The second information revolution: digitalization brings opportunities and concerns for public health. *Eur J Pub Health*. (2019) 29:3–6. doi: 10.1093/eurpub/ckz160

28. Qin SM, Zhang ML, Hu HJ. Ternary interaction evolutionary game of rumor and anti-rumor propagation under government reward and punishment mechanism. *Nonlinear Dynam*. (2023) 111:21409–39. doi: 10.1007/s11071-023-08962-1

29. Wang Y, Zheng L, Zuo J. Online rumor propagation of social media on NIMBY conflict: temporal patterns, frameworks and rumor-mongers. *Environ Impact Assess Rev*. (2021) 91:106647. doi: 10.1016/j.eiar.2021.106647

30. Wang XL, Chen SQ, Xie YX, Zhang J. An interaction model among enterprise and government actions and public opinion dissemination in negative events. *Electron Commer Res*. (2023) 19:5. doi: 10.1007/s10660-023-09767-5

31. Cao F, Zhang L, Wu YH. The Whistleblower's dilemma: an evolutionary game analysis of the public health early warning system. *Discret Dyn Nat Soc*. (2022) 2022:1–13. doi: 10.1155/2022/5796428

32. Li XY, Li QZ, Du YJ, Fan YQ, Chen XL, Shen FS, et al. A novel tripartite evolutionary game model for misinformation propagation in social networks. *Secur Commun Netw*. (2022) 2022:1–13. doi: 10.1155/2022/1136144

33. Peng LJ, Chen TG, Yang JJ, Cong TL. Management and control of Enterprise negative network public opinion dissemination based on the multi-stakeholder game mechanism in China. *System*. (2022) 10:33. doi: 10.3390/systems10050140

34. Sun Y, Liu BY, Fan J, Qiao Q. The multi-player evolutionary game analysis for the protective development of ecotourism. *Environ Sci Pol*. (2021) 126:111–21. doi: 10.1016/j.envsci.2021.09.026

35. Wang HY, Gao L, Jia Y. The predicament of clean energy technology promotion in China in the carbon neutrality context: lessons from China's environmental regulation policies from the perspective of the evolutionary game theory. *Energy Rep*. (2022) 8:4706–23. doi: 10.1016/j.egyr.2022.03.142

36. Xia XN, Li PW, Cheng Y. Tripartite evolutionary game analysis of power battery carbon footprint disclosure under the EU battery regulation. *Energy*. (2023) 284:129315. doi: 10.1016/j.energy.2023.129315

37. Dong W, Tao J, Xia X, Ye L, Xu H, Jiang P, et al. Public emotions and rumors spread during the COVID-19 epidemic in China: web-based correlation study. *J Med Internet Res*. (2020) 22:e21933. doi: 10.2196/21933

38. Na K, Garrett RK, Slater MD. Rumor acceptance during public health crises: testing the emotional congruence hypothesis. *J Health Commun*. (2018) 23:791–9. doi: 10.1080/10810730.2018.1527877

39. Liu J, Qi J. Online public rumor engagement model and intervention strategy in major public health emergencies: from the perspective of social psychological stress. *Int J Environ Res Public Health*. (2022) 19:1988. doi: 10.3390/ijerph19041988

40. Pearson G. Sources on social media: information context collapse and volume of content as predictors of source blindness. *New Media Soc*. (2021) 23:1181–99. doi: 10.1177/1461444820910505

41. Lalani HS, DiResta R, Baron RJ, Scales D. Addressing viral medical rumors and false or misleading information. *Ann Intern Med*. (2023) 176:1113–20. doi: 10.7326/m23-1218

42. Krause NM, Freiling I, Scheufele DA. The "Infodemic" Infodemic: toward a more nuanced understanding of truth-claims and the need for (not) combatting misinformation. *Ann Am Acad Pol Soc Sci*. (2022) 700:112–23. doi: 10.1177/00027162221086263

43. Cotfas L-A, Delcea C, Gherai R. COVID-19 vaccine hesitancy in the month following the start of the vaccination process. *Int J Environ Res Public Health*. (2021) 18:438. doi: 10.3390/ijerph181910438

44. Dai B, Fu D, Meng G, Liu B, Li Q, Liu X. The effects of governmental and individual predictors on COVID-19 protective behaviors in China: a path analysis model. *Public Adm Rev*. (2020) 80:797–804. doi: 10.1111/puar.13236

45. Hou Z, Du F, Zhou X, Jiang H, Martin S, Larson H, et al. Cross-country comparison of public awareness, rumors, and behavioral responses to the COVID-19 epidemic: Infodemiology study. *J Med Internet Res*. (2020) 22:e21143. doi: 10.2196/21143

frontiers | Frontiers in Public Health

TYPE Perspective
PUBLISHED 12 March 2024
DOI 10.3389/fpubh.2024.1375776

OPEN ACCESS

EDITED BY
Fatjona Kamberi,
University of Vlorë, Albania

REVIEWED BY
Kelly Ann Zongo,
The END Fund, United States

*CORRESPONDENCE
Sunday Jimmy Obol
✉ oboljimmy@gmail.com

RECEIVED 24 January 2024
ACCEPTED 22 February 2024
PUBLISHED 12 March 2024

CITATION
Obol SJ and Nzedibe O (2024) Critical perspective on infodemic and infodemic management in previous Ebola outbreaks in Uganda.
Front. Public Health 12:1375776.
doi: 10.3389/fpubh.2024.1375776

Critical perspective on infodemic and infodemic management in previous Ebola outbreaks in Uganda

Sunday Jimmy Obol[1]* and Okechi Nzedibe[2]

[1]Freelance Consultant, Kampala, Uganda, [2]International Public Health, Euclid University, Bangui, Central African Republic

This research investigates the complex dynamics of Uganda's recent Ebola outbreaks, emphasizing the interplay between disease spread, misinformation, and existing societal vulnerabilities. Highlighting poverty as a core element, it delves into how socioeconomic factors exacerbate health crises. The study scrutinizes the role of political economy, medical pluralism, health systems, and informal networks in spreading misinformation, further complicating response efforts. Through a comprehensive analysis, this study aims to shed light on the multifaceted challenges faced in combating epidemics in resource-limited settings. It calls for integrated strategies that address not only the biological aspects of the disease but also the socioeconomic and informational ecosystems that influence public health outcomes. This perspective research contributes to a better understanding of how poverty, medical pluralism, political economy, misinformation, and health emergencies intersect, offering insights for future preparedness and response initiatives.

KEYWORDS

medical pluralism, health system, Ebola outbreak, structural violence, coloniality, infodemic, syndemic, exploitation and injustices

Introduction

The Ebola outbreak in Uganda, while successfully contained, laid bare the complex interplay between disease, misinformation, and pre-existing vulnerabilities. The World Health Organization (WHO) defines an infodemic as too much information, including false or misleading information, in digital and physical environments during a disease outbreak. In the previous Ebola outbreak, the infodemic was only realized through the physical rather than the digital environment, for reasons such as outbreaks happening in rural areas with limited access to smartphones, where literacy levels are very low, and poverty is an economic norm. Poverty, a significant factor within the affected communities, is intertwined with the infodemic fueled by social media and informal communication channels. This perspective of research examines the intersections of these forces. Poverty in Uganda manifests in limited access to healthcare, education, and reliable information. These factors created fertile ground for misinformation to flourish. Rumors about the virus' origin, dubious cures, and government conspiracies spread rapidly, hindering containment efforts and stoking fear. Communities steeped in poverty lacked the resources and awareness to counter these narratives effectively. International donor organizations were crucial in tackling the outbreak, providing

medical supplies, training healthcare workers, and supporting community engagement initiatives. However, their interventions often lacked contextual understanding, perpetuating top-down approaches that may not resonate with local cultural sensitivities or address broader structural inequalities.

Structural violence

Infodemic is an underlying symptom and not a disease, as it is a product of the structural ambiguity of health systems, both globally and locally. Uganda's current health system suffers from structural violence due to a lack of will by the authorities. Structural violence is defined as the "social structures-economic, political, religious, legal, and cultural that stop groups, individuals, and societies from reaching their full capability" (1). During Ebola outbreaks, humanitarianism becomes the central pillar of intervention, negating the health system's structural challenges that should have become a priority in managing outbreaks and their ability to detect disease incidences promptly. A lack of well-equipped rural facilities to ensure surveillance, as well as the human-animal interaction embedded in culture, continues to expose the population to risk factors for the Ebola outbreak. Such a deficit has promoted health seeking and healthcare access from traditional healers. Poverty and the structures in place designed to maintain it are evident throughout all places that have had Ebola outbreaks documented. The WHO pronounced this as the world's 25th, having been registered in settings of profound poverty (2). Ebola incident cases have never occurred in an urban setting, making it a rural panacea for those at the periphery of societal favors.

Infodemic during an Ebola outbreak is syndemic to the structural challenges that fail to detect or manage it. Syndemic is a synergistic interaction between socioecological and biological factors that result in adverse health outcomes (3). Social determinants of health, such as poverty, social inequality, social stigma, and the environment, where people live and work, have greatly affected the intensity of the syndemic. Syndemic describes how co-occurring epidemics interact biologically and occur in the sociocultural, economic, and physical environments in which they appear. The syndemic and structural violence of epidemic diseases, such as HIV/AIDS, tuberculosis, Ebola, and COVID-19, need to be understood as multilevel phenomena shaped by history, political economy, and social context (4). These provide a signal manifestation and contribution to the documentation of underlying syndemic factors; the role of power, control, oppression, and social inequality in making health and disease are abundantly evident in these studies. Unless such power imbalances are rectified in building a robust health system, syndemic conditions will always provide fertile ground for any infodemic. Structural violence remains a rural society disease, making misinformation a base for seeking care from an array of healers. This result is based on the reality of fragility and vulnerable settings where healthcare infrastructure is limited and national investments in health are inadequate.

Infodemics in the global south should not be thought of as subalterns in so far as health intervention issues in Uganda and the general global south are concerned. Instead of equitable investment in developed health systems and infrastructure that could benefit everyone, the global south is often seen as fodder for the interests of international actors, leading to uneven development and limited access to crucial resources. The continuation of inordinate mortality from Ebola in Uganda and other global southern countries is not the result of an intractable problem thwarting the global communities' best efforts. Instead, it is a moral detachment that is subservient to the protected affluent, where mistrust has been at the backbone of achieving global health equity. Other than the lack of investment in the health system to ensure health equity, survival for the fittest remains a modern reality for many rural Ugandans when it comes to accessing quality healthcare services at all times.

Coloniality/historical underlying mistrust

Regarding biomedicine, not everything that glitters is gold in the face of historical injustices. The establishment of health facilities followed a pattern of colonial settlement that was based on other interests instead of service provision. Colonialism deeply affected Uganda's social fabric and inherently changed social, cultural, political, and economic structures in a way that continues to be felt to date (5). Understanding mistrust in Uganda's population means understanding the culture of the community and the colonial impact on the establishment of social services. A history of colonialism has been a major factor in determining the health of many vulnerable population groups, and this has affected the health system and all governance systems within it. Framed as a disease control initiative, health laws were introduced in 1908 and 1909 to consolidate and later deport 33 island villages in Lake Victoria to the mainland. These regulations were a hidden method of strategically reducing the population of people from an area rich in hunting, fishing, and charcoal (6). Most times, Ebola outbreaks in Uganda have occurred in places where the population is not in support of the seating government, as sometimes the outbreak is seen as a punishment; looking at the 2001 outbreak in Gulu, as well as the 2022 Mubende and Kasanda outbreak that saw the opposition political party win the seats in the two districts.

Therefore, exposing epistemic violence by analytically ignoring the power dynamics determining levels of trust in the post-colony should be central in infodemic management. Besides, some colonial laws are still being applied, such as the Public Health Act of 1935 and the Penal Code Act of 1950. These laws sustain the deterioration of indigenous community fabrics and colonial attempts at social control (7). In the event of ensuring infodemic management, in most cases, infodemic management is seen as a flagrant display of power and disrespect toward those whose views are censored. Infodemic management should aim to demonstrate how modern social scientists should not have their moral outlooks stunted, which then delimits how they gather facts during epidemic outbreaks such as Ebola. This approach should not be through discussing counterhegemonic ways of interpreting health phenomena; instead, it should be through ways to delink knowledge production from the colonial matrix of power.

Infodemic managers, such as epidemiologists, view outbreaks through the lens of tracing the causal pathway of Ebola transmission in a "lack of trust to non-compliant actors to Ebola outbreak propagation" (8). Because of its discursive power, there is a possibility that its historical and geopolitical roots could be overlooked. Different scholars posit varied opinions on the role of infodemic managers. Richardson argues that infodemic managers prevent structural

determination from becoming commonsensical by dominating how people should perceive and interpret health phenomena, therefore, such interpretations commit hermeneutic injustice (9). This means malfeasance in the way one interprets what one sees, thereby rejecting conspiracy theories as legitimate criticisms of the coloniality of power and repurposing cultural causality claims as explanations for more than a century of predatory accumulation and colonial atrocities (10). This leaves infodemic managers to ask more nuanced exploratory questions regarding misinformation and distrust during public health interventions, acknowledging structural colonial deficits and debunking them in an attempt to create more power imbalances.

Accordingly, conspiracy theories merge with other post-colonial criticisms to form truth claims that call for redistributive justice and reparations instead of bourgeois empiricism, which is characterized as gathering facts "that hide behind scientific objectivity to perpetuate dependency, exploitation, elitism, racism, and colonialism" (11). The priority of making locals understand the gravity of a public health emergency, and what is being done to arrest the situation ensures the involvement of all in managing the said epidemic. However, when infodemic managers are fronted as the crisis caravan such as the flotilla of developmental agencies and non-governmental organizations that shifts between emergencies, "scattering information aid like confetti," (12) it exposes the social science profession as a neocolonial front for the powers that be. Therefore, there is a need for infodemic managers to pause questions before censoring any information, putting into consideration the historical and social construction of the said community. It is to help them reflect on their stance on public health emergency interventions and detach them from being crisis caravans in debunking or censoring misinformation.

The perspective of patients running away from treatment facilities is not necessarily derived from a lack of care but from historical reality. For example, the epistemic reconstitution of previous medical intervention studies aimed at eradicating human African trypanosomiasis (sleeping sickness) in French Equatorial Africa. Thirty years of archival data from French military archives show that lower levels of trust in modern medicine are correlated with greater exposure to colonial medical campaigns marked by forced lumbar punctures and treatment with aminophenyl arsonic acid (atoxyl), a somewhat effective arsenic compound that left 20% of patients blind. While this recapitulates the conflation of trust and health-seeking behavior, this is an example of how public health interventions can turn into variables for computational modeling purposes of historical and structural factors influencing how people feel about medicine and healthcare (9). In dealing with people's fears of spreading misinformation or running away from a treatment center, explaining the current variables from the colonial ones during public health emergency interventions is very important. Information sharing should reflect empowerment through a rights-based approach. A similar intervention event created mistrust in the Belgian colony across the Congo River, where individuals suspected of having sleeping sickness were held in camps renowned for their toxic therapy, unfavorable living conditions, scarcity of food, and the permanent separation of patients from their families, all while being watched over by armed guards (9). A further good example is the research on modern mistrust associated with the awful unethical Tuskegee experiments. The lingering effects of medieval medicine serve as a reminder that mistrust does not develop in a vacuum and that "cultural" views do not supersede behaviors related to obtaining health care. Thus, as infodemic managers, our aim must not be short of past reality, but rather one that ensures knowledge is at the foundation of our duty in shaping our responsibilities.

Sociocultural knowledge has been essential to comprehending the virus and implementing containment measures in any Ebola outbreak. Social scientists on the ground have demonstrated why people reacted so negatively, even violently, to curfews and quarantines; why Ebola rumors should not be discounted as irrational or paranoid; and why grieving families chose to conceal bodies rather than turn them in for official burial (13). Countering misinformation must reflect the historical context of subjectivity. The recognition of history, politics, and culture productively liberates people from the decontextualized, faceless, and pliable role of "victim" (13). Furthermore, it becomes evident how much of the blame for the epidemic did not rest with culture itself when one examines the institutional cultures of different institutions and the government itself. Before biomedicine, a culture existed and still dominates not only health-seeking behaviors but also health and healing overall. During disease outbreaks in Uganda, despite the perception that culture was limited, irrational, or dangerous, it actually sparked specific decisions and debates inside and among a worldwide class of purported saviors.

Health system

Infodemic management is incomplete without the role of an effective and efficient health system in the promotion of good quality health outcomes since the study of disease is characterized by the investigation of a set of factors, including biology, epidemiology, sufferer, and community understandings of the disease of concern (14), and the social, political, and economic conditions that may have contributed to the development of ill health. This is part of its effort to identify and understand health within the intersecting political economy and biosocial causality frameworks. The health system is not independent of the forces that shape its operationality, which is not limited to financing but also establishment. Therefore, the efficiency and effectiveness of the services provided will always depend on the intersecting frameworks. The vulnerability of the health system remains the sole cause of outbreaks and epidemics in Uganda. Therefore, the particularly devastating course of the Ebola epidemic' should not be attributed to the "biological characteristics of the virus alone (15); rather, the result of the combination of "dysfunctional health systems in the country. The lack of economic independence in low-income countries, such as Uganda, has seen them fail to build robust health systems for their citizens.

The World Bank and International Monetary Fund's conditional loans have contributed to and continued to undermine health systems in low- and middle-income countries. Besides, such negligence leads to trust issues regarding the role of health service providers, who are, in reality, incapacitated by their governing structures. Therefore, without addressing such issues, infodemic management remains more knee-jerk to underlying issues beyond a government's means. These institutions limit public spending for Uganda and other developing countries, leading to a dependence on developmental aid funding from wealthier countries such as the

United States (16). Dependence on development aid places the entire population in strict isolation as a kind of abandonment. This has deprived investment in the health system hence leading to the deaths of many Africans due to preventable epidemics or the chronicity of the different epidemics without a functioning health system.

Centuries of exploitation and injustice highlight their impact on the failings of the healthcare system. By focusing greater attention on the historical and capitalistic patterns of violence and dispossession, the need to speak to social, political, economic, and historical determinants of health and wellbeing lies at the heart of health advocacy work and approach (17). Infodemic management should not be limited to outcomes of such grounded reality; rather, they must focus on the root cause of recurrent epidemics such as Ebola to weed out the coloniality of injustices.

Medical pluralism

There has never been a universal medical cultural practice, unless before the biomedical revolution. The different global cultures have practiced different healing practices and assigned different meanings to illness occurrences. Therefore, the practice of seeking healing has never depended on one healing approach limited to spiritual, herbal, or even biomedicine, as practiced during colonial or post-colonial times. Therefore, all these have different meanings, especially during an outbreak. The availability of various medical approaches, treatments, and institutions for individuals to utilize in their pursuit of health is medical pluralism, and it involves seeking care from several sources (18). Thus, through what prism, must we define infodemic well knowing there is no universal culture based on the reality of cultural diversity in health-seeking behaviors?

Medical practitioners and ordinary citizens are becoming more aware that we need to put into perspective cultural variations in medical belief and practice (19). Understanding how health and illness are handled in various cultural contexts helps us identify "culture-bound" aspects of our own medical practices and beliefs, as seen in the role of anthropology during different Ebola outbreaks and during the COVID-19 pandemic. Addressing misinformation requires a cultural understanding of illnesses in different cultural settings. Infodemic management is an innovation in modern industrial or post-industrial societies, and biomedicine is the dominant system. These two are factors to consider in medical pluralism. Besides, these two factors tend to exist in a competitive relationship with other systems such as chiropractic, naturopathy, Christian science, evangelical faith healing, and various folk medical systems (20). The duo is prominent based on their technological prowess, forgetting how such cannot influence cultural practices.

Understanding the confluence of biomedicine and the pharmaceutical industry, the heartbeat of biomedicine in the modern world since biomedicine has become the focus of the pharmaceutical industry. Infodemic managers should play a role in the translation of medical discoveries and package information, in addition to propagating health education. Infodemic managers also need to be anchored in understanding the cultural connotations of health and illness. They also need to understand how medical pluralism is defined by a pattern in which biomedicine exercises dominance over alternative medical systems, whether or not they are professionalized. It is this dominance that aims to leverage accurate information through censorship or gagging any unscientific information in the face of cultural diversity. When we understand how medical pluralism flourishes in all class-divided societies, it tends to mirror the wider sphere of unequal social relationships, with the patterns of hierarchy among co-present medical systems being based upon the reigning structure of class, caste, racial, ethnic, regional, religious, or gender distinctions (21). In the process of managing infodemics during recent outbreaks, there is a need to realize how it is more accurate to say that national medical systems in the modern or postmodern world tend to be plural, giving birth to different information meanings than what was structured during the colonial and pre-colonial eras. Should we claim that infodemic management will equally enjoy biomedicine dominance status over all heterodox and ethnomedical practices, knowing well how political misinformation is at the heart of modern-day infodemics?

Conclusion

The research critically examines the multifaceted impacts of structural violence and infodemics on health outcomes, particularly in the context of Ebola outbreaks in Uganda. The research elucidates how structural violence, rooted in economic, political, and cultural systems, prevents societies from achieving their full potential, thereby exacerbating health crises. The document highlights the syndemic nature of infodemics, which, fueled by structural challenges, worsen health disparities, especially in rural settings lacking robust healthcare infrastructure. The interplay between socioecological and biological factors highlights the necessity to address social determinants of health to mitigate adverse outcomes.

Furthermore, the research delves into the historical and colonial underpinnings of mistrust in health systems, underscoring how colonial legacies continue to shape health behaviors and perceptions in Uganda. It argues for a nuanced understanding of infodemic management that acknowledges the colonial matrix of power and seeks to empower communities by contextualizing health interventions within their historical and cultural realities, looking at it from a syndemic perspective. According to (22), syndemics are "the concentration and deleterious interaction of two or more diseases or other health conditions in a population, especially as a consequence of social inequity and the unjust exercise of power." In addressing infodemics during a disease outbreak, a syndemic framework must be used to address the biosocial relationships during outbreaks. Syndemics develop under conditions of health disparities caused by poverty, stress, and structural violence that lead to further suffering by patients whose pain could be managed but whose conditions deteriorate because of the co-occurrence of another disease.

In conclusion, this research advocates for a comprehensive approach to health crises that transcends biological interventions to include social, economic, and political considerations. It calls for the dismantling of structural violence and the coloniality of power to build more equitable and responsive health systems. Addressing the root causes of health disparities, including poverty, social inequality, and historical injustices, is essential for preventing future epidemics and ensuring that all individuals have the opportunity to achieve optimal health outcomes. The article highlights the importance of medical pluralism and cultural competency in infodemic management, emphasizing that health interventions must be grounded in the local sociocultural context to be effective.

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 approval was not required for the study involving humans in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and the institutional requirements.

Author contributions

SO: Conceptualization, Writing – original draft, Writing – review & editing. ON: Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest

SO was employed by the Freelance Consultant.

The remaining 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.

Publisher's note

References

1. Farmer PE, Bruce N, Sara S, Salmaan K. Structural violence and clinical medicine. *PLoS Med*. (2006) 3:e449–e1691. doi: 10.1371/journal.pmed.0030449

2. Available at: https://www.who.int/news-room/fact-sheets/detail/ebola-virus-disease.

3. Yadav UN, Rayamajhee B, Mistry SK, Parsekar SS, Mishra SK. A Syndemic perspective on the Management of non-communicable Diseases amid the COVID-19 pandemic in low- and middle-income countries. *Front Public Health*. (2020) 8:508. doi: 10.3389/fpubh.2020.00508

4. Singer M, Rylko-Bauer B. The Syndemics and structural violence of the COVID pandemic: anthropological insights on a crisis. *Open Anthropol Res*. (2021) 1:7–32. doi: 10.1515/opan-2020-0100

5. Griffiths K, Coleman C, Lee V, Madden R. How colonisation determines social justice and indigenous health: a review of the literature. *J Popul Res*. (2016) 33:9–30. doi: 10.1007/s12546-016-9164-1

6. Hoppe KA. Lords of the fly: colonial visions and revisions of African sleeping-sickness environments on Ugandan Lake Victoria, 1906–61. *J Int Afr Inst*. (1997) 67:86–105. doi: 10.2307/1161271

7. Mulumba M, Ruano AL, Perehudoff K, Ooms G. Decolonizing health governance: a Uganda case study on the influence of political history on community participation. *Health Hum Rights J*. (2021, 2021) 23:259–71.

8. Richardson ET, Polyakova A. The illusion of scientific objectivity and the death of the investigator. *Eur J Clin Investig*. (2012) 42:213–5. doi: 10.1111/j.1365-2362.2011.02569.x

9. Richardson ET. On the coloniality of global public health. *Med Anthropol Theory*. (2019) 6:101–18. doi: 10.17157/mat.6.4.761

10. Richardson ET, Barrie MB, Daniel Kelly J, Dibba Y, Koedoyoma S, Farmer PE. Biosocial approaches to the 2013–16 Ebola pandemic. *Health Hum Rights*. (2016) 18:167–79.

11. Singer M. A rejoinder to Wiley's critique of critical medical anthropology. *Med Anthropol Q*. (1993) 7:185–91.

12. Polman Linda, (2010). *The crisis caravan: what's wrong with humanitarian aid?*. New York, N.Y. USA: Picador.

13. Biehl J. Theorizing global health. *Med Anthropol Theory*. (2016) 3:127. doi: 10.17157/mat.3.2.434

14. Ember Carol R., Ember Melvin. (2004). *Encyclopedia of medical anthropology; health and illness in the world's cultures*. New York: Kluwer Academic/Plenum.

15. Farrar J, Piot P. The Ebola emergency: immediate action, ongoing strategy. *N Engl J Med*. (2014) 371:1545. doi: 10.1056/NEJMe1411471

16. Medeiros P, Oliphant A, Farrow S, Gill P. Anthropological engagements with Global Health. *Med Anthropol Theory*. (2022) 9:1–10. doi: 10.17157/mat.9.3.5628

17. Pfeiffer J, Chapman R. Anthropological perspectives on structural adjustment and public health. *Annu Rev Anthropol*. (2010) 39:149–65. doi: 10.1146/annurev.anthro.012809.105101

18. Khalikova V. Medical pluralism In: *The open encyclopedia of anthropology, edited by Felix stein. Facsimile of the first edition in the Cambridge encyclopedia of anthropology* (2021). 12:100978. doi: 10.1016/j.imr.2023.100978

19. Human Relations Area Files Inc. *Encyclopedia of medical anthropology: health and illness in the world's cultures*. New York, NY: Kluwer Academic/Plenum (2004).

20. Baer HA. Medical pluralism In: CR Ember and M Ember, editors. *Encyclopedia of medical anthropology*. Boston, MA: Springer (2004).

21. Singer M. Critical medical anthropology In: CR Ember and M Ember, editors. *Encyclopedia of medical anthropology*. Boston, MA: Springer (2004).

22. Singer M. Toward a critical biosocial model of ecohealth in Southern Africa: The HIV/AIDS and nutrition insecurity syndemic. *Annals of Anthropological Practice [Internet]*. (2011). Available at: http://onlinelibrary.wiley.com/doi/10.1111/j.2153-9588.2011.01064.x/full.

frontiers | Frontiers in Public Health

TYPE Review
PUBLISHED 15 March 2024
DOI 10.3389/fpubh.2024.1343902

OPEN ACCESS

EDITED BY
Selen Yeğenoğlu,
Hacettepe University, Türkiye

REVIEWED BY
Vieri Lastrucci,
Meyer Children's Hospital, Italy
Daisy Volmer,
University of Tartu, Estonia

*CORRESPONDENCE
Lamis Abuhaloob
✉ lamisabuhaloob@yahoo.com

RECEIVED 24 November 2023
ACCEPTED 04 March 2024
PUBLISHED 15 March 2024

CITATION
Abuhaloob L, Purnat TD, Tabche C, Atwan Z, Dubois E and Rawaf S (2024) Management of infodemics in outbreaks or health crises: a systematic review.
Front. Public Health 12:1343902.
doi: 10.3389/fpubh.2024.1343902

Management of infodemics in outbreaks or health crises: a systematic review

Lamis Abuhaloob[1]*, Tina D. Purnat[2], Celine Tabche[1], Zeenah Atwan[3], Elizabeth Dubois[1] and Salman Rawaf[1]

[1]Faculty of Medicine, WHO Collaborating Centre for Public Health Education and Training, School of Public Health, Imperial College London, London, United Kingdom, [2]University of Memphis School of Public Health, Memphis, TN, United States, [3]Department of Microbiology, Faculty of Medicine, University of Al-Basra, Al-Basra, Iraq

Introduction: The World Health Organization (WHO) defined an infodemic as an overabundance of information, accurate or not, in the digital and physical space, accompanying an acute health event such as an outbreak or epidemic. It can impact people's risk perceptions, trust, and confidence in the health system, and health workers. As an immediate response, the WHO developed the infodemic management (IM) frameworks, research agenda, intervention frameworks, competencies, and processes for reference by health authorities.

Objective: This systematic review explored the response to and during acute health events by health authorities and other organizations operating in health. It also assessed the effectiveness of the current interventions.

Methods: On 26 June 2023, an online database search included Medline (Ovid), Embase, Cochrane Library, Scopus, Epistemonikos, and the WHO website. It included English-only, peer-reviewed studies or reports covering IM processes applied by health organizations that reported their effectiveness. There was no restriction on publication dates. Two independent reviewers conducted all screening, inclusion, and quality assessments, and a third reviewer arbitrated any disagreement between the two reviewers.

Results: Reviewers identified 945 records. After a final assessment, 29 studies were included in the review and were published between 2021 and 2023. Some countries (Pakistan, Yemen, Spain, Italy, Hong Kong, Japan, South Korea, Singapore, United Kingdom, United States, New Zealand, Finland, South Korea, and Russia) applied different methods of IM to people's behaviors. These included but were not limited to launching media and TV conservations, using web and scientific database searches, posting science-based COVID-19 information, implementing online surveys, and creating an innovative ecosystem of digital tools, and an Early AI-supported response with Social Listening (EARS) platform. Most of the interventions were effective in containing the harmful effects of COVID-19 infodemic. However, the quality of the evidence was not robust.

Discussion: Most of the infodemic interventions applied during COVID-19 fall within the recommended actions of the WHO IM ecosystem. As a result, the study suggests that more research is needed into the challenges facing health systems in different operational environments and country contexts in relation to designing, implementing, and evaluating IM interventions, strategies, policies, and systems.

KEYWORDS

infodemic, infodemic management, infodemiology, COVID-19, outbreak, health crisis, health emergency, misinformation

1 Introduction

1.1 Infodemics and the health system

The WHO defined an infodemic as an overabundance of information, accurate or not, in the digital and physical space, accompanying an acute health event such as an outbreak or epidemic (1–4). An infodemic consists of accurate, inaccurate, and outdated health information, information voids, as well as narratives and mis- and disinformation.

When acute health events occur, the information environment changes—people actively search for and share health information. The government is actively communicating on a particular topic and other experts contribute to the discussion of the subject in society. Communities who are not usually interested in health are now talking about it, and media and fact-checkers cover the topic of health more. In the uncertainty of an emergency, and often with evolving scientific knowledge about the topic, the chaotic information environment can make it difficult for people to find health information they search for, and need to protect themselves and their families, irrespective of their health literacy (1). In addition, a chaotic information environment, coupled with limits in access to health services and health diagnostics, therapeutics and vaccines. Those together with individual socioeconomic drivers and aspects of health and digital information literacies can limit the adherence to recommended health guidance and public health and social measures, and uptake of diagnostics and vaccine service (4–8).

Infodemics impact all levels of society: individual, family, community, health system, government, and society, and can lead to a variety of harms. Such harms include skewed risk perception and delayed healthcare seeking, victimization and stigmatization of vulnerable populations, panic buying, and falling for deceptive marketing. Mistrust in the government, health system, health workers, public health, social and medical countermeasures, lead to low adherence to recommended health guidance, anxiety, and stress (1, 9, 10).

1.2 Infodemic management and WHO infodemic management program

Infodemic management is the systematic use of risk- and evidence-based analysis and approaches to promote a healthier information environment and resilience against infodemics negative impacts on health behaviors during health emergencies. Systematic application of infodemic management approaches can mitigate the harm from infodemics during emergencies and promote resilience to infodemics and health misinformation, especially in populations experiencing inequities and vulnerabilities (4). During the COVID-19 pandemic, the WHO set up a toolbox of infodemic management interventions, promoting the science of infodemiology, professionalization of infodemic management practice, and partnerships across all of society (such as with civil society, media, private sector, and multilateral and international organizations) (11). This was described through a whole-of-society framework for responding to the COVID-19 infodemic and 50 actions that can be taken across society to do so (2), along with four pillars: (1) Identify evidence, (2) Translate knowledge and science, (3) amplify action, (4) quantify impact.

Based on that, to tackle infodemics during the COVID-19 pandemic, the WHO infodemic management team conducted global online consultations and conferences on various aspects of prioritizing infodemiological research, sharing experiences and tools, developing capacities and competency framework for infodemic management, to advance metrics and frameworks (12–15). Operationally, WHO developed partnerships with search, social, and digital companies like Facebook, Google, Tencent, Baidu, Twitter, TikTok, Weibo, Pinterest, and YouTube to promote distribution of WHO's health content. Regionally, Africa Infodemic Response Alliance, a partnership hosted by WHO Regional Office for Africa, was established to facilitate social listening and rapid response to misinformation and infodemic impacts on communities (16, 17). As part of the WHO incident management response, the WHO infodemic management developed and implemented novel analytical approaches in over 18 languages for weekly social listening, integrated analysis, and infodemic insights generation. In addition to finding information voids, circulating narratives on mis- and disinformation, they used these to understand peoples' questions, concerns, and provide recommendations for actions to address them (1, 14, 16).

Through various activities, the WHO identified interdisciplinary approaches and frameworks to measure the burden of infodemics (2, 4, 7, 9, 18). Four categories of intervention that the WHO recommends managing infodemics. These are (1) listening questions, concerns, information voids, and circulating narratives including mis- and disinformation, (2) communicating science and risk, (3) promoting resilience to infodemics and health misinformation, and (4) engaging and empowering communities (9). The WHO recommends that successful infodemic management should be embedded within health authority's routine functions and structures (4).

As the health systems globally have moved to restore routine health services and recovery from the pandemic impacts, an effort has been made to integrate the lessons learned. These efforts involved new partnerships, and tools that were established during the pandemic into other emergency responses, the health system and into preparedness planning. For example, social listening infodemic insights and infodemic management have been included in the WHO toolkits for country preparedness and resilience planning. These include emerging threats for pandemic influenza preparedness and for response to influenza outbreaks in animals, WHO's global architecture for health emergency prevention, preparedness, response and resilience, WHO and partners' framework for vaccine demand promotion and integration for COVID-19 vaccination into routine immunization and primary health care, among others (19–24). While countries have reported to WHO conferences and trainings their infodemic management activities, health authorities have not yet extensively reported and published their experience in scientific literature, with Germany being the first (25, 26).

1.3 The gap in evidence related to infodemic management interventions

During the COVID-19 pandemic, many different strategies were designed and applied globally and in different settings to mitigate the

Abbreviations: WHO, World Health Organisation; RCT, Randomized Control Trial.

harms from the COVID-19 infodemic and infodemics accompanying other outbreaks such as mpox, cholera, Ebola, measles, and diphtheria. The WHO recognized that there is a need to develop a comprehensive taxonomy of infodemic management interventions and outcomes and has convened an expert group to perform an evidence and gap map (27).

While this is ongoing, there is a lack of information on the practices in infodemic management in countries and different sectors of society. Thus, this systematic review aims to explore how health authorities and other organizations working in health have responded to the COVID-19 infodemic and assess the management effectiveness.

2 Methods

The main research question is, "Are infodemic management interventions that have been used during health crises effective?" Other questions to address are: Which infodemic management interventions, strategies and approaches have been used by health authorities to manage infodemics? Are current infodemic management strategies effective enough to mitigate harm from an infodemic?

To address these questions, a systematic search was conducted for primary and secondary literature in the databases (Embase®, WHO IRIS, Cochrane Library of Systematic Reviews, Scopus and Epistemonikos) and explored the reference lists of the included studies. We conducted the search on 26 June 2023. The search included MeSH terms and free text within each database, as illustrated in Box 1.

No time restriction was applied, and only studies published in English were included. After removing duplicates, two authors independently screened the title, abstract, and full text of articles and included eligible articles for evaluation. An independent third author resolved any disagreements. We performed the screening process in Covidence.

2.1 Selection of the literature

The following inclusion criteria were applied in the selection process: (1) Populations: any population that is experiencing an infodemic during outbreaks or health crises, (2) Interventions: peer-reviewed articles for any quasi-experiment, randomized control trial (RCT), interventions or programs aiming to manage infodemics (questions, concerns, information voids, narratives or mis- and disinformation) when preventing, preparing, or responding to acute health events, (3) Comparison: studies compared, evaluated, assessed, or planned spread, effect, or mitigating measures for infodemic during an outbreak, (4) Outcome: change in the harm from infodemic impact on the population of focus (e.g., change in health behaviors), (5) Study designs included observational and experimental studies, including RCT, cluster-RCT, and controlled before-after (CBA) studies.

The exclusion criteria included (1) Wrong study population: populations not targeted by infodemics during outbreaks or health crises, (2) Unreported study design: did not provide information about infodemic management interventions and/or their outcomes, (3) Unclear study outcome: did not record any information on the impact of infodemics management on the population, (4) Studies not published in English, (5) Study full text not found, (6) Duplicated paper.

2.2 Quality assessment

The study quality was assessed by two independent reviewers. CASP tools were used for assessing the qualities of experimental and observational studies and systematic reviews except for cross-sectional studies. The later study design was evaluated using JBI Critical Appraisal Tools.

2.3 Data extraction

The articles and reports that met the inclusion criteria were retained for data extraction and further analysis. Supplementary Table S1 shows the template developed to extract review-related information. The research team discussed and agreed upon the final characteristics of the table to extract data in this review. Two reviewers developed data extraction; one reviewer extracted the data to the template, and the second reviewer double-checked the extractions by the first reviewer. A third reviewer arbitrated any disagreement between the two reviewers.

2.4 Data analyses and synthesis

The synthesis included the categorization of relevant study findings. No attempt was made to perform a meta-analysis because of the high heterogeneity regarding population and intervention in the included studies. Finally, a descriptive-analytical method was used to present the review's outcome. Conclusions and recommendations emerged from the findings and gaps identified by this review.

3 Results

The database search identified 945 records. After removing duplications and screening abstracts according to our inclusion and exclusion criteria, our results came to 199 full-text studies. Finally, only 29 studies were included (Figure 1). Retained studies were published during the Pandemic between 2021 and 2023.

The studies were conducted in different countries, including Pakistan, Yemen, the Kingdom of Saudi Arabia, Spain, Italy, Hong Kong, Japan, South Korea, Singapore, the UK, the USA, New Zealand, Finland, South Korea, and Russia. The study designs of the included papers were observational and experimental studies. All studies tackled an aspect of the infodemic during the COVID-19 pandemic.

3.1 Sources of the infodemic

These studies focused on the analysis of different digital and physical environments and sources of health information such as social media posts and conservations, web, news, radio, TV talk shows, press conferences, national press, pre-print and peer-reviewed papers.

BOX 1 Search string used within the database.

1 "management/ or manag*.mp," 2 "misinformation/ or Misinformation.mp," 3 "Misleading information.mp," 4 "False information.mp," 5 "gossip*.mp," 6 "rumour*.mp," 7 "hoax*.mp," 8 "urban legend*.mp," 9 "myth*.mp," 10 "fallac*.mp," 11 "infodemic/ or infodemiology/," 12 "infodemic*.mp," 13 "infodemiology.mp," 14 "2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13," 15 "Disease outbreak.mp. or epidemic/," 16 "pandemic/ or pandemic*.mp," 17 "epidemic*.mp," 18 "15 or 16 or 17," 19 "infodemic/ or Infodemic management.mp," 20 "infodemiology/ or Infodemiology management.mp," 21 "19 or 20," 22 "1 and 14 and 18," 23 "program effectiveness/ or effectiveness.mp," 24 "health impact assessment/ or impact.mp. or program impact/," 25 "23 or 24," 26 "22 and 25," 27 "21 or 26," 28 "infodemiology/ or infodemi*.mp. or infodemic/," 29 "manage*.mp," 30 "28 and 29," 31 "cris*.mp," 32 "pandemic/ or pandemic.mp," 33 "outbreak*.mp. or epidemic/," 34 "31 or 32 or 33," 35 "30 and 34," 36 "27 or 35"

3.2 Infodemic impact on the health

A large adverse physical, social, political, and psychological harm from infodemics was detected by included studies on individual level (health behavior misaligned with recommended health guidance, fear or panic, and vaccine hesitancy), organizational level (misallocation of health resources and ineffective communication of risk), national level (unintended consequences of pandemic countermeasures and reduced cyber and information security, harm to public health) and global level (increased harm to mental health globally). On the other hand, it found that lower degree of government transparency accompanied with specific misinformation narratives lowered risk perception of COVID-19 and enacting recommended health behaviors.

3.3 Tools for managing infodemics

Methods used to manage the negative impact of infodemics were directed to the digital and physical platforms used for republishing and amplifying messages. Most of these interventions showed effectiveness in reducing harm from the infodemic. However, the overall quality of the evidence on effectiveness was only moderate. For example, Moretti et al. (28) reported an increase in the level of digital health literacy from 2.9 to 4.2 ($p = 0.001$) among Italian medical students after attending an infodemic course. This course trained students on the use of the "dottoremaeveroche" (DMEVC) web resource to assess the quality of medical information. However, the overall quality of evidence on effectiveness was only moderate. Identifying search keywords to learn about the outbreak or crises, is the initial tool for predicting the adverse effects on the individual, family, community and population health, as well as impacts at health systems and societal levels. The implemented interventions for infodemic management are summarized in Supplementary Table S2.

4 Discussion

This systematic review was conducted to explore how health authorities and other organizations working in health attempted to address the COVID-19 infodemic and assessed the effectiveness of these interventions. Although an infodemic consists of questions, concerns, information voids, and circulating narratives, including mis- and disinformation, most of the studies focused only on the misinformation element. It is estimated that only 0.2–28.8% of Twitter, Facebook, YouTube, and Instagram posts were of health-related misinformation (29, 30). This means that interventions that are reported in this review are dressing only a small part of the health information that is circulating at any one time in the information environment, and it is not comprehensive in its approach. Moreover, agreement is reported on the critical role of social media in addressing misinformation during crises (29), but again focuses only on digital environments and only on misinformation.

Although harmful impacts of health misinformation were experienced by a diverse set of health programs in the past, it was a niche area of academic research and practice in globally funded programs like immunization. Moreover, the terminology to describe the science and understanding of the complex challenge of the information environment on people's risk perceptions and behaviors during acute health events changed and evolved over time. A common language, definitions of risk assessment approach, multilevel interventions and systems for health authorities can address it in a systematic, evidence-based way, only gained traction after 2020. This was associated with the evolution and investment into promoting the uptake of public health and social measures, and demand for treatments, diagnostics, and vaccines during the biggest pandemic the world experience in recent memory. The studies that are included in this systematic review were, therefore, unsurprisingly published between 2021 and 2023.

The WHO defined infodemic management as the systematic use of evidence-based risk analysis, and approaches to manage the infodemics and reduce any negative impact on health behaviors during emergencies (1, 9). Purnat et al. (9) discuss the infodemic management framework as the main component for health organizations to ensure that health system's communications, services, actions, and interventions are meeting the needs of different populations and therefore enjoy the trust necessary to be resilient to information overload, unsettled science, inaccurate information and misinformation. One review, discussing social media platforms, suggests that together with improving people's digital and health literacy, multi-sectorial action, governance policies, and implementing awareness campaigns, are all urgently needed (29).

Different countries responded to the COVID-19 pandemic and the associated infodemic by implementing digital interventions. For example, the Kingdom of Saudi Arabia hosted the Riyadh Global Digital Health Summit, which articulated nine recommendations for data communication and digital health that need to be adopted by the global health community to address future pandemics and health threats (31). The Riyadh Summit committee was looking to build on the declaration and to provide a resource and toolkit to develop digital health infrastructure at national and supranational levels to prepare for future health threats (31). The estimated budget for implementing such an initiative was equivalent to US$2.5 billion annually in Low- and Middle-Income Countries. In this review, only Yemen and Pakistan, as Low- and Middle-Income Countries, responded to the COVID-19 pandemic and infodemic (32, 33).

Around third of included studies were characterizing the flow of information by using Web and scientific database searches. Examples

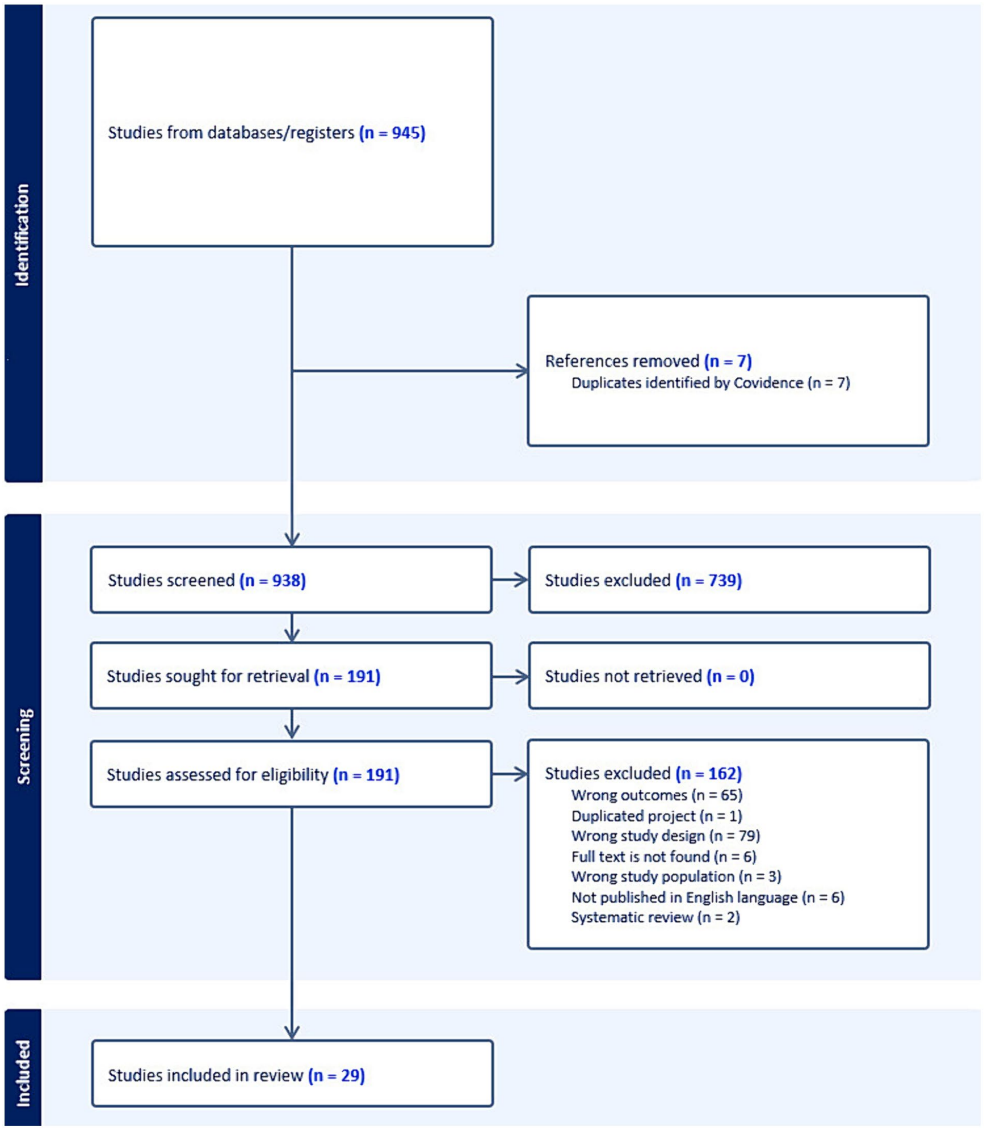


FIGURE 1
PRISMA for the literature selection process.

include developing a global search index based on Google Trends data and combining it with keywords to predict people's offline attitudes and behaviors in the context of public health and social measures. It found that the most searched keywords to learn about the COVID-19 pandemic, during the first 6 months after the SARS-CoV-2 outbreak (1 January to 30 June 2020), were "pastCoVepidemics" and "presCoVpandemic" (34). In addition, it identified the predictors of people's behavior toward public health measures, and they were "social distancing," "wash hands," "isolation," and "quarantine" (34). Another study created a codebook of online English-language anti-vaccination narratives and rhetoric and identified the nine most used codes. They were "Corrupt Elites," "Vaccine Injury," "Sinister Origins," "Freedom Under Siege," "Health Freedom," "Think of the Children," "Do Your Own Research," "Heroes and Freedom Fighters," and "Panic Button" from YouTube, Twitter, Facebook, and Instagram platforms (35). In addition, in Spain, the COVID-19 typology was identified by analyzing the science and health-related hoaxes that spread during the pandemic. This can serve as a preliminary framework for future research and can help develop systems for automated detection of health and science-related hoaxes. According to their connection to scientific knowledge, the four types were "hasty" science, decontextualized science, badly interpreted science, and falsehood without a scientific basis (36). Analysis of Facebook and Twitter posts in Finland helped develop a risk perception framework that included knowledge, perceptions, personal experiences, trust, attitudes, and cultural values that could be used as search terms to monitor public risk perception in future pandemics and to inform formulating effective messages (37).

In Russia, analysis of text from social media was used to model the detection of social stress in users. It used a neural network and linguistic analysis methods to assess users' perception of government actions and identified points of tension in matters of communication during emergencies. It aims at improving the interaction between the government and society and to timely adjust government plans and actions to ensure resilience in emergencies for public health purposes (38).

Online surveys and analysis of epidemiological data were implemented in high-income countries such as Hong Kong, Japan, South Korea, Singapore, the UK, the USA, Italy, and New Zealand. These surveys aimed to investigate the relationship between infodemic with vaccine willingness and uptake, the strictness of public health and social measures, COVID-19 vaccine coverage, and health literacy (39–41).

Digital tools and technologies were used to address the challenge of synthesizing unsettled science and informing science translation and communication. EpidemiXs has been used by 30 health institutions in Spain, and a novel ecosystem of digital tools centralizing official and validated information on COVID-19 for health workers and the public in a single hub. EpidemiXs reached 1 million users and 2 million views in March 2020. It served as an evidence aggregation and science translation function, covering over 150 COVID-19-related studies in easy-to-understand and user-friendly formats. This made the scientific evidence more accessible to the public (42). In another example, Illinois-based medical professionals developed the IMPACT amplifier to facilitate interdisciplinary discussion and coordinate action. This tool allows the dissemination of accurate medical information and debunks misinformation while minimizing harm related to personal and professional harassment that can come with social media advocacy (43). In addition, the UK National Institute of Health and Clinical Excellence (NICE) in the UK adopted three automation approaches to evidence review and synthesis to facilitate faster processing of the new COVID-19 evidence in the production of surveillance guidelines. This approach demonstrated that human analysts accepted the assistance of machine-learning technology and showed that the approach was as good as using human analysts in the evidence search and synthesis process (44).

This study has several limitations. As health authorities and other sectors of society responded to the global COVID-19 pandemic and effects of the infodemic in their communities, much of the experience and knowledge that was gained from the response still needs to be evaluated and reported. Close to 4 years after the start of the COVID-19 pandemic, there are still gaps in the evaluation and reporting of the experience from national health authorities and other organizations working in health. This gap is apparent when comparing reporting of infodemic management projects at WHO infodemic management conferences, at conferences of national and regional public health association's or on social and behavior change, digital society, health communications, or broader complexity science, misinformation, or epidemiological topics, for example. Challenges in capturing this arose due to the dynamic nature of the COVID-19 epidemiology globally and locally. As seen in the transition from public health and social measures to manage the pandemic, to the introduction of vaccines. Another example is, the refocus of the health systems to restoration of essential health services and programs while dealing with the impact of the pandemic on the essential health services, notably the burnout of health workers. Furthermore, the changing information environment in relation to attempts to regulate digital platforms and counter hate speech along with technologies like generative AI, contributed. As did the effects of pandemic fatigue on the attitudes of populations in relation to recommended health guidance. These continue to be challenges most health authorities struggle with today. As the information environment, epidemiology, health system priorities and capacities were changing, so did the actions and strategies used. This might have additionally slowed the evaluation and reporting of strategies and interventions used for infodemic management. This systematic review captures a snapshot of the evidence as available at this time and shows the need to systematically capture the evolution of evidence reported and generated. Such rapidly growing fields of research and practice are an example for establishment of living literature reviews that are updated regularly. This has also been recognized by the WHO as a process of setting up a structure for a living evidence gap map on infodemic management interventions (27).

Because the field is so new, it is also possible that this review might have missed studies that were not using the keywords that the field is using today, but rather were published in with the language and frameworks that are specific to their scientific discipline. For example, health promotion and commercial determinant of health, digital sociology, participatory action research, health literacy, information science and information related behaviors. Also those in topics tangential to health and infodemics, such as climate change misinformation, and misinformation during elections, cybersecurity, or health equity. Consequently, the studies that were included in this review do not cover the complex online-offline information environments (45, 46), and focus on social media and text messaging instead of social relationships, designed environments, and differentials of impact of content in different communities (47–49), and miss the person-centric understanding of what kind of information did they have (13, 50).

Infodemic management is a public health practice that has supported the response to the COVID-19 pandemic and other outbreaks since 2020, such as Ebola, diphtheria, mpox, measles, and polio. It is likely many interventions and practices that have been used in the field have not yet been reported in the literature by practitioners; this is evident by the number of reports from the field and from many countries and health authorities globally that presented and participated in WHO infodemic management conferences, but that has not yet been reported in the research literature. Moreover, the evaluation frameworks related to health information and health behaviors in the scope of infodemic management are still in development and are difficult to implement, which may have also contributed to the lag in publication. The WHO infodemiology research agenda emphasized implementation research and human-centered design approaches to speed up the generation of knowledge based on infodemic management interventions and strategies, as well as their transferability across health topics and contexts.

Moreover, the included studies showed the diversity of focus in the components of the infodemic (some focusing only on misinformation, or disinformation, on the changing scientific knowledge base, on people's questions, etc.), or on either online or offline spaces. Because the infodemic phenomenon is so complex and encompasses the entirety of the information environment's interaction with the health system, future work might consider reporting the focus of the study as an attribute in the analysis.

5 Conclusion

Most of the infodemic management interventions in this study implement a simple understanding of the WHO infodemic management framework which has itself rapidly matured over time since 2020. Future investments, strategies, and interventions should empower health authorities and health workers to apply the evidence-based and risk assessment to monitoring, detecting, and intervening on infodemic

challenges, as well as learning from the experience and strengthening the systems to improve operations and develop more mature infodemic management systems and strategies. Moreover, a strong infodemic management function in a health authority at national and subnational level will promote better recognition of infodemic and misinformation. It will inform the delivery of communications, engagement, services, and interventions that are acceptable and usable by communities they serve. Some resources from the WHO that can help build capacity in the workforce and plan integration of infodemic management into routine processes are the WHO/UNICEF manual on how to build an infodemic insights report (51), an OpenWHO infodemic management eLearning channel (52), and the WHO competency framework for building a workforce to manage infodemics (12).

Strengthening health and digital literacy, engaging and empowering communities via participatory design, implementation and evaluation methods therefore are a priority. The COVID-19 infodemic was a great leveler; no one country mitigated the harmful effects of the COVID-19 infodemic easily. International collaboration, new partnerships across parts of society, and risk-based interventions and policies by health authorities are needed to tackle this. As declared in the hosted Riyadh Global Digital Health Summit, developing a resilient infodemic management plan, and creating curricula to elevate workforce skills and capabilities is urgently required.

Author contributions

LA: Conceptualization, Writing – review & editing, Supervision, Data curation, Formal analysis, Investigation, Methodology, Software, Validation, Writing – original draft. TP: Conceptualization, Writing – review & editing. CT: Writing – review & editing, Data curation. ZA: Writing – review & editing, Data curation. ED: Writing – review & editing, Conceptualization. SR: Conceptualization, Writing – review & editing, Supervision.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Acknowledgments

The Department of Primary Care and Public Health at Imperial College London is grateful for support from the NIHR Applied Research Collaborations (ARC) Northwest London and the NIHR Biomedical Research Centre. Thank you to Rachel Barker for proofreading this manuscript.

Conflict of interest

SR and TP are members of the WHO Technical Consultation on Building a Global University. Curriculum for Infodemic Management/ Belgrade, Serbia, 21–22 March 2023.

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

Publisher's note

Author disclaimer

The views expressed in this publication are those of the authors and not necessarily those of the NIHR or the Department of Health and Social Care.

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1343902/full#supplementary-material

References

1. World Health Organisation. *Understanding the infodemic and misinformation in the fight against COVID-19*. Pan American Health Organization (2020). Available at: https://iris.paho.org/bitstream/handle/10665.2/52052/Factsheetinfodemic_eng.pdf

2. Tangcharoensathien V, Calleja N, Nguyen T, Purnat T, D'Agostino M, Garcia-Saiso S, et al. Framework for managing the COVID-19 infodemic: methods and results of an online, crowdsourced WHO technical consultation. *J Med Internet Res.* (2020) 22:e19659. doi: 10.2196/19659

3. Ishizumi A, Yau B. Key concepts and definitions in infodemic management In: *Managing infodemics in the 21st century*. Cham: Springer (2023). 17–25.

4. Briand S, Hess S, Nguyen T, Purnat TD. Infodemic management in the twenty-first century In: *Managing infodemics in the 21st century*. Cham: Springer (2023). 1–16.

5. Lorini C, del Riccio M, Zanobini P, Biasio RL, Bonanni P, Giorgetti D, et al. Vaccination as a social practice: towards a definition of personal, community, population, and organizational vaccine literacy. *BMC Public Health*. (2023) 23:1501. doi: 10.1186/s12889-023-16437-6

6. Sørensen K, Van den Broucke S, Fullam J, Doyle G, Pelikan J, Slonska Z, et al. Health literacy and public health: a systematic review and integration of definitions and models. *BMC Public Health*. (2012) 12:80. doi: 10.1186/1471-2458-12-80

7. Wilhelm E, Ballalai I, Belanger ME, Benjamin P, Bertrand-Ferrandis C, Bezbaruah S, et al. Measuring the burden of infodemics: summary of the methods and results of the fifth WHO Infodemic management conference. *JMIR Infodemiol.* (2023) 3:e44207. doi: 10.2196/44207

8. Abad N, Bonner KE, Kolis J, Brookmeyer KA, Voegeli C, Lee JT, et al. Strengthening COVID-19 vaccine confidence & demand during the US COVID-19 emergency response. *Vaccine*. (2024). doi: 10.1016/j.vaccine.2024.01.029

9. Purnat TD, Nguyen T, Briand S. *Managing Infodemics in the 21st century: addressing new public health challenges in the information ecosystem* Springer Nature (2023).

10. Stewart R, Madonsela A, Tshabalala N, Etale L, Theunissen N. The importance of social media users' responses in tackling digital COVID-19 misinformation in Africa. *Digit Health*. (2022) 8:20552076221085070. doi: 10.1177/20552076221085070

11. World Health Organisation. *An overview of infodemic management during COVID-19 pandemic, January 2020–July 2022*. Geneva: World Health Organization (2023).

12. Rubinelli S, Purnat TD, Wilhelm E, Traicoff D, Namageyo-Funa A, Thomson A, et al. WHO competency framework for health authorities and institutions to manage

infodemics: its development and features. *Hum Resour Health*. (2022) 20:35. doi: 10.1186/s12960-022-00733-0

13. Dunn AG, Purnat TD, Ishizumi A, Nguyen T, Briand S. Measuring the burden of infodemics with a research toolkit for connecting information exposure, trust, and health behaviours. *Arch Public Health*. (2023) 81:1–8. doi: 10.1186/s13690-023-01101-7

14. White BK, Gombert A, Nguyen T, Yau B, Ishizumi A, Kirchner L, et al. Using machine learning technology (early artificial intelligence–supported response with social listening platform) to enhance digital social understanding for the COVID-19 Infodemic: development and implementation study. *JMIR Infodemiol*. (2023) 3:e47317. doi: 10.2196/47317

15. Elkin JA, McDowell M, Yau B, Machiri SV, Pal S, Briand S, et al. The good talk! A serious game to boost People's competence to have open conversations about COVID-19: protocol for a randomized controlled trial. *JMIR Res Protoc*. (2023) 12:e40753. doi: 10.2196/40753

16. Purnat TD, Vacca P, Czerniak C, Ball S, Burzo S, Zecchin T, et al. Infodemic signal detection during the COVID-19 pandemic: development of a methodology for identifying potential information voids in online conversations. *JMIR Infodemiol*. (2021) 1:e30971. doi: 10.2196/30971

17. World Health Organisation African Region. *The Africa Infodemic response Alliance*. (2023) Available at: https://www.afro.who.int/aira (Accessed November 8, 2023).

18. World Health Organisation. *WHO competency framework: building a response workforce to manage infodemics*. (2021).

19. Boender TS, Schneider PH, Houareau C, Wehrli S, Purnat TD, Ishizumi A, et al. Establishing Infodemic Management in Germany: a framework for social listening and integrated analysis to report Infodemic insights at the National Public Health Institute. *JMIR Infodemiol*. (2023) 3:e43646. doi: 10.2196/43646

20. World Health Organisation. *Preparedness and resilience for emerging threats—module 1: planning for respiratory pathogen pandemics*. Version 1.0. (2023).

21. World Health Organisation. *Strengthening the global architecture for health emergency prevention, preparedness, response and resilience*. (2023).

22. World Health Organisation. *Pandemic influenza preparedness framework: partnership contribution high-level implementation plan III 2024-2030* World Health Organization (2023).

23. WHO, GAVI, and UNICEF and Partners. *Operational framework for demand promotion—integration of COVID-19 vaccination into routine immunization and primary health care 2023*. Available at: https://demandhub.org/operational-framework-for-demand-promotion/ (Accessed November 18, 2023).

24. European Centre for Disease Prevention and Control. *Core competencies for EU public health epidemiologists in communicable disease surveillance and response*. (2022) Available at: https://www.ecdc.europa.eu/en/news-events/competencies-applied-epidemiologists-now-available-all-eueea-languages (Accessed November 8, 2023).

25. Nigeria Centre for Disease Control and Prevention. *NCDC & Partners Launch Media Fellowship to strengthen health reporting in Nigeria*. (2023). Available at: https://ncdc.gov.ng/news/490/ncdc-%26-partners-launch-media-fellowship-to-strengthen-health-reporting-in-nigeria (Accessed 8 November 2023).

26. World Health Organisation. *Country health authorities track*. (2023). Available at: https://www.who.int/teams/epi-win/infodemic-management/3rd-virtual-global-who-infodemic-management-conference/country-health-authorities-track (Accessed 18 November 2023).

27. Purnat T, Pundir P, Machiri S, Ishizumi A, Rajwar E, Murthy S, et al. Evidence and gap map of infodemic management interventions in emergencies: a case of COVID-19. *Eur J Pub Health*. (2023) 33:ckad160.1676. doi: 10.1093/eurpub/ckad160.1676

28. Moretti V, Arnoldo L, Valdi G, Conte A, Masoni M, Guelfi MR, et al. Digital health literacy and Infodemic: the impact on Italian medical students between 2019-2020. *Eur J Pub Health*. (2022) 32:ckac130.063. doi: 10.1093/eurpub/ckac130.063

29. BorgesdoNascimento IJ, Pizarro AB, Almeida JM, Azzopardi-Muscat N, Gonçalves MA, Björklund M, et al. Infodemics and health misinformation: a systematic review of reviews. *Bull World Health Organ*. (2022) 100:544–61. doi: 10.2471/BLT.21.287654

30. Gabarron E, Oyeyemi SO, Wynn R. COVID-19-related misinformation on social media: a systematic review. *Bull World Health Organ*. (2021) 99:455–463A. doi: 10.2471/BLT.20.276782

31. AlKnawy B, Kozlakidis Z, Tarkoma S, Bates D, Honkela A, Crooks G, et al. Digital public health leadership in the global fight for health security. *BMJ Glob Health*. (2023) 8:e011454. doi: 10.1136/bmjgh-2022-011454

32. Abbas J, Wang D, Su Z, Ziapour A. The role of social media in the advent of COVID-19 pandemic: crisis management, mental health challenges and implications. *Risk Manag Healthc Policy*. (2021) 14:1917–32. doi: 10.2147/RMHP.S284313

33. Al-Aghbari AAA, Hassan OEH, Iang MD, Jahn A, Horstick O, Dureab F. Exploring the role of Infodemics in People's incompliance with preventive measures during the COVID-19 in conflict settings (mixed method study). *Healthcare*. (2023) 11:952. doi: 10.3390/healthcare11070952

34. Akpan IJ, Aguolu OG, Kobara YM, Razavi R, Akpan AA, Shanker M. Association between what people learned about COVID-19 using web searches and their behavior toward public health guidelines: empirical infodemiology study. *J Med Internet Res*. (2021) 23:e28975. doi: 10.2196/28975

35. Hughes B, Miller-Idriss C, Piltch-Loeb R, Goldberg B, White K, Criezis M, et al. Development of a codebook of online anti-vaccination rhetoric to manage COVID-19 vaccine misinformation. *Int J Environ Res Public Health*. (2021) 18:7556. doi: 10.3390/ijerph18147556

36. León B, Martínez-Costa M-P, Salaverría R, López-Goñi I. Health and science-related disinformation on COVID-19: a content analysis of hoaxes identified by fact-checkers in Spain. *PLoS One*. (2022) 17:e0265995. doi: 10.1371/journal.pone.0265995

37. Lohiniva A-L, Pensola A, Hyökki S, Sivelä J, Tammi T. COVID-19 risk perception framework of the public: an infodemic tool for future pandemics and epidemics. *BMC Public Health*. (2022) 22:2124. doi: 10.1186/s12889-022-14563-1

38. Raskhodchikov AN, Pilgun M. COVID-19 and public health: analysis of opinions in social media. *Int J Environ Res Public Health*. (2023) 20:971. doi: 10.3390/ijerph20020971

39. Chen X, Lee W, Lin F. Infodemic, institutional trust, and COVID-19 vaccine hesitancy: a cross-national survey. *Int J Environ Res Public Health*. (2022) 19:8033. doi: 10.3390/ijerph19138033

40. Etta G, Galeazzi A, Hutchings JR, James Smith CS, Conti M, Quattrociocchi W, et al. COVID-19 infodemic on Facebook and containment measures in Italy, United Kingdom and New Zealand. *PLoS One*. (2022) 17:e0267022. doi: 10.1371/journal.pone.0267022

41. Feinberg I, Scott JY, Holland DP, Lyn R, Scott LC, Maloney KM, et al. The relationship between health literacy and COVID-19 vaccination prevalence during a rapidly evolving pandemic and Infodemic. *Vaccine*. (2022) 10:1989. doi: 10.3390/vaccines10121989

42. Lemaire J, Ramil E, Thouvenot VI, Pons JS. EpidemiXs: harnessing digital technology in the fight against COVID-19 and the associated infodemic. *Technol Health Care*. (2022) 30:509–12. doi: 10.3233/THC-213567

43. Royan R, Pendergrast TR, del Rios M, Rotolo SM, Trueger NS, Bloomgarden E, et al. Use of twitter amplifiers by medical professionals to combat misinformation during the COVID-19 pandemic. *J Med Internet Res*. (2022) 24:e38324. doi: 10.2196/38324

44. Sood M, Sharp S, McFarlane E, Willans R, Hopkins K, Karpusheff J, et al. Managing the evidence infodemic: automation approaches used for developing NICE COVID-19 living guidelines. *medRxiv*. (2022). doi: 10.1101/2022.06.13.22276242

45. Eminente C, Artime O, De Domenico M. Interplay between exogenous triggers and endogenous behavioral changes in contagion processes on social networks. *Chaos, Solitons Fractals*. (2022) 165:112759. doi: 10.1016/j.chaos.2022.112759

46. d'Andrea V, Artime O, Castaldo N, Sacco P, Gallotti R, de Domenico M. Epidemic proximity and imitation dynamics drive infodemic waves during the COVID-19 pandemic. *Phys Rev Res*. (2022) 4:013158. doi: 10.1103/PhysRevResearch.4.013158

47. Illari L, Restrepo NJ, Johnson NF. Rise of post-pandemic resilience across the distrust ecosystem. *Sci Rep*. (2023) 13:15640. doi: 10.1038/s41598-023-42893-6

48. Illari L, Restrepo NJ, Johnson NF. Losing the battle over best-science guidance early in a crisis: COVID-19 and beyond. Science. *Advances*. (2022) 8:eabo8017. doi: 10.1126/sciadv.abo8017

49. Nyhan B, Settle J, Thorson E, Wojcieszak M, Barberá P, Chen AY, et al. Like-minded sources on Facebook are prevalent but not polarizing. *Nature*. (2023) 620:137–44. doi: 10.1038/s41586-023-06297-w

50. Scales D, Gorman JM, DiCaprio P, Hurth L, Radhakrishnan M, Windham S, et al. Community-oriented motivational interviewing (MI): a novel framework extending MI to address COVID-19 vaccine misinformation in online social media platforms. *Comput Hum Behav*. (2023) 141:107609. doi: 10.1016/j.chb.2022.107609

51. Purnat T, Wilhelm E, Abeyesekera S, White BK, Hassan N, Pastorino A, et al. A WHO/UNICEF manual for health workforce on how to build an infodemic insights report in 6 steps. *Eur J Pub Health*. (2023) 33:ckad160.560. doi: 10.1093/eurpub/ckad160.560

52. Purnat T, Bertrand-Ferrnadis C, Wilhelm E, Utunen H, Briand S, Nguyen T. Building a comprehensive online course series to enhance infodemic management globally. *Eur J Pub Health*. (2023) 33:ckad160.1473. doi: 10.1093/eurpub/ckad160.1473

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 15 March 2024
DOI 10.3389/fpubh.2024.1340614

OPEN ACCESS

EDITED BY
Fatjona Kamberi,
University of Vlorë, Albania

REVIEWED BY
Rezarta Lalo,
University of Vlorë, Albania
Luiz Ricardo Berbert,
Federal University of Rio de Janeiro, Brazil

*CORRESPONDENCE
Sami Hamdan Alzahrani
✉ salzahrani4@kau.edu.sa

RECEIVED 18 November 2023
ACCEPTED 01 March 2024
PUBLISHED 15 March 2024

CITATION
Alzahrani SH (2024) The impact of health beliefs and trust in health information sources on SARS-CoV-2 vaccine uptake.
Front. Public Health 12:1340614.
doi: 10.3389/fpubh.2024.1340614

The impact of health beliefs and trust in health information sources on SARS-CoV-2 vaccine uptake

Sami Hamdan Alzahrani[1,2]*

[1]Family Medicine Department, Faculty of Medicine, King Abdulaziz University, Jeddah, Saudi Arabia, [2]Health Promotion Center Research Group, Deanship of Scientific Research, King Abdulaziz University, Jeddah, Saudi Arabia

Background: Health beliefs may mediate the relationship between trust and vaccination decisions, as confidence in online health information has expanded quickly. However, little is known about how health attitudes and trust in health information affect COVID-19 vaccine intention. This study aimed to assess the effect of health beliefs and trust in information sources on the willingness to receive a COVID-19 vaccine among the general public in Saudi Arabia.

Methods: This study was designed and carried out at the Faculty of Medicine, King Abdulaziz University, Jeddah, Saudi Arabia. Selected items were extracted from the Saudi Residents' Intention to Get Vaccinated Against COVID-19 (SRIGVAC) survey. They were categorized and validated into constructs of a health belief model (the perceived threat of COVID-19, vaccine-related benefits, barriers, and safety concerns) and trust in health information (from online platforms and health authorities/providers). Regression analysis and parallel mediation were used to assess the predictors of vaccination intentions.

Results: Based on the responses of 3,091 participants, vaccine-related barriers and safety concerns negatively influenced vaccination intention, whereas vaccine benefits and the perceived threat of COVID-19 were positively correlated with vaccination intention. Trust in online health information had a direct relationship with intentions ($\beta = 0.09$, $p < 0.0001$) as well as indirect relationships through the perceived benefits ($\beta = 0.095$), the perceived barriers ($\beta = -0.029$), and the perceived safety concerns toward the vaccine ($\beta = -0.010$). The relationship between the willingness to vaccinate and trust in authentic information was fully mediated by all domains of health beliefs, with indirect coefficients of 0.004, 0.310, −0.134, and −0.031 for the perceived threat, vaccine benefits, barriers, and safety concerns, respectively.

Conclusion: The relationship between the willingness to vaccinate and trust in authentic information was fully mediated by all domains of health beliefs. Vaccine coverage in Saudi Arabia can be optimized by targeting the health beliefs of the general public.

KEYWORDS

trust, COVID-19, vaccine uptake, health communication, health belief

Introduction

The coronavirus disease (COVID-19) has impacted the global public health sector and caused economic, mental, and social turmoil (1). Research and published literature have expanded significantly since the discovery of SARS-CoV-2 to better understand several aspects of the disease, such as transmission, pathophysiology, therapy, diagnostics, vaccine development and utilization, and people's attitudes and misconceptions (2, 3).

There were 830,127 confirmed cases and 9,618 deaths, and 77.58% of the population received at least one dose till March 10, 2023 (4). The COVID-19 vaccination hesitancy rates in the United States range from 2.69 to 26.7% (5). A Saudi survey revealed that 36.9% of people hesitated to vaccinate (6). Behavioral determinants for COVID-19 vaccination are important because they determine whether people choose to be vaccinated or not. Understanding and managing these behavioral variables allows public health efforts to be more focused, resulting in increased vaccination acceptance and higher levels of population immunity, which is critical for preventing the development of infectious illnesses such as COVID-19. Understanding these determinants also allows public health officials, lawmakers, and healthcare professionals to develop effective vaccination promotion initiatives.

In Saudi Arabia, various trustworthy sources of information on COVID-19 exist, including the Saudi Ministry of Health (MOH), the Saudi Center for Disease Prevention and Control (Weqaya), the Saudi Press Agency, and local health agencies. The Saudi Ministry of Health's official website featured COVID-19-related information, directives, and resources. It contains information about testing, vaccination, and health measures. The Weqaya platform offered COVID-19 information, such as statistics, guidelines, and resources. It offered updates on the situation in Saudi Arabia as well as preventive measures.

Several COVID-19 vaccines have been authorized and are now being used globally (7). Estimates indicate that approximately 60–70% of the general public should be vaccinated to attain herd immunity (8). A data-driven model of SARS-CoV-2 transmission suggested that vaccine-induced herd immunity would require coverage of 93% or higher because not all vaccines have equal efficacy and the emergence of new resistant variants (9). However, the behavioral intentions of individuals to get vaccinated are major determinants of the successful establishment of the threshold of herd immunity. These intentions can be impacted by concerns regarding the rapidity of vaccine development, the perceived barriers to vaccination, and the accumulated data from different sources of information that formulate individuals' perceptions (10, 11).

For this reason, it is important to quantify the behavioral determinants of the general public's desire to get the COVID-19 vaccine via reliable and validated measures. The health belief model (HBM) has been frequently used in the literature to measure the ability of people to make health-related decisions based on distinct variables, including the perceived susceptibility to and severity of a disease, the perceived benefits of engagement in a health-promoting behavior, the perceived barriers, and cues to actions (12). The HBM has been a useful tool for predicting short- and long-term health-related behaviors, and it has been recently validated in studies investigating the behavioral intentions to get the COVID-19 vaccine (13, 14). Nevertheless, scholars have revealed a limited power of the HBM measurements for behavioral prediction, and they suggested extending the variables of HBM models to improve their explanatory power (15, 16).

Concomitantly, focusing on the context of COVID-19, the behavioral intentions might have been affected by other factors that go beyond those utilized in the HBM model. For example, due to the lack of information about the vaccine, individuals may rely on a trusted party to make a risk/benefit-based decision to get the vaccine (17). In essence, the trusted party usually holds the best interests and the expected competence that would ultimately help reduce decision complexity by the individuals (18). Therefore, trust in health information from scientific/evidence-based sources, such as national and international health authorities and healthcare providers, might directly influence the levels of vaccine uptake. The COVID-19 pandemic witnessed a surge in the utilization of social media platforms to obtain information, which was concurrently linked to heightened levels of stress among the general populace (19). Moreover, vaccine acceptance is likely to be affected by the information retrieved from internet sources. This is because trust in health information obtained from online sources and social media has grown rapidly, with approximately 72–83% of individuals seeking medical information in the United States and Europe (20), and 33% of Saudi residents receiving health information from social media on daily and weekly basis (21). Rather than these direct effects, health beliefs may act as potential mediators that alter the relationship between trust and vaccination decisions. However, little is known about the impact and the explanatory power of health beliefs and trust in health information on the intention to get the COVID-19 vaccine, and the knowledge about such a domain in Saudi Arabia is no exception. In the present study, we have adapted multiple items from the questionnaire used in the Saudi Residents' Intention to Get Vaccinated Against COVID-19 (SRIGVAC) study to investigate the role of health beliefs and trust in health information on vaccination intentions among the general public in Saudi Arabia.

Methods

Study design

The study data was derived from the SRIGVAC study (22). In brief, the SRIGVAC study employed a cross-sectional, survey-based design based on a 56-item questionnaire (the items are provided in the Supplementary material), which assessed participants' intentions to receive the COVID-19 vaccine in addition to their personal perceptions about the potential benefits and harms of COVID-19 vaccination, the perceived barriers, and the perceived trust in the sources of information about the vaccine. The study was carried out between "December 25, 2020, and February 15, 2021." All the samples were collected by an online questionnaire. The questionnaire and data collection details have been mentioned in the SRIGVAC study (22). The responses of 3,091 participants had been collected and were previously analyzed for the demographic predictors of the vaccination intent (22).

Ethics statement

protocol of the present study was approved by the Research Ethics Committee (REC) of King Abdulaziz University, Jeddah, Saudi Arabia (Reference No. 422-23-11). Additionally, all experiments were performed in accordance with relevant guidelines and regulations (23–25). Written informed consent was obtained and documented from all participants. They were informed about the nature of the study and the confidentiality of their responses.

Study instrument

Participants were requested to complete a structured online questionnaire distributed digitally via various social media channels (22). The first screen notified potential participants about the survey's objectives and included an informed consent notification. The questionnaire was written in English, but most participants spoke Arabic. Thus, two bilingual translators handled the bidirectional translation. The questionnaire was then revised to increase respondents' comprehension while retaining its content and meaning. A pilot test with fifty individuals from the general public was undertaken to ensure that the questionnaire was comprehensible, and it was then further modified as needed. The questionnaire's reliability was 0.82 and measured by Cronbach's alpha. Two senior faculty members and a medical educationist examined the questionnaire's construct and content validity, and it was modified as recommended. The snowball technique was employed to acquire data due to COVID-19 constraints. The calculated sample size was 770, and we further inflated that number to get valid and generalizable results. The responses of 3,091 participants had been collected and were previously analyzed for the demographic predictors of vaccination intent (22).

Measures

Initially, 35 items were selected based on the study's objectives and conceptual framework. Of them, nine items were related to the demographic and clinical characteristics of the participants, including age, gender, educational level, nationality, current employment status, monthly income, household size, geographic location, and the status of receiving an influenza vaccine recently. Additionally, the participants' behavioral intentions were assessed using a single item: "If the Covid-19 vaccine has become available in your country and it is recommended to you for free by the government, would you likely to receive it?." The responses were graded on a five-point Likert scale, ranging from strongly disagree (1) to strongly agree (5) (Supplementary Table S1). A participant with a high score had a more positive intention to get vaccinated.

Subsequently, the remaining items ($n = 25$) were entered in an exploratory factor analysis (EFA) to classify the retrieved items into valid constructs (the analysis was performed in SPSS v.26, SPSS Inc., Chicago, IL, United States). Based on a Promax rotation method with an Eigenvalue of >1, the EFA indicated a six-factor solution (Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.927, Chi-Square = 6164.21, $p < 0.0001$). The obtained items were categorized into the following domains and constructs: (1) the health beliefs domain, including the perceived threat of COVID-19 ($n = 2$), the perceived benefits of the SARS-CoV-2 vaccine ($n = 5$), the perceived barriers of the vaccine ($n = 6$), and the perceived safety concerns ($n = 7$); (2) the perceived trust domain, including the trust in online sources ($n = 2$) and health authorities and healthcare providers ($n = 3$) as sources of information about the vaccine. Notably, the perceived COVID-19 threat domain included a combination of the susceptibility and severity domains as described previously (26). Additionally, although the perceived barriers domain usually includes safety-related barriers, safety concerns were added to a separate construct to assess its direct effects on the primary outcomes exclusively and to explore its potential interaction with the trust domains on vaccination intentions (27). The obtained constructs from the EFA were further validated in a confirmatory factor analysis (AMOS V.26). The model showed acceptable goodness-of-fit statistics, with a significant chi-square value ($\chi^2 = 2932.50$, df = 293, $p < 0.0001$) and adequate indicators of fit indices (RMSEA = 0.054; CFI = 0.961; TLI = 0.953; GFI = 0.925). Therefore, no additional modifications were carried out. Table 1 shows the descriptive statistics, the response structure, the estimated standardized factor loadings of all items, and the outcomes of the reliability analysis for all domains.

Statistical analysis

SPSS v.26 was used to conduct the statistical analysis. The mean scores of different items, including the variables of health beliefs and trust as well as the intention to get vaccinated scale, were calculated based on the overall mean value of each item. Bivariate associations between the continuous variables were investigated using Pearson's correlation, and the results were presented in a correlation matrix. The univariate associations between participants' intention to get vaccinated (as a continuous variable) and demographic characteristics were assessed using *t* tests (for gender, nationality, and the previous history of receiving an influenza vaccine) and one-way analysis of variance (ANOVA) for other demographic variables. A three-step hierarchical linear multiple regression analysis was employed to explore the predictors of vaccination intention, where the significantly associated factors from the univariate correlation tests were exclusively included as independent variables and the intention to receive the vaccine was the dependent variable. Demographic variables were entered in Block 1, health beliefs variables in Block 2, and trust in information sources in Block 3. Such an approach was used to test whether individuals' trust could influence the likelihood of getting vaccinated against COVID-19, above and beyond demographic characteristics and health beliefs. The results of the regression model were expressed as standardized regression coefficients (β) and their respective 95% confidence intervals (95%CIs). The amount of variance explained in the model as well as the changes in the amount of variance were presented as R2 and changes in R2, respectively. A *p*-value of < 0.05 indicated statistical significance. Therefore, to assess whether distinct health beliefs have accounted for such relationships, we carried out a parallel mediation analysis using the PROCESS macro in SPSS (28). Such an analysis considers multiple dimensions as potential mediators while accounting for the shared variance between them (28).

TABLE 1 Descriptive and validity statistics of the study measures.

Study measurements	Scale	Mean ± SD	SFL	Cronbach's alpha
Perceived threat of COVID-19				0.750
In your opinion, to what extent does the emerging corona virus, COVID-19, pose a threat to people in your country?	No risk (1)-Very high risk (4)	2.21 ± 0.89	0.887	
In your opinion, to what extent does the emerging corona virus, COVID-19, pose a threat to you?	No risk (1)-Very high risk (4)	1.80 ± 1.09	0.690	
Perceived benefits				0.847
Vaccines are effective in preventing the emerging corona	Strongly Disagree (1)-Strongly Agree (5)	3.43 ± 1.00	0.707	
The new Corona vaccines are safe	Strongly Disagree (1)-Strongly Agree (5)	3.38 ± 1.03	0.841	
The government should enforce everyone to get vaccinated	Strongly Disagree (1)-Strongly Agree (5)	2.87 ± 1.17	0.611	
Vaccines are a big advance for humanity	Strongly Disagree (1)-Strongly Agree (5)	3.93 ± 1.03	0.680	
To protect public health, we must follow government guidelines on vaccines	Strongly Disagree (1)-Strongly Agree (5)	4.05 ± 1.00	0.723	
Perceived barriers				0.938
I will refuse the vaccine because of the side effects	Strongly Disagree (1)-Strongly Agree (5)	2.94 ± 1.15	0.859	
I will refuse the vaccine because the clinical trials are done quickly	Strongly Disagree (1)-Strongly Agree (5)	3.09 ± 1.19	0.819	
I will refuse the vaccine because it will not be effective for preventing infection with the virus	Strongly Disagree (1)-Strongly Agree (5)	2.76 ± 1.12	0.902	
I will refuse the vaccine because the chances of me being at risk of contracting the emerging virus are low, so the vaccination is meaningless	Strongly Disagree (1)-Strongly Agree (5)	2.73 ± 1.16	0.830	
I will refuse the vaccine because the pandemic or vaccinations are a conspiracy of companies or organizations	Strongly Disagree (1)-Strongly Agree (5)	2.43 ± 1.16	0.800	
I will reject the vaccine because the vaccinations represent a trick by the pharmaceutical companies and the organizations that promote them for financial gain	Strongly Disagree (1)-Strongly Agree (5)	2.48 ± 1.18	0.808	
Perceived safety concerns				0.957
Corona vaccines contain mercury in dangerous quantities	Strongly Disagree (1)-Strongly Agree (5)	2.64 ± 0.97	0.773	
Corona vaccines contain dangerous ingredients	Strongly Disagree (1)-Strongly Agree (5)	2.63 ± 1.05	0.831	
Corona vaccines cause autism	Strongly Disagree (1)-Strongly Agree (5)	2.39 ± 1.03	0.873	
Corona vaccines cause infertility in women	Strongly Disagree (1)-Strongly Agree (5)	2.49 ± 1.00	0.902	
Corona vaccines cause infertility in men	Strongly Disagree (1)-Strongly Agree (5)	2.50 ± 0.99	0.896	
Corona vaccines cause AIDS	Strongly Disagree (1)-Strongly Agree (5)	2.24 ± 0.99	0.878	
Corona vaccines cause death	Strongly Disagree (1)-Strongly Agree (5)	2.46 ± 1.05	0.887	
Perceived trust (online sources)				0.789
Evaluate your reliability regarding the information on the new Corona COVID-19 vaccines: websites	Very Unconfident (1)- Very Confident (5)	3.04 ± 1.07	0.820	

(Continued)

TABLE 1 (Continued)

Study measurements	Scale	Mean ± SD	SFL	Cronbach's alpha
Evaluate your reliability regarding the information on the new Corona COVID-19 vaccines: social media applications	Very Unconfident (1)- Very Confident (5)	2.87 ± 1.12	0.795	
Perceived trust (health authorities)				0.791
Evaluate your reliability regarding the information on the new Corona COVID-19 vaccines: Ministry of Health	Very Unconfident (1)- Very Confident (5)	4.29 ± 0.94	0.893	
Evaluate your reliability regarding the information on the new Corona COVID-19 vaccines: WHO	Very Unconfident (1)- Very Confident (5)	3.65 ± 1.20	0.644	
Evaluate your reliability regarding the information on the new Corona COVID-19 vaccines: healthcare providers	Very Unconfident (1)- Very Confident (5)	3.94 ± 0.93	0.764	

SFL, standardized factor loadings.

Results

In the domain of perceived threat of COVID-19, participants perceive a moderate threat of COVID-19 to people in their country (mean = 2.21, SD = 0.89), while participants perceive a lower threat to themselves (mean = 1.80, SD = 1.09). The internal consistency reliability (Cronbach's alpha) for the perceived threat scale was good (0.770). In the domain of perceived barriers, participants express some concerns or potential barriers to vaccination, such as side effects and skepticism about clinical trials. The mean scores for perceived barriers range from 2.43 to 3.09. This section showed high internal consistency with a Cronbach's alpha value of 0.938. In the domain of perceived safety concerns, participants disagree with various misinformation regarding vaccine safety (e.g., mercury content, causing autism or infertility). The mean scores for safety concerns range from 2.24 to 2.64. Internal consistency was good, with a Cronbach's alpha value of 0.957. Other domain scores are shown in Table 1.

Regarding the primary outcome variable, when the participants were asked about their intentions to get the COVID-19 vaccine, 9.8% of the participants responded as "strongly disagree," 10.5% as "disagree," 26.8% as "neither agree nor disagree," 23.2% as "agree," and 29.7% as "strongly agree." The mean ± SD intention score was 3.52 ± 1.28. Univariate analyses showed that the intent to receive the vaccine was significantly higher among males ($p < 0.001$), Saudis ($p < 0.001$), as well as the participants with < secondary education ($p = 0.001$), a monthly income of SAR10,000 or higher ($p = 0.002$), and those residing in the Southern region ($p < 0.001$) compared to their peers. In addition, respondents who had received an influenza vaccine were significantly more likely to be willing to get vaccinated than those who had not received the vaccine ($p < 0.001$, Table 2).

Table 3 shows the relationship between participants' intention to receive the COVID-19 vaccine and the items of HBM and trust in information sources. Intention to get a COVID-19 vaccine was positively correlated with the perceived threat of COVID-19 and the perceived benefits of the vaccine, while it was negatively correlated with the perceived barriers and the perceived safety concerns toward the vaccine. In addition, willingness to get the vaccine was positively associated with the perceived trust in online information sources and information obtained from health authorities/healthcare providers (Table 3).

The significantly associated categorical and continuous variables with the intention to receive the COVID-19 vaccine (Tables 2, 3) were further entered in hierarchical multivariate regression models to test the independent predictors of the intent to vaccinate (Table 4). The control model containing the demographic variables (Model 1) explained 9.4% of the variation in vaccination intention, which increased with the addition of trust variables (29.1% for Model 2) and health beliefs variables (58.4% for Model 3).

Regarding trust variables, vaccination intention was predicted by individuals' trust in health information sources from online platforms ($\beta = 0.06$, $p = 0.004$) and authentic sources ($\beta = 0.64$, $p < 0.001$, Model 2). However, with the addition of health beliefs variables to the model (Model 3), the willingness to vaccinate was independently associated with trust in online information ($\beta = 0.09$, $p < 0.001$) but not with trust in authentic health information (Table 4).

These results indicate that health beliefs have partially mediated the relationship between trust in online sources and vaccination intentions, and fully mediated the relationship between trust in authentic sources and vaccination intentions. Two separate mediation models were conducted, where each variable of trust in information sources was entered as a predictor variable in each model, health beliefs variables as parallel mediators, vaccination intention as a dependent variable, and demographic predictors as covariates (Figure 1). Based on a 95% bias-corrected confidence interval of 1,000 bootstrap samples, the indirect effect of trust in online information through the perceived benefits of the vaccine was entirely above zero ($\beta = 0.095$, 95% CI, 0.075 to 0.117), while the indirect effects through the perceived barriers and the perceived safety concerns were below zero ($\beta = -0.029$, 95%CI, −0.043 to −0.015 and $\beta = -0.010$, 95%CI, −0.016 to −0.004, respectively, Figure 1A). Additionally, the indirect coefficients for the relationship between trust in authentic information and vaccination intention were significant via all domains of the HBM, including the perceived threat of COVID-19 ($\beta = 0.004$, 95%CI, 0.001 to 0.008), the perceived benefits of the vaccine ($\beta = 0.310$, 95%CI, 0.281 to 0.337), the perceived barriers to vaccination ($\beta = -0.134$, 95%CI, −0.156 to −0.114), and the perceived safety concerns ($\beta = -0.031$, 95%CI, −0.045 to −0.017, Figure 1B).

Discussion

Understanding the predictors of vaccine uptake is crucial to determine the reasons for vaccine hesitancy and promote vaccine coverage. Our results indicated that 52.9% of adults in the general public intend to receive the COVID-19 vaccine, which is lower than the required threshold for achieving herd immunity (8). As such, it is

TABLE 2 Demographic differences in the intention to get the COVID-19 vaccine.

Parameter	Category	Mean	SD	*p*-value
Age	18–29 y	3.56	1.27	0.066
	30–44 y	3.46	1.31	
	45–59 y	3.59	1.25	
	≥60 y	3.83	1.05	
Gender	Female	3.32	1.31	<0.001*
	Male	3.84	1.16	
Nationality	Saudi	3.56	1.27	<0.001*
	Non-Saudi	3.24	1.36	
Educational level	<Secondary education	4.21	0.93	0.001*
	Secondary	3.37	1.31	
	University	3.53	1.28	
	Post-graduate	3.53	1.28	
Employment status	Employed-Government	3.57	1.26	0.388
	Private/self-employed	3.51	1.34	
	Student	3.54	1.26	
	Not working	3.46	1.29	
Monthly income (SAR)	<3,000	3.51	1.28	0.002*
	3,000–10,000	3.43	1.32	
	>10,000–25,000	3.60	1.24	
	>25,000	3.86	1.20	
Household size	1–3	3.49	1.29	0.055
	4–6	3.50	1.27	
	7–9	3.52	1.29	
	≥10	3.71	1.30	
Geographic location	Western	3.53	1.25	<0.001*
	Eastern	3.45	1.33	
	Northern	3.38	1.30	
	Central	3.37	1.36	
	Southern	3.88	1.18	
Received an influenza vaccine shot in the past year	Yes	3.87	1.17	<0.001*
	No	3.28	1.30	

*p-value of < 0.05 indicated statistical significance.

TABLE 3 Correlation matrix for the relationships between COVID-19 vaccine uptake and the variables of the health beliefs model and trust in information sources.

Variable	1	2	3	4	5	6
1. Intention to get the vaccine						
2. Perceived threat of COVID-19	0.118**					
3. Perceived benefits	0.703**	0.083**				
4. Perceived barriers	−0.573**	−0.093**	−0.553**			
5. Perceived safety concerns	−0.408**	−0.016	−0.459**	0.701**		
6. Perceived trust in online sources	0.138**	−0.021	0.163**	0.075**	0.118**	
7. Perceived trust in health authorities or healthcare providers	0.431**	0.095**	0.549**	−0.402**	−0.363**	0.202**

*p-value of < 0.05 indicated statistical significance.

important to assess the independent personal health beliefs associated with vaccine acceptance and the main trusted parties that could communicate vaccine-related information as perceived by the general public. The results of the present study showed that health beliefs and trust in online information were independent predictors of vaccine acceptance. All the domains of HBM have fully mediated the

TABLE 4 The results of the hierarchical regression analysis for the predictor of vaccination intentions among the general public in Saudi Arabia.

Parameter	Estimate	Model 1		Model 2		Model 3	
		Beta (95% CI)	*p*-value	Beta (95% CI)	*p*-value	Beta (95% CI)	*p*-value
	Adjusted R2	0.092		0.291		0.584	
	ΔR2	0.094		0.199		0.293	
Gender	Male	0.53 (0.44 to 0.63)	<0.0001	0.46 (0.38 to 0.55)	<0.0001	0.24 (0.18 to 0.31)	<0.001*
	Female	Ref		Ref		Ref	
Nationality	Saudi	0.34 (0.19 to 0.48)	<0.0001	0.29 (0.16 to 0.42)	0.086	0.10 (0.05 to 0.20)	0.048*
	Non-Saudi	Ref		Ref		Ref	
Educational level	<Secondary education	0.65 (0.26 to 1.03)	0.001	0.40 (0.06 to 0.74)	0.022	0.54 (0.28 to 0.81)	<0.001*
	Secondary	−0.12 (−0.30 to 0.06)	0.184	−0.09 (−0.25 to 0.07)	0.272	0.10 (−0.03 to 0.22)	0.126
	University	0.03 (−0.09 to 0.15)	0.655	0.02 (−0.09 to 0.13)	0.732	0.07 (−0.02 to 0.15)	0.113
	Post-graduate	Ref		Ref		Ref	
Monthly income (SAR)	<3,000	−0.03 (−0.28 to 0.22)	0.795	−0.09 (−0.31 to 0.13)	0.405	0.001 (−0.17 to 0.17)	0.973
	3,000–10,000	−0.26 (−0.51 to −0.02)	0.037	−0.25 (−0.47 to −0.03)	0.026	−0.11 (−0.28 to 0.06)	0.188
	>10,000–25,000	−0.28 (−0.51 to −0.04)	0.025	−0.22 (−0.44 to −0.01)	0.038	−0.09 (−0.25 to 0.07)	0.276
	>25,000	Ref		Ref		Ref	
Geographic location	Western	−0.25 (−0.40 to −0.11)	0.001	−0.20 (−0.33 to −0.07)	0.002	−0.18 (−0.27 to −0.08)	<0.001*
	Eastern	−0.32 (−0.51 to −0.12)	0.001	−0.23 (−0.40 to −0.06)	0.008	−0.18 (−0.31 to −0.05)	0.008*
	Northern	−0.34 (−0.56 to −0.12)	0.002	−0.32 (−0.51 to −0.12)	0.001	−0.21 (−0.36 to −0.06)	0.005*
	Central	−0.35 (−0.52 to −0.18)	<0.0001	−0.24 (−0.39 to −0.09)	0.002	−0.18 (−0.30 to −0.06)	0.003*
	Southern	Ref		Ref		Ref	
Recently received an influenza vaccine	Yes	0.54 (0.63 to 0.45)	<0.0001	0.41 (0.49 to 0.33)	<0.0001	0.19 (0.26 to 0.13)	<0.001*
	No	Ref		Ref		Ref	
Trust in information sources	Trust in information from online sources	NA	NA	0.06 (0.02 to 0.1)	0.004	0.09 (0.06 to 0.12)	<0.001*
Trust in information sources	Trust in information from health authorities	NA	NA	0.64 (0.59 to 0.68)	<0.0001	0.01 (−0.03 to 0.06)	0.633
HBM	Perceived threat of COVID-19	NA	NA	NA	NA	0.04 (0.01 to 0.08)	0.014*
HBM	Perceived benefits	NA	NA	NA	NA	0.79 (0.73 to 0.84)	<0.001*
HBM	Perceived barriers	NA	NA	NA	NA	−0.43 (−0.47 to −0.38)	<0.001*
HBM	Perceived safety concerns	NA	NA	NA	NA	−0.10 (−0.05 to −0.15)	<0.001*

*p-value of < 0.05 indicated statistical significance. HBM, health belief model.

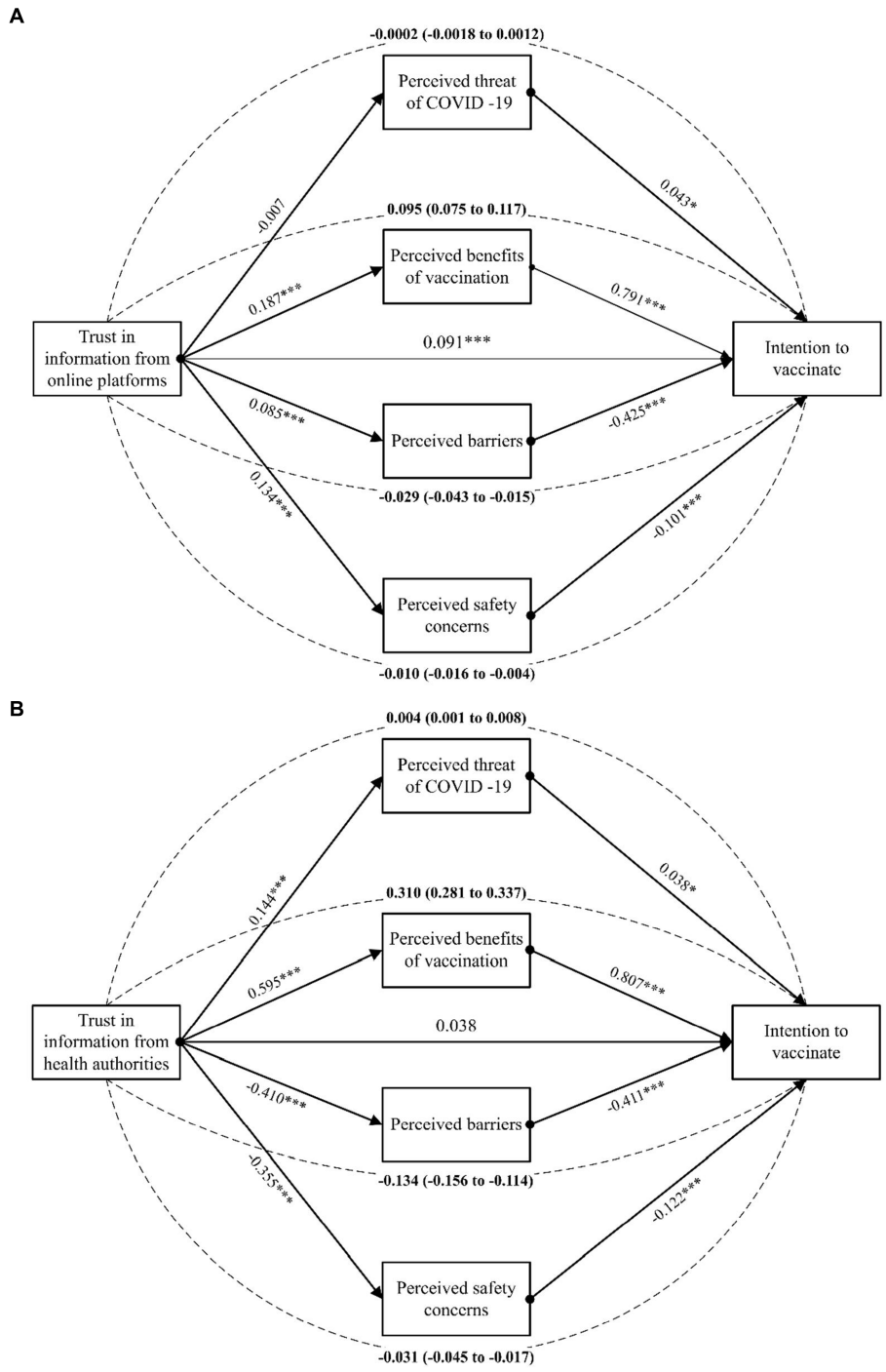


FIGURE 1
The results of the health beliefs as potential mediators of the relationship between vaccination intention and trust in health information from online sources **(A)** and from authentic sources **(B)**. Dashed lines indicate completely standardized indirect effects. *$p < 0.05$; **$p < 0.01$; ***$p < 0.0001$.

relationship between vaccine uptake and trust in authentic health information (retrieved from healthcare providers, the Ministry of Health, or international health organizations), whereas vaccine-related health beliefs (vaccine benefits, barriers, and safety concerns) have partially mediated the impact of individuals' trust in online information on vaccine acceptance.

Our findings are consistent with previous reports, which showed significant effects of the HBM constructs on vaccine uptake. For example, risk perception of COVID-19 was independently associated with the willingness to get vaccinated in Asia (29, 30), Europe (29), and the United States (31). Vaccine-related constructs, including the benefits, barriers, and safety concerns, were all significant factors that could explain vaccine uptake behavior in multiple investigations (29, 30, 32). A Chinese study reported "perceived benefits, cues to action, and various occupations" were positively associated with "vaccine acceptance." In contrast,

"perceived susceptibility and perceived barriers" were negatively associated with vaccine acceptance (33). These findings imply that public health authorities should communicate vaccine-related information based on the available clinical trials to fill the gap in the knowledge regarding vaccine efficacy and safety. However, targeting the perceived beliefs could be further optimized by getting deeper insights into the most trusted parties through which information could be communicated.

Generally, the core elements of trust include trust in the product itself (the vaccine), the provider (healthcare professionals), or the policy maker (the government or healthcare authorities) (34). In our study, since the vaccine was introduced during data collection, the trust in healthcare providers and policymakers may be exclusively meaningful. These sources are expected to communicate evidence-based information via reliable platforms, and the participants expressed the highest levels of trust in the Ministry of Health, followed by healthcare providers. However, although trust in national and international health authorities, as well as healthcare providers, was associated with the willingness to get vaccinated against COVID-19 in the univariate analysis, such a relationship was fully mediated by the health beliefs of individuals. In other words, trust in evidence-based information was associated with the intention to receive the vaccine, which was higher as mediated by the perceived threat of COVID-19 and the perceived benefits of vaccination and lower as mediated by the high levels of perceived barriers and safety concerns. Interestingly, a recent study observed that vaccine hesitancy had a negative relationship with age, family income, education status, coronavirus risk perception, faith in government, scientific and medical authorities, and traditional media, and was positively correlated with female gender, non-white ethnicity, and social media (35). Distrust, fear, and disinformation are important influencers of health beliefs about vaccination (36). Rathje et al. demonstrated that social media engagement is linked to vaccine views and that low-quality news sites predicted lower trust in the COVID-19 vaccine (37). Influencers can substantially impact COVID-19 vaccination uptake by building trust and distributing factual information or instilling fear, disinformation, and distrust. Public health campaigns should work strategically with influencers to increase positive influence and address concerns that may contribute to vaccine reluctance.

On the other hand, there was a significant direct effect of online platforms as sources of vaccine-related information on vaccination intention, irrespective of individual health beliefs. Moreover, the relationship between trust in online platforms and vaccine intention was relatively strengthened by higher perceived benefits and weakened by increased barriers and safety concerns, as reported by the participants. Similarly, Allington et al. have recently shown that the reliance on social media among US and UK residents was significantly greater than informational reliance on legacy media, which has finally impacted vaccine intentions (38). In addition, the use of social media to organize offline behavioral decisions in the UK has been associated with negative attitudes toward vaccination (39). This might underline the role of social media and health websites as external levers of vaccination decision-making.

The aforementioned results indicate that the trust in official, reliable sources of information was exclusively dependent on the personal beliefs. It is likely that people with unfavorable health beliefs toward the vaccine have been affected by other influencers that may actively oppose vaccination despite their perceived trust in health authorities. The present study showed several influencers, including the perceived threat of COVID-19, perceived benefits, perceived barriers, perceived safety concerns, perceived trust (online sources), and perceived trust (health authorities). Like the present study findings, Bateman et al. also mentioned influencers such as "perceived susceptibility, perceived severity, perceived obstacles, and others" in the constructs of the HBM (36).

Influencers are essential in creating perceptions of COVID-19 vaccination uptake, influencing people's perspectives in various ways. Influencers who effectively convey perceived benefits might substantially impact vaccination acceptance by emphasizing the advantages of immunization in reducing disease and promoting community health. In contrast, influencers may contribute to perceived barriers by emphasizing possible adverse effects or uncertainties associated with the vaccine, causing public skepticism. Addressing perceived safety concerns is critical; influencers focusing on and communicating vaccines' rigorous testing and monitoring processes can reduce anxiety and boost confidence. If influencers share reliable and evidence-based information, the perceived trust in online sources can positively affect opinions. However, the use of online platforms to disseminate misinformation may undermine confidence. Additionally, influencers can substantially impact perceived trust in health authorities by either approving or questioning their advice. Collaboration with influencers who agree with health officials' statements can boost trust, whereas discordant messages can weaken public confidence in immunization efforts. Overall, influencers have a multidimensional impact on COVID-19 vaccination uptake by altering perceptions of advantages, barriers, safety, and trust in online sources and health authorities.

Notwithstanding the positive relationship between trust in online information and in vaccination intention, the role of online misinformation on vaccine hesitancy should not be neglected. It is recommended that public health beliefs should be targeted via well-organized, web-based strategies. First, social media companies should direct their users away from unreliable, low-quality information sources, and these should be replaced by trusted data from reputable content producers. Second, health authorities should transparently communicate evidence-based information preferentially via official social media pages and dedicated health websites that promote individuals' trust in information and help in decision-making. Third, although social media platforms and online resources can be useful for disseminating information about vaccine safety and acceptance, a holistic approach is necessary for effective communication and education. This includes community engagement, peer-to-peer advocacy, health literacy initiatives, mobile health (mHealth) applications, and programs offered in schools, colleges, and workplaces.

Strengths and limitations

The current study addresses a highly relevant and urgent problem by considering the factors influencing COVID-19 vaccine intention in Saudi Arabia. Given the global importance of pandemic immunization, the findings may provide significant insights. Including a large sample size (3,091) improves the statistical power and generalizability of the findings, making them more robust and credible. The study employs the HBM to categorize and validate selected items. This model is a well-established framework in health psychology, strengthening the study's theoretical basis. The study

recognizes the role of trust in online health information, which is particularly relevant in the era of information technology. Understanding the impact of online sources on vaccine intentions helps provide more comprehensive knowledge of health decision-making. We used a unique approach to examine the predictors of vaccination intentions. Rather than focusing on rational calculations of health beliefs, we extended the hypothetical framework of behavioral intentions to the social context that may shape those beliefs, aka trust in information sources. The study's conclusion has practical implications for increasing vaccine coverage in Saudi Arabia, underscoring the significance of tackling health attitudes. This information is helpful for public health officials and policymakers tasked with developing effective immunization campaigns.

However, the cross-sectional nature of data collection might limit to obtain reliable causal relationships between the predictors and the outcome. Despite being the largest national study to date, the present study's findings could not be generalized to other countries with different ethnic and cultural determinants of vaccination uptake. Finally, the online survey might have induced selection bias, where participants with active internet connections could access the survey. Finally, potential social desirability biases among participants could be a significant constraint. It is likely that participants provided social desirability bias by responding in ways that aligned with societal standards or were viewed as socially acceptable. This could affect the accuracy of stated attitudes and intentions.

Conclusion

All HBM constructs were significant predictors of vaccination intentions; vaccine-related benefits and the perceived threat of COVID-19 were positively correlated, whereas vaccine barriers and safety concerns were negatively correlated. Trust in health websites and social media platforms was independently associated with the willingness to vaccinate, and it was partially mediated by HBM variables. Trust in authentic information from governmental organizations and healthcare providers was fully mediated by HBM constructs. The present study highlights the significance of online platforms on vaccine uptake, whereas the role of information from authentic sources (the government, healthcare providers, etc.) was exclusively dependent on the health beliefs of individuals. Utilizing the general public's health beliefs can improve vaccine coverage 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 studies involving humans were approved by the protocol of the present study was approved by the Research Ethics Committee (REC) of King Abdulaziz University, Jeddah, Saudi Arabia (Reference No. 422-23-11). 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

SA: Writing – review & editing, Writing – original draft, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Funding

The author declares that financial support was received for the research, authorship, and/or publication of this article. This work was funded by the Deanship of Scientific Research (DSR), KAU, Jeddah, under grant No. IFPDP-285-22. The author acknowledges DSR with thanks for their technical and financial support. The funders had no role in the study's design, data collection and analysis, decision to publish, or preparation of the manuscript.

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.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1340614/full#supplementary-material

References

1. Ahmad T, Haroon BM, Hui J. Coronavirus Disease 2019 (COVID-19) pandemic and economic impact. *Pak J Med Sci*. (2020) 36:S73–8. doi: 10.12669/pjms.36.COVID19-S4.2638

2. Ahmad T, Murad MA, Baig M, Hui J. Research trends in COVID-19 vaccine: a bibliometric analysis. *Hum Vaccin Immunother*. (2021) 17:2367–72. doi: 10.1080/21645515.2021.1886806

3. Rehman R, Jawed S, Ali R, Noreen K, Baig M, Baig J. COVID-19 pandemic awareness, attitudes, and practices among the Pakistani general public. *Front Public Health*. (2021) 9:588537. doi: 10.3389/fpubh.2021.588537

4. Coronavirus Resource Center. John Hopkins University. Available at: https://coronavirus.jhu.edu/region/saudi-arabia (Accessed February 15, 2024).

5. Estimates of Vaccine Hesitancy for COVID-19. Center for disease Control and Prevention (CDC). Available at: https://data.cdc.gov/stories/s/Vaccine-Hesitancy-for-COVID-19/cnd2-a6zw/ (Accessed February 15, 2024).

6. Almalki M, Sultan MK, Abbas M, Alhazmi A, Hassan Y, Varghese J. COVID-19 vaccine hesitancy among population in Jazan region of Saudi Arabia. *Healthcare*. (2023) 11:3051. doi: 10.3390/healthcare11233051

7. WHO. COVID-19 vaccine tracker and landscape. (2023). Available at: https://www.who.int/publications/m/item/draft-landscape-of-covid-19-candidate-vaccines (Accessed May 28, 2023).

8. Randolph HE, Barreiro LB. Herd immunity: understanding COVID-19. *Immunity*. (2020) 52:737–41. doi: 10.1016/j.immuni.2020.04.012

9. She J, Hou D, Chen C, Bi J, Song Y. Challenges of vaccination and herd immunity in COVID-19 and management strategies. *Clin Respir J*. (2022) 16:708–16. doi: 10.1111/crj.13543

10. Tariq S, Tariq S, Baig M, Saeed M. Knowledge, awareness, and practices regarding the novel coronavirus among a sample of a Pakistani population: a cross-sectional study. *Disaster Med Public Health Prep*. (2022) 16:934–9. doi: 10.1017/dmp.2020.408

11. Baig M, Jameel T, Alzahrani SH, Mirza AA, Gazzaz ZJ, Ahmad T, et al. Predictors of misconceptions, knowledge, attitudes, and practices of COVID-19 pandemic among a sample of Saudi population. *PLoS One*. (2020) 15:e0243526. doi: 10.1371/journal.pone.0243526

12. Becker MH, Maiman LA. Sociobehavioral determinants of compliance with health and medical care recommendations. *Med Care*. (1975) 13:10–24. doi: 10.1097/00005650-197501000-00002

13. Wong LP, Alias H, Wong PF, Lee HY, AbuBakar S. The use of the health belief model to assess predictors of intent to receive the COVID-19 vaccine and willingness to pay. *Hum Vaccin Immunother*. (2020) 16:2204–14. doi: 10.1080/21645515.2020.1790279

14. Zampetakis LA, Melas C. The health belief model predicts vaccination intentions against COVID-19: a survey experiment approach. *Appl Psychol Health Well-Being*. (2021) 13:469–84. doi: 10.1111/aphw.12262

15. Harrison JA, Mullen PD, Green LW. A meta-analysis of studies of the health belief model with adults. *Health Educ Res*. (1992) 7:107–16. doi: 10.1093/her/7.1.107

16. Carpenter CJ. A meta-analysis of the effectiveness of health belief model variables in predicting behavior. *Health Commun*. (2010) 25:661–9. doi: 10.1080/10410236.2010.521906

17. Cummings L. The trust heuristic: arguments from authority in public health. *Health Commun*. (2014) 29:1043–56. doi: 10.1080/10410236.2013.831685

18. Larson HJ, Clarke RM, Jarrett C, Eckersberger E, Levine Z, Schulz WS, et al. Measuring trust in vaccination: a systematic review. *Hum Vaccin Immunother*. (2018) 14:1599–609. doi: 10.1080/21645515.2018.1459252

19. Rizwan M, Ahmad T, Qi X, Murad MA, Baig M, Sagga AK, et al. Social media use, psychological distress and knowledge, attitude, and practices regarding the COVID-19 among a sample of the population of Pakistan. *Front Med*. (2021) 8:754121. doi: 10.3389/fmed.2021.754121

20. Massey PM. Where do US adults who do not use the internet get health information? Examining digital health information disparities from 2008 to 2013. *J Health Commun*. (2016) 21:118–24. doi: 10.1080/10810730.2015.1058444

21. Alhaddad MS. The use of social media among Saudi residents for medicines related information. *Saudi Pharm J*. (2018) 26:1106–11. doi: 10.1016/j.jsps.2018.05.021

22. Alzahrani SH, Baig M, Alrabia MW, Algethami MR, Alhamdan MM, Alhakamy NA, et al. Attitudes toward the SARS-CoV-2 vaccine: results from the Saudi Residents' intention to get vaccinated against COVID-19 (SRIGVAC) study. *Vaccine*. (2021) 9:798. doi: 10.3390/vaccines9070798

23. National Committee of Bioethics – King Abdulaziz City of Science and Technology. (2010). Law of ethics of research on living creatures. Available at: http://bioethics.kacst.edu.sa/getattachment/4bd0d4e2-1b93-4c32-b483-57902227fae2/Bioethic-Rgl-fin-bks.aspx.

24. Ministry of Health, Saudi Arabia. Guidelines on Ethical Conduct and Publication of Health Research. Available at: https://www.moh.gov.sa/en/Ministry/eParticipation/Documents/Publishing.pdf (Accessed February 15, 2024).

25. WMA: Declaration of Helsinki. Ethical Principles for Medical Research Involving Human Subjects. (2011). Available at: http://www.wma.net/en/30publications/10policies/b3/index.html.

26. Glanz K, Rimer BK, Viswanath K. *Health behavior and health education: Theory, research, and practice*. San Francisco, USA: John Wiley & Sons (2008).

27. Kim J. The relationship of health beliefs with information sources and HPV vaccine acceptance among young adults in Korea. *Int J Environ Res Public Health*. (2018) 15:673. doi: 10.3390/ijerph15040673

28. Hayes AF. *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. *3rd* ed. New York, USA: Guilford Publications (2022).

29. Goruntla N, Chintamani SH, Bhanu P, Samyuktha S, Veerabhadrappa KV, Bhupalam P, et al. Predictors of acceptance and willingness to pay for the COVID-19 vaccine in the general public of India: a health belief model approach. *Asian Pac J Trop Med*. (2021) 14:165–75. doi: 10.4103/1995-7645.312512

30. Wong MC, Wong EL, Huang J, Cheung AW, Law K, Chong MK, et al. Acceptance of the COVID-19 vaccine based on the health belief model: a population-based survey in Hong Kong. *Vaccine*. (2021) 39:1148–56. doi: 10.1016/j.vaccine.2020.12.083

31. Chu H, Liu S. Integrating health behavior theories to predict American's intention to receive a COVID-19 vaccine. *Patient Educ Couns*. (2021) 104:1878–86. doi: 10.1016/j.pec.2021.02.031

32. Saied SM, Saied EM, Kabbash IA, Abdo SA. Vaccine hesitancy: beliefs and barriers associated with COVID-19 vaccination among Egyptian medical students. *J Med Virol*. (2021) 93:4280–91. doi: 10.1002/jmv.26910

33. Cai Z, Hu W, Zheng S, Wen X, Wu K. Cognition and behavior of COVID-19 vaccination based on the health belief model: a cross-sectional study. *Vaccine*. (2022) 10:544. doi: 10.3390/vaccines10040544

34. Larson HJ, Schulz WS, Tucker JD, Smith DM. Measuring vaccine confidence: introducing a global vaccine confidence index. *PLoS Curr*. (2015) 7:ecurrents.outbreaks.ce0f6177bc97332602a8e3fe7d7f7cc4. doi: 10.1371/currents.outbreaks.ce0f6177bc97332602a8e3fe7d7f7cc4

35. Allington D, McAndrew S, Moxham-Hall V, Duffy B. Coronavirus conspiracy suspicions, general vaccine attitudes, trust and coronavirus information source as predictors of vaccine hesitancy among UK residents during the COVID-19 pandemic. *Psychol Med*. (2023) 53:236–47. doi: 10.1017/S0033291721001434

36. Bateman LB, Hall AG, Anderson WA, Cherrington AL, Helova A, Judd S, et al. Exploring COVID-19 vaccine hesitancy among stakeholders in African American and Latinx communities in the deep south through the lens of the health belief model. *Am J Health Promot*. (2022) 36:288–95. doi: 10.1177/08901171211045038

37. Rathje S, He JK, Roozenbeek J, Van Bavel JJ, van der Linden S. Social media behavior is associated with vaccine hesitancy. *PNAS Nexus*. (2022) 1:207. doi: 10.1093/pnasnexus/pgac207

38. Allington D, McAndrew S, Moxham-Hall VL, Duffy B. Media usage predicts intention to be vaccinated against SARS-CoV-2 in the US and the UK. *Vaccine*. (2021) 39:2595–603. doi: 10.1016/j.vaccine.2021.02.054

39. Wilson SL, Wiysonge C. Social media and vaccine hesitancy. *BMJ Glob Health*. (2020) 5:e004206. doi: 10.1136/bmjgh-2020-004206

frontiers | Frontiers in Public Health

TYPE Opinion
PUBLISHED 08 April 2024
DOI 10.3389/fpubh.2024.1348095

OPEN ACCESS

EDITED BY
Dilek Aslan,
Hacettepe University, Türkiye

REVIEWED BY
Vieri Lastrucci,
Meyer Children's Hospital, Italy
Nilay Etiler,
University of Nevada, Reno, United States

*CORRESPONDENCE
Irina Bergenfeld
ibergen@emory.edu

RECEIVED 01 December 2023
ACCEPTED 22 March 2024
PUBLISHED 08 April 2024

CITATION
Bergenfeld I (2024) What can public health communicators learn from Reddit? A perspective for the next pandemic. *Front. Public Health* 12:1348095. doi: 10.3389/fpubh.2024.1348095

What can public health communicators learn from Reddit? A perspective for the next pandemic

Irina Bergenfeld*

Hubert Department of Global Health, Emory University, Atlanta, GA, United States

KEYWORDS

COVID-19, vaccines, infodemic, social media, participatory

Introduction

COVID-19 emerged in a world in which vaccine hesitancy was already endemic (1). According to the Alma Ata Declaration, providing "immunization against the major infectious diseases" is one of governments' basic responsibilities to their citizens (2), yet national governments have often struggled to find effective and ethically sound strategies to improve vaccine uptake among the hesitant and vaccine-averse. In 2019, the World Health Organization warned that vaccine misinformation had become a leading threat to global public health (3). The politicization of the COVID-19 pandemic and of efforts to control it accompanied a flood of mis- and disinformation, which governments and the private sector failed to effectively counter. As a result, even in countries with adequate vaccine supply and relatively few barriers to access, vaccination rates lagged well behind available doses, and excess vaccines expired unused. Local governments began offering cash incentives to motivate resistant individuals to get vaccinated, to little effect (4) and much ethical debate about coerciveness (5). In the US, official sources of health information, including the White House, Centers for Disease Control and Prevention, and local health departments offered confusing and sometimes conflicting information on COVID-19 and the vaccine. In Europe, "over-zealous" national governments discontinued the use of a specific vaccine against World Health Organization recommendations, undermining confidence in its safety (6). This lack of coordinated, effective messaging around COVID vaccination compounded an existing dearth of trust in public institutions and served to further hinder demand creation for the vaccine (6, 7).

The World Health Organization outlines four key activities for infodemic management: (1) listening to community concerns and questions; (2) promoting understanding of risk and health expert advice; (3) building resilience to misinformation; and (4) engaging and empowering communities to take positive action (8). The COVID-19 pandemic underscored that current and future efforts to address vaccine hesitancy will require interdisciplinary and multisectoral approaches involving the coordinated efforts of institutions, healthcare providers, behavioral scientists, and the media. Knowledge transfer from public health institutions to the public will not be sufficient to create demand for a product as contentious as a new vaccine (6). Researchers who study vaccine hesitancy and acceptance have found that emotions dominate health decision-making around vaccines (9–11) and that narratives and tropes are often more influential than facts and statistics (12, 13). Loss-framed messaging emphasizing the potential risks of not getting vaccinated may be more impactful on behavioral intention than gain-framed messaging about vaccine benefits (14–16). Message framing may be especially crucial for newer vaccines, which are

perceived as riskier than established ones (17). This is true across the world- in a large, qualitative study on vaccine demand creation among pregnant women in Kenya, several participants recalled a persuasive radio advertisement featuring a man paralyzed by polio who wished he had been vaccinated as a child (18). At the provider level, where directly addressing misinformation can increase hesitancy, active and empathetic listening is a key avenue for reaching vaccine hesitant individuals and their children (7, 19, 20). While social media companies have responded to misinformation by increasing fact-checking efforts and removing disinformation, these are often "too little, too late" (21, 22). As an alternative, multidisciplinary researchers have begun to explore the potential of "inoculating" social media users against misinformation by familiarizing them with the common tactics that shady actors use to promote false and misleading vaccine narratives (23). Still others have taken a bigger-picture view, emphasizing the importance of proactive efforts to improve vaccine literacy (24) and public trust in government (25) to lay a foundation for improving vaccine uptake.

Participatory health communication to promote scientific literacy and combat misinformation: examples from the pandemic

Social media often served to amplify misinformation during the pandemic and to weaken confidence in vaccines (26), as anti-vax content was able to emerge and spread while official vaccine communication was still "getting its pants on," so to speak (27). However, there were notable exceptions where private citizens leveraged social media to fill the public health communication gap. Unsurprisingly, jokes and memes have been found to be some of the most popular formats for both pro- and anti-vax messaging on social media (28). The viral success of Vick Krishna, whose humorous 2021 "Fork Hands" TikTok post explaining mRNA technology to lay audiences was viewed by millions, demonstrates the potential of social media approaches in promoting vaccine literacy (24) among the general population (https://www.npr.org/sections/goatsandsoda/2021/04/01/983397422/the-viral-tiktok-video-that-explains-vaccine-science-and-makes-you-laugh). Another example of the organic emergence of vaccine communication during the COVID-19 pandemic is the Reddit community, or *subreddit,* known as r/HermanCainAward, which reached over half a million members by the end of 2023. The subreddit features posts of a chronologically sequenced, anonymized screenshots of social media accounts that shared COVID or vaccine-related disinformation. Each post forms a narrative that follows the "nominee"'s social media posts from misinformation to hospitalization (and often death). It is possible to trace the ebb and flow of the pandemic itself in the r/HermanCainAward post history, with trends in traffic on the subreddit paralleling COVID surges. As the community's popularity grew, it sparked attention, criticism, and debate among traditional media outlets such as Fox News, VICE, and National Public Radio. A 2021 piece from *Slate* magazine presciently observes: "[The Herman Cain Award subreddit] is an anti-persuasive venue, a place that dispenses with rational appeals for people to behave better in favor of something much more primal and horrifying. And who knows? Maybe it's persuading people specifically because it's not trying to." After the introduction of the vaccine, qualitative evidence of the subreddit's impact appeared in the rise of #IPA (Immunized to Protect against Award) posts, in which previously vaccine hesitant members photograph their vaccination cards as proof of their commitment to avoid becoming the next "nominee."

Debate around the ethics of the Herman Cain Award, while rightly questioning the morality of public shaming, neglect the potential effectiveness of certain aspects of its approach. The online community adopted many of the recommended strategies for vaccine messaging, which official sources had largely neglected up to that point in the pandemic's trajectory. Firstly, Reddit's front page is visible to all users, regardless of their personal browsing history. This may be key to overcoming the siloing between anti-vax and pro-vax networks that occurs on other platforms, allowing messaging to reach a broad range of individuals across the spectrum of vaccine acceptance (29). Secondly, posts on r/HermanCainAward, taken straight from the source, are not burdened with the level of public distrust that increasingly plagues experts and public health institutions (30). The message content is produced by members of its target audience and curated by Reddit users to follow a simple narrative format, an example of the participatory approach to public health communication enabled by social media (31). Thirdly, messaging is strongly loss-framed, which may be necessary to overcome the increased risk aversion associated with decision-making around newer vaccines. Finally, r/HermanCainAward highlights the role that exposure to misinformation played in the deaths of awardees, and may therefore function similarly to inoculation strategies against false and misleading vaccine narratives (23).

Discussion

This piece focuses on a single specific example of participatory vaccine communication on a single social media platform, limiting the conclusions that can be drawn. Reddit users are not necessarily representative of social media users generally, and content moderation works differently on Reddit than on many other sites. Moreover, defining roles and responsibilities of private social media companies in combating disinformation and promoting vaccination remains a contentious ethical issue (32, 33). Nevertheless, the Herman Cain Award presents an innovative approach to vaccine communication of which public health officials might consider adopting specific aspects: (1) narrative elements, (2) loss-framed messaging, (3) highlighting the dangers of disinformation, (4) knowledge co-creation, (5) and non-traditional partnerships and channels of dissemination. Indeed, 3 years into the pandemic, it seems that some institutions may be starting to test more effective strategies. For example, the White House has begun to recruit social media influencers to promote uptake for available COVID-19 vaccines, getting the message to those who might otherwise avoid pro-vaccine content (https://www.nytimes.com/2021/08/01/technology/vaccine-lies-influencer-army.html) (34). While such approaches do have their limits, leveraging personal social media accounts with broader

audiences can be one of a range of strategies to reach individuals who might be less likely to trust more "official" sources of public health information. Where formal public health communicators still have a lot of work to do is the content and framing of their messaging. Large public health institutions still define their mission with regard to vaccine hesitancy as one of knowledge transfer to the public, assuming that simply conveying facts will be sufficient to change minds (and behaviors) when empirical evidence does not support this strategy (35). The marketing departments of pharmaceutical companies understand that their job is to create demand, and a compelling story is often a better strategy than an infographic. It is time for public health institutions to recognize that if they want to improve COVID-19 vaccination rates, they will need to provide more than facts and statistics and begin to leverage the tools of behavioral science, as advertisers do. Researchers have already found some success using strategies such as social listening (36) and knowledge co-creation (37) to combat vaccine misinformation. Producing coordinated, targeted, and narrative-based social marketing that makes the intended audience and their concerns feel heard will require public health institutions to form non-traditional partnerships and engage more reciprocally with the people they serve. Ultimately, if we are going to combat the flood of vaccine disinformation ahead of the next pandemic, we cannot be afraid to get our feet wet.

Author contributions

IB: Writing – original draft, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Acknowledgments

We would like to thank Jim Lavery and my cohort mates Zarmeen Shakil, Ahmed Haji Said, Aradhana Thapa, Md Abul Kalam, and Felix Teufel for their encouragement and feedback.

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.

Publisher's note

References

1. Lane S, MacDonald NE, Marti M, Dumolard L. Vaccine hesitancy around the globe: analysis of three years of WHO/UNICEF Joint Reporting Form data-2015–2017. *Vaccine.* (2018) 36:3861–7. doi: 10.1016/j.vaccine.2018.03.063

2. World Health Organization. *Declaration of Alma-Ata*. Geneva: World Health Organization. Regional Office for Europe (1978).

3. Broniatowski DA, Quinn SC, Dredze M, Jamison AM. Vaccine communication as weaponized identity politics. *Am J Public Health.* (2020) 110:617. doi: 10.2105/AJPH.2020.305616

4. Schwalbe N, Hanbali L, Nunes MC, Lehtimaki S. Use of financial incentives to increase adult vaccination coverage: a narrative review of lessons learned from COVID-19 and other adult vaccination efforts. *Vaccine.* (2022) 2022:100225. doi: 10.1016/j.jvacx.2022.100225

5. Jecker NS. Cash incentives, ethics, and COVID-19 vaccination. *Science.* (2021) 374:819–20. doi: 10.1126/science.abm6400

6. Evans WD, French J. Demand creation for COVID-19 vaccination: overcoming vaccine hesitancy through social marketing. *Vaccines.* (2021) 9:319. doi: 10.3390/vaccines9040319

7. Alderotti G, Corvo MF, Buscemi P, Stacchini L, Giorgetti D, Lorini C, et al. Communicating with patients about COVID-19 vaccination: a qualitative study on vaccinators in Tuscany Region, Italy. *Vaccines.* (2023) 11:223. doi: 10.3390/vaccines11020223

8. World Health Organization. *Infodemic.* (2024). Geneva: World Health Organization. Available online at: https://www.who.int/health-topics/infodemic#tab=tab_1 (accessed March 12, 2024).

9. Chou WYS, Budenz A. Considering emotion in COVID-19 vaccine communication: addressing vaccine hesitancy and fostering vaccine confidence. *Health Commun.* (2020) 35:1718–22. doi: 10.1080/10410236.2020.1838096

10. Gavaruzzi T, Caserotti M, Leo I, Tasso A, Speri L, Ferro A, et al. The role of emotional competences in parents' vaccine hesitancy. *Vaccines.* (2021) 9:298. doi: 10.3390/vaccines9030298

11. Chapman GB, Coups EJ. Emotions and preventive health behavior: worry, regret, and influenza vaccination. *Health Psychol.* (2006) 25:82. doi: 10.1037/0278-6133.25.1.82

12. Shelby A, Ernst K. Story and science: how providers and parents can utilize storytelling to combat anti-vaccine misinformation. *Hum Vaccin Immunother.* (2013) 9:1795–801. doi: 10.4161/hv.24828

13. Haase N, Betsch C. Parents trust other parents: lay vaccination narratives on the Web may create doubt about vaccination safety. *Med Decision Mak.* (2012) 32:645. doi: 10.1177/0272989X12445286

14. Lee MJ, Cho J. Promoting HPV vaccination online: message design and media choice. *Health Promot Pract.* (2017) 18:645–53. doi: 10.1177/1524839916688229

15. Ye W, Li Q, Yu S. Persuasive effects of message framing and narrative format on promoting COVID-19 vaccination: a study on Chinese college students. *Int J Environ Res Public Health.* (2021) 18:9485. doi: 10.3390/ijerph18189485

16. Prakash A, Nathan RJ, Kini S, Victor V. Message framing and COVID-19 vaccine acceptance among millennials in South India. *PLoS ONE.* (2022) 17:e0269487. doi: 10.1371/journal.pone.0269487

17. Wang K, Wong EL-Y, Cheung AW-L, Chung VC-H, Wong CH-L, Dong D, et al. Impact of information framing and vaccination characteristics on parental COVID-19 vaccine acceptance for children: a discrete choice experiment. *Eur J Pediatr.* (2022) 181:3839–49. doi: 10.1007/s00431-022-04586-6

18. Nganga S. *Patient and Provider Perspectives on How Patient Trust Within the Patient-Provider Relationship Influences Maternal Vaccine Acceptance Among Pregnant Women in Kenya* (2018).

19. Limaye RJ, Opel DJ, Dempsey A, Ellingson M, Spina C, Omer SB, et al. Communicating with vaccine-hesitant parents: a narrative review. *Academic Pediatr.* (2021) 21:24–9. doi: 10.1016/j.acap.2021.01.018

20. Breckenridge LA, Burns D, Nye C. The use of motivational interviewing to overcome COVID-19 vaccine hesitancy in primary care settings. *Public Health Nurs.* (2022) 39:618–23. doi: 10.1111/phn.13003

21. Chou WYS, Gaysynsky A, Vanderpool RC. The COVID-19 misinfodemic: moving beyond fact-checking. *Health Educ Behav.* (2021) 48:9–13. doi: 10.1177/1090198120980675

22. Broniatowski DA, Simons JR, Gu J, Jamison AM, Abroms LC. The efficacy of Facebook's vaccine misinformation policies and architecture during the COVID-19 pandemic. *Sci Adv.* (2023) 9:eadh2132. doi: 10.1126/sciadv.adh2132

23. Roozenbeek J, Van der Linden S. Fake news game confers psychological resistance against online misinformation. *Palgrave Commun.* (2019) 5:1–10. doi: 10.1057/s41599-019-0279-9

24. Lorini C, Del Riccio M, Zanobini P, Biasio RL, Bonanni P, Giorgetti D, et al. Vaccination as a social practice: towards a definition of personal, community, population, and organizational vaccine literacy. *BMC Public Health.* (2023) 23:1501. doi: 10.1186/s12889-023-16550-6

25. Lim J, Moon KK. Political ideology and trust in government to ensure vaccine safety: using a US survey to explore the role of political trust. *Int J Environ Res Public Health.* (2023) 20:4459. doi: 10.3390/ijerph20054459

26. Chen X, Lee W, Lin F. Infodemic, institutional trust, and COVID-19 vaccine hesitancy: a cross-national survey. *Int J Environ Res Public Health.* (2022) 19:8033. doi: 10.3390/ijerph19138033

27. Kalichman SC, Eaton LA, Earnshaw VA, Brousseau N. Faster than warp speed: early attention to COVD-19 by anti-vaccine groups on Facebook. *J Public Health.* (2022) 44:e96–e105. doi: 10.1093/pubmed/fdab093

28. Zaidi Z, Ye M, Samon F, Jama A, Gopalakrishnan B, Gu C, et al. Topics in antivax and provax discourse: yearlong synoptic study of COVID-19 vaccine tweets. *J Med Internet Res.* (2023) 25:e45069. doi: 10.2196/45069

29. Johnson NF, Velásquez N, Restrepo NJ, Leahy R, Gabriel N, Oud SE, et al. The online competition between pro- and anti-vaccination views. *Nature.* (2020) 582:230–3. doi: 10.1038/s41586-020-2281-1

30. Palmedo PC, Rauh L, Lathan HS, Ratzan SC. Exploring distrust in the wait and see: lessons for vaccine communication. *Am Behav Scient.* (2022) 2022:27642211062865. doi: 10.1177/00027642211062865

31. Syed-Abdul S, Gabarron E, Lau A. *Participatory Health Through Social Media.* Cambridge, MA: Academic Press (2016).

32. Freiling I, Krause NM, Scheufele DA. Science and ethics of "curing" misinformation. *Am Med Assoc J Ethics.* (2023) 25:228–37. doi: 10.1001/amajethics.2023.228

33. Lovari A, Bowen SA. Social media in disaster communication: a case study of strategies, barriers, and ethical implications. *J Publ Aff.* (2020) 20:e1967. doi: 10.1002/pa.1967

34. Haji Said A. *Countering Vaccine Hesitancy in the Context of Global Health.* Atlanta, GA: Emory University (2022).

35. Greenberg J, Dubé E, Driedger M. Vaccine hesitancy: in search of the risk communication comfort zone. *PLoS Curr.* (2017) 9:ecurrents.outbreaks.0561a011117a1d1f9596e24949e8690b. doi: 10.1371/currents.outbreaks.0561a011117a1d1f9596e24949e8690b

36. Hou Z, Tong Y, Du F, Lu L, Zhao S, Yu K, et al. Assessing COVID-19 vaccine hesitancy, confidence, and public engagement: a global social listening study. *J Med Internet Res.* (2021) 23:e27632. doi: 10.2196/27632

37. Lohiniva A-L, Nurzhynska A, Hudi A-H, Anim B, Aboagye DC. Infodemic management using digital information and knowledge cocreation to address COVID-19 vaccine hesitancy: case study from Ghana. *JMIR Infodemiol.* (2022) 2:e37134. doi: 10.2196/37134

frontiers | Frontiers in Public Health

TYPE Perspective
PUBLISHED 08 April 2024
DOI 10.3389/fpubh.2024.1378412

OPEN ACCESS

EDITED BY
Fatjona Kamberi,
University of Vlorë, Albania

REVIEWED BY
Becky White,
Curtin University, Australia

*CORRESPONDENCE
Silvan Wehrli
✉ WehrliS@rki.de

RECEIVED 29 January 2024
ACCEPTED 22 March 2024
PUBLISHED 08 April 2024

CITATION
Wehrli S, Irrgang C, Scott M, Arnrich B and Boender TS (2024) The role of the (in) accessibility of social media data for infodemic management: a public health perspective on the situation in the European Union in March 2024.
Front. Public Health 12:1378412.
doi: 10.3389/fpubh.2024.1378412

The role of the (in)accessibility of social media data for infodemic management: a public health perspective on the situation in the European Union in March 2024

Silvan Wehrli[1]*, Christopher Irrgang[1], Mark Scott[2], Bert Arnrich[3] and T. Sonia Boender[4,5,6]

[1]Centre for Artificial Intelligence in Public Health Research, Robert Koch Institute, Berlin, Germany, [2]Brown University's School of Public Health, Brown University, Providence, RI, United States, [3]Digital Health–Connected Healthcare, Hasso Plattner Institute, University of Potsdam, Potsdam, Germany, [4]Department of Infectious Diseases, Public Health Service Amsterdam, Amsterdam, Netherlands, [5]Department of Health Sciences, Faculty of Science, Amsterdam Public Health Research Institute Amsterdam and Amsterdam Institute for Immunology and Infectious Diseases, Vrije Universiteit, Amsterdam, Netherlands, [6]Risk Communication Unit, Robert Koch Institute, Berlin, Germany

Public health institutions rely on the access to social media data to better understand the dynamics and impact of *infodemics* – an overabundance of information during a disease outbreak, potentially including mis-and disinformation. The scope of the COVID-19 infodemic has led to growing concern in the public health community. The spread of harmful information or information voids may negatively impact public health. In this context, social media are of particular relevance as an integral part of our society, where much information is consumed. In this perspective paper, we discuss the current state of (in)accessibility of social media data of the main platforms in the European Union. The European Union's relatively new Digital Services Act introduces the obligation for platforms to provide data access to a wide range of researchers, likely including researchers at public health institutions without formal academic affiliation. We examined eight platforms (Facebook, Instagram, LinkedIn, Pinterest, Snapchat, TikTok, X, YouTube) affected by the new legislation in regard to data accessibility. We found that all platforms apart from TikTok offer data access through the Digital Services Act. Potentially, this presents a fundamentally new situation for research, as before the Digital Services Act, few platforms granted data access or only to very selective groups of researchers. The access regime under the Digital Services Act is, however, still evolving. Specifics such as the application procedure for researcher access are still being worked out and results can be expected in spring 2024. The impact of the Digital Services Act on research will therefore only become fully apparent in the future.

KEYWORDS

infodemic, infodemic management, public health, social media, data access, digital services act, misinformation, disinformation

1 Infodemic management in the current social media landscape

The overabundance of information (true or false) in both the digital and physical world during a disease outbreak is described as an *infodemic* (1). False or misleading information is commonly referred to as misinformation, independent of the intention to spread such information. Disinformation, on the other hand, entails the intention to deceive (2). Social media platforms such as Facebook and Instagram (both Meta) or X (formerly Twitter) play an important role in infodemics due to their widespread use (3), fostering the rapid and global spread of information (4). Obar and Wildman (5) provide the following definition: *social media platforms are internet-based applications, contain mainly user-generated content, allow to create user-specific profiles and to connect with other users on the platform*. Notably, the definition of social media is debatable and has changed over time (6). The here used definition captures platforms that are most relevant in the context of infodemics, i.e., platforms on which any kind of information, opinion or view can be shared and discussed, not restricted to any medium (e.g., text, image, video).

Managing infodemics during disease outbreaks is essential for public health as misinformation can be harmful to the health of individuals, deteriorate the efficacy of public health measures, and disturb social cohesion (7). In addition to the challenges of misinformation, monitoring the online public discourse, concerns, and information voids is essential to facilitate beneficial data-driven public health actions (8). Examples for infodemics have been found in connection with the outbreaks of SARS [e.g., (9)], A(H1N1) [e.g., (10)], measles virus [e.g., (11)], and SARS-CoV-2 (COVID-19).

The velocity and volume of information spread during the COVID-19 pandemic was unprecedented, rendering this infodemic unique in its scope (1). Social media platforms likely played a pivotal and catalyst role in enabling the extent of the COVID-19 infodemic, due to a significantly higher usage during the outbreak and their algorithms designed for content to go viral (12, 13). The severity of the COVID-19 infodemic has led to initiatives of national and international key public health players to build infodemic management capacities: In a joint effort, the WHO has formulated a research agenda, outlining major research areas such as detecting the emergence and spread of an infodemic through social listening tools (14). The Centers for Disease Control and Prevention have presented the COVID-19 State of Vaccine Confidence Insight Reporting System as a first implemented infodemic surveillance system and as prototype for future systems (15). The national public health institute in Germany, the Robert Koch Institute, has developed a framework for using social listening, building the fundament for infodemic management in Germany (16). The Finnish Institute for Health and Welfare and the Africa Infodemic Response Alliance under the hood of the WHO demonstrated similar efforts (17, 18).

These calls have led to manifold efforts in understanding social media narratives: the WHO has developed a taxonomy to rapidly classify online conversations related to COVID-19 (19), mpox (20), and respiratory pathogens (21). The taxonomies have also served as basis for the WHO's Early AI-supported Response with Social Listening Platform [EARS (22, 23)], which, unfortunately, had to be discontinued from January 2024. Social media data are also used to improve the understanding of social media's role in infodemics: how COVID-19-related topics spread online [e.g., (24, 25)], the prevalence of misinformation [e.g., (26, 27)], or misinformation interventions [e.g., (28)]. This, in return, helps to improve data-driven social listening tools based on scientific findings and public health needs. To drive public health research and infodemic management forward, public health (research) institutions rely on data access to major social media platforms. However, the access to data from these platforms has been challenging for public health institutions, especially for non-academic organizations [*cf.* (16)].

Recently, X attracted attention with a paradigm shift after restricting access to its data. In the past, it had provided the research community with a relatively generous research access. In March 2023, X switched to a more restrictive policy (29), which had, in advance, led to public criticism from well-known researchers and organizations (30). Others like TikTok (31) have developed new data access regimes but limit access to almost exclusively academic researchers.

At the same time, a European legal framework, the Digital Services Act [DSA, (32)], has come into force on 16 November 2022 (33). Its aim, in part, is to boost transparency and accountability over social media platform operations. These measures include the creation of binding data access regimes to allow researchers to conduct independent research on how these platforms operate.

In the following, we discuss the challenging access to data from social media platforms within the European Union (EU). We provide an overview on data access programs of major social media platforms included in the DSA. We take the perspective of national public health institutes (such as the Robert Koch Institute in Germany) or international public health agencies in the EU (such as the European Center for Disease Prevention and Control) and qualify our findings in terms of usability for such actors. These organizations are key players in public health crisis management and help shape national and international public health measures. Typically, these organizations conduct research to implement measures that are evidence-based and data-driven, and have therefore a need for accessing relevant data for infodemic management, preparedness and response. In a second part, we contextualize the overview with the DSA, serving as a new legal framework for researchers to access data. We first introduce the aim and functioning of the DSA to then relate its use to public health research.

2 Accessing data from major social media platforms

To assess the data accessibility of major social media platforms for public health researchers in the EU, we limited our discussion to platforms that fall under the European Commission's definition of very large online platforms (VLOPs). To qualify as a VLOP, a platform must have at least 45 million average monthly users in the EU (32), corresponding to roughly 10% of the EU's total population. Obligations for social media platforms introduced in the context of the DSA only apply to VLOPs, which is why we focused on these platforms. At the time of writing (March 2024), 21 platforms[1] were designated as VLOPs (34, 35). We then selected social media platforms following the definition presented earlier. From this selection,

1 These platforms are (in alphabetical order): Alibaba, AliExpress, Amazon Store, Apple AppStore, Booking.com, Facebook, Google Play, Google Maps, Google Shopping, Instagram, LinkedIn, Pinterest, Pornhub, Snapchat, Stripchat, TikTok, Wikipedia, X, XVideos, YouTube, and Zalando.

TABLE 1 Data access programs for social media platforms designated as Very Large Online Platforms (VLOPs), March 2024.

Platform	Monthly average users (in million, self-reported)	Data accessibility and purpose
Facebook (Meta)	258 (49)	CrowdTangle (36–38): access to popular public pages (Facebook), groups and verified profile (Facebook, Instagram); only for Facebook partners, Journalists, research NGOs, and non-governmental, non-profit academic institutions; discontinued from August 14, 2024 (application no longer possible) FORT (39): access to selected datasets related to elections & democracy; only for Facebook partners, currently no applications possible DSA research access through the "Meta Content Library and API" (40, 41): access to full public archive of different meta data
Instagram (Meta)	257 (49)	CrowdTangle (see above) DSA research access through the "Meta Content Library and API" (see above)
LinkedIn	45.23 (50)	DSA research access (42): access to public data upon successful application, scope of data unclear
Pinterest	>45 (43)	DSA research access (43): access to public data upon successful application, scope of data unclear
Snapchat	102 (51)	DSA research access (44): access to public data upon successful application, scope of data unclear
TikTok	134 (52)	TikTok Research API (31): access to account and content data; only for non-profit academic institutions in the U.S. or Europe
X (formerly Twitter)	111.4 (53)	X API (45): access scope depends on commercial access tier; available for any institution DSA research access (46): through a form in the developer and agreement policy, scope of data unclear
YouTube	425.2 (54)	YouTube Researcher Program (47): access to the global YouTube video metadata corpus; only for researchers at academic institutions DSA research access (48): access to public data upon successful application, scope of data unclear

we excluded Wikipedia (because of its primary function as an encyclopedia) as well as Pornhub and XVideos (because of their specific focus on pornographic content). We included the following platforms: Facebook, Instagram, LinkedIn, Pinterest, Snapchat, TikTok, X, and YouTube. Finally, we gathered information on available data access programs for these platforms based on their websites, as of March 2024. We regarded any dedicated offer provided by the platforms to collect, view, or analyze data as a "data access program." We did not focus on specific accessibility methods (i.e., application programming interface (API) versus web-based dashboards), aiming to evaluate the general availability of data. Of note, programs exclusively built and used for marketing purposes were not considered relevant to public health practice because of their limited scope. Finally, we did not include alternatives to official programs offered by the platforms such as commercial data aggregators.

Table 1 lists the identified data access programs for all platforms and the number of monthly average users that qualify these platforms as VLOPs. All examined platforms offer at least one data access program. LinkedIn, Pinterest, Snapchat, and TikTok offer one program; Instagram, X, and YouTube two programs; and Facebook three programs. Accessibility criteria can greatly vary between platforms and even for programs of the same platform. The "TikTok Research API" is only available to researchers employed by a university, which excludes researchers at non-academic public health institutions. LinkedIn, Pinterest and Snapchat, on the other hand, allow data access through the DSA, which likely includes access for public health institutions (*cf.* next section). Similarly, X and YouTube offer DSA data access. Additionally, X offers a commercial API-based data access (45), which, however, is reported to possibly cost tens of thousands of dollars per month (55). YouTube's second research program "YouTube Research Program" only accepts applications from university-based researchers similar to the "TikTok Research API" program. As such, data access from X and YouTube is most likely possible for public health researchers through the DSA, as the other options either exclude non-academic researchers (YouTube) or likely cause unaffordable cost for continued data access (X). Out of the two options for Instagram, the "Meta Content Library and API" is likely accessible for public health institutions being a DSA-conform research program. The other option, CrowdTangle, will be discontinued in August 2024 and no longer accepts new applications. These two options are also available for data access from Facebook and a similar conclusion applies. Facebook's third option, FORT, is limited to selected partners, and has so far focused on elections and democracy as focus research areas, thus excluding the public health domain.

Out of the examined 11 access programs, seven are likely accessible for researchers at public health institutions, resulting in potential data access to seven (Facebook, Instagram, LinkedIn, Pinterest, Snapchat, X, and YouTube) out of the eight examined platforms, but only through the DSA. We point out that data access under the DSA is a new possibility, and the specifics of this data access (e.g., what data can be retrieved from platforms) are still under development, as discussed in the next section.

3 The DSA and infodemic management

In the following, we shift the discussion to the DSA and how it can be expected to improve the situation for infodemic management. We first introduce the goal and the fundamental building blocks of the DSA, which is defined in EU Regulation 2022/2065 (56).

The DSA targets illegal online activities and disinformation spread via online intermediaries and platforms like marketplaces and social networks, aiming to safeguard European citizens' digital rights through clear regulatory standards for digital companies (57). This

includes a variety of transparency and accountability requirements for social media platforms in the form of regular reports, outside audits and risk assessments. In September 2023, the targeted companies published their initial transparency reports (58), including details such as the number of content moderators (by EU language) or the amount of content removed over a given time period. These reporting duties represent an important building block of the DSA as it allows to assess the platforms adherence to their legal obligations. The legislation includes fines of up to 6 % of a company's annual global turnover, and the platforms' mandatory reports can serve as evidence for the European Commission to start formal investigations into violations of the DSA. So far, this has happened for X in December 2023 (59) and TikTok in February 2024 (60).

A second building block consists of Digital Services Coordinators (DSCs). By February 2024, each EU member country had to designate an individual or a local agency to be its DSC, yet not all countries have done this so far (61). DSCs serve as main contact point for both individuals seeking redress and for cross-border issues (61, 62). The European Commission will chair the European Board for Digital Services, in which representatives from each member country will convene regularly to discuss implementation and enforcement issues related to the DSA (63).

A third building block constitutes the platforms' obligation to give researcher access to platform data from VLOPs to conduct research on systemic risks, defined in DSA Article 34 (1), including the protection of the public health. The requirements for research data access are outlined in Article 40 of the DSA (56, 64). Article 40(8) states that researchers can apply for the status of "vetted researcher" to the DSC, who then acts as an intermediary between vetted researchers and VLOPs. For a successful application, researchers must meet certain conditions: affiliation with a research organization, independence of commercial interests, disclosure of funding, fulfillment of required data security and confidentiality requirements, research in line with the DSA's purpose, and open-access research. The definition of a "research organization" is set in in Article 2 (1) in EU Directive 2019/70 (65) and includes, apart from universities, not-for-profit research institutes with a primary goal of scientific research. This likely includes national public health institutes as research is typically a main focus of their work [e.g., as described in the Robert Koch Institute' mission statement (66)]. Applications for vetted researcher access are expected to be possible later in 2024 (64). In addition, Article 40(12) allows data access of publicly available platform data for research that only fulfill a subset of the criteria for the status of vetted research (i.e., who are not affiliated with a research organization and without the requirement of open-access research).

The DSA lacks clarity in some aspects as it is not specified what platform data VLOPs will need to share with vetted researcher, what is considered "publicly available data" and how this differs from data available for vetted researchers, or what organizations will effectively be considered "research organizations." The DSA research access programs identified (Table 1) all refer to DSA Article 40(12), so it is not fully clear what data can be expected through these channels. Fittingly, we were only able to find detailed information on data availability for the Meta access program (40). Currently, the European Commission prepares an additional regulation intended to clarify these uncertainties (67). The results are planned to be published in spring 2024 and are based on feedback from more than 130 interested parties from a call for evidence, which, overall, outlines (public) data access needs, formats, and application procedure with a need for action (68). What is more, the case of X raises some doubts in regard to how platforms implement data access in reality so far, given the current investigations into X's potential failure to give researcher data access (59). It is therefore rather doubtful that the DSA has already had a significant influence on current public health research. This conclusion is consistent with impressions from interviews with members from different public health agencies (personal communication, 2022–2023)[2]: Currently, few public health experts have direct access to existing social media listening tools. Instead, the primary dataset used by researchers — specifically related to COVID-19 analysis — is Google Trends, followed by *ad hoc* research via Facebook private groups and previously scrapped X datasets.

4 Conclusion

In this work, we summarized the social media data (in) accessibility for public health institutions in the EU, which is required for current investments in infodemic preparedness at these institutions. We examined eight major social media platforms. We find that data access to potentially seven platforms (Facebook, Instagram, LinkedIn, Pinterest, Snapchat, X, YouTube) is accessible for public health institutes, which in all cases relies on access through the DSA (or, in the case of X, possibly through a commercial option). The remaining platform, TikTok, limits access to academic institutions. Yet, it can be expected that TikTok data accessibility will align with the DSA, which it is required to do. Without considering the DSA-mandated data access, platforms would either not allow any data access at all (LinkedIn, Pinterest, Snapchat) or restrict data access to selected groups of researchers such as academics (Facebook, Instagram, YouTube). As such, the DSA is clearly a step in the right direction: The legislation acknowledges that social media platforms can foster harmful societal developments and must be held accountable. The DSA aims to create equal rights and obligations for platforms and researchers alike, which is a clear departure from the pre-DSA era with very heterogenous access possibilities. However, it is still evolving (e.g., the implementation of research access for vetted researchers) and the full potential will only become apparent once the DSA is fully implemented.

While we have focused on data access of major social media platforms in this work, we point out that the success of managing infodemics goes beyond just having data access to these platforms: the preparation for infodemics also relies on infrastructure, social listening tools, and personnel training (69); the collection and processing of data for social listening raises ethical questions, which need to be adequately addressed (70); (fringe) social media not covered by the DSA may still be relevant (71); and generative AI may change the misinformation landscape in the future substantially (72).

2 Mark Scott has conducted 13 interviews on the subject of the "Use of social media for infodemic management and how that data was accessed" with interviewees from the Centers for Disease Control and Prevention, European Centre for Disease Prevention and Control, European Commission, European Medicines Agency, Maltese Ministry of Health, Robert Koch Institute, United Nations Children's Fund, University of Belgrad, and the World Health Organization. The interviews were conducted between October 2022 and May 2023 in a semi structured format, encompassed by 12 set questions, and lasted between 1 and 1:30h.

Importantly, social media data are one piece of information of the health information ecosystem. To manage infodemics and to tackle mis-and disinformation is a complex endeavor that concerns many stakeholders and must therefore be solved together – which the president of the European Commission, Ursula von der Leyen, has also emphasized at the World Economic Forum in 2024 (73). In the context of social media data, we believe that the DSA may serve as a platform for such collaboration, where the needs and rights of all stakeholders can be considered.

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

SW: Investigation, Methodology, Writing – original draft, Writing – review & editing. CI: Methodology, Supervision, Writing – original draft, Writing – review & editing. MS: Investigation, Methodology, Resources, Validation, Writing – original draft, Writing – review & editing. BA: Supervision, Validation, Writing – review & editing. TB: Conceptualization, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Acknowledgments

We would like to thank Ines Lein for reviewing the manuscript during the revision process.

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.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

1. Briand S, Hess S, Nguyen T, Purnat TD. Infodemic management in the twenty-first century In: TD Purnat, T Nguyen and S Briand, editors. *Managing Infodemics in the 21st century: Addressing new public health challenges in the information ecosystem*. Cham: Springer International Publishing (2023). 1–16.

2. Lewandowsky S, Cook J, Ecker U, Albarracín D, Kendeou P, Newman EJ, et al. *The Debunking Handbook*. Nebraska: University of Nebraska (2020).

3. We Are Social, DataReportal, Meltwater. *Global Social Network Penetration Rate as of January 2023, by Region Statista*. (2023). Available at: https://www.statista.com/statistics/269615/social-network-penetration-by-region/ (Accessed January 26, 2024).

4. Vraga EK, Ecker UKH, Žeželj I, Lazić A, Azlan AA. To debunk or not to debunk? Correcting (Mis)information In: TD Purnat, T Nguyen and S Briand, editors. *Managing Infodemics in the 21st century: Addressing new public health challenges in the information ecosystem*. Cham: Springer International Publishing (2023). 85–98.

5. Obar JA, Wildman S. Social media definition and the governance challenge: an introduction to the special issue. *Telecommun Policy*. (2015) 39:745–50. doi: 10.1016/j.telpol.2015.07.014

6. Aichner T, Grünfelder M, Maurer O, Jegeni D. Twenty-five years of social media: a review of social media applications and definitions from 1994 to 2019. *Cyberpsychol Behav Soc Netw*. (2020) 24:215–22. doi: 10.1089/cyber.2020.0134

7. Borges do Nascimento IJ, Pizarro AB, Almeida JM, Azzopardi-Muscat N, Gonçalves MA, Björklund M, et al. Infodemics and health misinformation: a systematic review of reviews. *Bull World Health Organ*. (2022) 100:544–61. doi: 10.2471/blt.21.287654

8. World Health Organization. *United Nations Children's fund (UNICEF). How to build an Infodemic insights report in six steps*. Geneva: World Health Organization (2023).

9. Wald P. *Contagious: Cultures, carriers, and the outbreak narrative*. Durham: Duke University Press (2008).

10. Lundgren B. 'Rhyme or reason?' saying no to mass vaccination: subjective re-interpretation in the context of the a (H1n1) influenza pandemic in Sweden 2009-2010. *Med Humanit*. (2015) 41:107–12. doi: 10.1136/medhum-2015-010684

11. Capurro G, Greenberg J, Dubé E, Driedger M. Measles, moral regulation and the social construction of risk: media narratives of "anti-Vaxxers" and the 2015 Disneyland outbreak. *Can J Sociol*. (2018) 43:25–48. doi: 10.29173/cjs29301

12. Senft TM, Greenfield S. People's experience of information overload and its impact on Infodemic harms In: TD Purnat, T Nguyen and S Briand, editors. *Managing Infodemics in the 21st century: Addressing new public health challenges in the information ecosystem*. Cham: Springer International Publishing (2023). 27–40.

13. GlobalWebIndex. *In-home media consumption due to the coronavirus outbreak among internet users worldwide as of March 2020, by country: Statista* (2020). Available at: https://www.statista.com/statistics/1106498/home-media-consumption-coronavirus-worldwide-by-country/ (Accessed January 24, 2024).

14. Calleja N, AbdAllah A, Abad N, Ahmed N, Albarracin D, Altieri E, et al. A public Health Research agenda for managing Infodemics: methods and results of the first who Infodemiology conference. *JMIR Infodemiol*. (2021) 1:e30979. doi: 10.2196/30979

15. Chiou H, Voegeli C, Wilhelm E, Kolis J, Brookmeyer K, Prybylski D. The future of Infodemic surveillance as public health surveillance. *Emerg Infect Dis J*. (2022) 28:S121–8. doi: 10.3201/eid2813.220696

16. Boender TS, Schneider PH, Houareau C, Wehrli S, Purnat TD, Ishizumi A, et al. Establishing Infodemic Management in Germany: a framework for social listening and integrated analysis to report Infodemic insights at the National Public Health Institute. *JMIR Infodemiol*. (2023) 3:e43646. doi: 10.2196/43646

17. WHO Regional Office for Africa. *Africa Infodemic response Alliance*. (2024). Available at: https://www.afro.who.int/aira. (Accessed January 26, 2024).

18. Lohiniva AL, Sibenberg K, Austero S, Skogberg N. Social listening to enhance access to appropriate pandemic information among culturally diverse populations: case study from Finland. *JMIR Infodemiol*. (2022) 2:e38343. doi: 10.2196/38343

19. Purnat TD, Vacca P, Czerniak C, Ball S, Burzo S, Zecchin T, et al. Infodemic signal detection during the Covid-19 pandemic: development of a methodology for identifying potential information voids in online conversations. *JMIR Infodemiol*. (2021) 1:e30971. doi: 10.2196/30971

20. World Health Organization. *Public health taxonomy for social listening on Monkeypox conversations*. (2022). Available at: https://www.who.int/publications/m/item/public-health-taxonomy-for-social-listening-on-monkeypox-conversations (Accessed January 26, 2024).

21. World Health Organization. *Public health taxonomy for social listening on respiratory pathogens*. (2023). Available at: https://iris.who.int/handle/10665/373534.

22. Purnat TD, Wilson H, Nguyen T, Briand S. Ears - a who platform for Ai-supported real-time online social listening of Covid-19 conversations. *Stud Health Technol Inform*. (2021) 281:1009–10. doi: 10.3233/shti210330

23. White BK, Gombert A, Nguyen T, Yau B, Ishizumi A, Kirchner L, et al. Using machine learning technology (early artificial intelligence-supported response with social listening platform) to enhance digital social understanding for the Covid-19 Infodemic: development and implementation study. *JMIR Infodemiol*. (2023) 3:e47317. doi: 10.2196/47317

24. Cinelli M, Quattrociocchi W, Galeazzi A, Valensise CM, Brugnoli E, Schmidt AL, et al. The Covid-19 social media Infodemic. *Sci Rep*. (2020) 10:16598. doi: 10.1038/s41598-020-73510-5

25. Gallotti R, Valle F, Castaldo N, Sacco P, De Domenico M. Assessing the risks of 'Infodemics' in response to Covid-19 epidemics. *Nat Hum Behav*. (2020) 4:1285–93. doi: 10.1038/s41562-020-00994-6

26. Suarez-Lledo V, Alvarez-Galvez J. Prevalence of health misinformation on social media: systematic review. *J Med Internet Res*. (2021) 23:e17187. doi: 10.2196/17187

27. Gisondi MA, Barber R, Faust JS, Raja A, Strehlow MC, Westafer LM, et al. A deadly Infodemic: social media and the power of Covid-19 misinformation. *J Med Internet Res*. (2022) 24:e35552. doi: 10.2196/35552

28. Smith R, Chen K, Winner D, Friedhoff S, Wardle C. A systematic review of Covid-19 misinformation interventions: lessons learned. *Health Aff*. (2023) 42:1738–46. doi: 10.1377/hlthaff.2023.00717

29. @XDevelopers. *For academia, we are looking at new ways to continue serving this community. In the meantime free, basic and Enterprise tiers are available for academics*. Stay Tuned to @Twitterdev to Learn More: X (30.03.2023). (2023). Available at: https://x.com/XDevelopers/status/1641222788911624192?s=20 (Accessed January 26, 2024).

30. Coalition for Independent Technology Research. *Letter: Imposing Fees to Access the Twitter Api Threatens Public-Interest Research*. (2023). Available at: https://independenttechresearch.org/letter-twitter-api-access-threatens-public-interest-research/ (Accessed January 26, 2024).

31. TikTok. *Research Api*. (2023). Available at: https://www.developers.tiktok.com/products/research-api. (Accessed January 26, 2024).

32. European Commission. *Dsa: Very large online platforms and search engines* (2023). Available at: https://digital-strategy.ec.europa.eu/en/policies/dsa-vlops (Accessed January 26, 2024).

33. Think Tank European Parliament. *Digital services act: Application timeline*. (2022). Available at: https://www.europarl.europa.eu/thinktank/en/document/EPRS_ATA(2022)739227. (Accessed March 08, 2024).

34. European Commission. *Digital services act: Commission designates first set of very large online platforms and search engines*. (2023). Available at: https://ec.europa.eu/commission/presscorner/detail/en/ip_23_2413 (Accessed January 26, 2024).

35. European Commission. *Commission designates second set of very large online platforms under the digital services act*. (2023). Available at: https://ec.europa.eu/commission/presscorner/detail/en/ip_23_6763 (Accessed January 26, 2024).

36. CrowdTangle. *What Data Is Crowdtangle Tracking?* Available at: https://help.crowdtangle.com/en/articles/1140930-what-data-is-crowdtangle-tracking (Accessed January 26, 2024).

37. CrowdTangle. *Crowdtangle Access Criteria*. (2024). Available at: https://www.crowdtangle.com/request (Accessed March 18, 2024).

38. CrowdTangle. *Crowdtangle for Academics and Researchers*. Available at: https://help.crowdtangle.com/en/articles/4302208-crowdtangle-for-academics-and-researchers (Accessed January 26, 2024).

39. Meta. *Researchers Use Our Tools and Data to Study Facebook's Impact on the World*. Available at: https://fort.fb.com/ (Accessed January 26, 2024).

40. Meta. *Meta Content Library and Api*. (2023). Available at: https://transparency.fb.com/researchtools/meta-content-library/ (Accessed January 26, 2024).

41. Clegg N. *New features and additional transparency measures as the digital services act comes into effect*. (2023) Available at: https://about.fb.com/news/2023/08/new-features-and-additional-transparency-measures-as-the-digital-services-act-comes-into-effect/ (Accessed January 26, 2024).

42. LinkedIn. *Researcher Access*. (2023). Available at: https://www.linkedin.com/help/linkedin/answer/a1645616? (Accessed March 08, 2024).

43. Pinterest. *Digital Services Act*. (2023). Available at: https://help.pinterest.com/en/article/digital-services-act (Accessed March 18, 2024).

44. Snap. *Researcher Data Access Instructions*. Available at: https://values.snap.com/privacy/transparency/researcher-access?lang=en-US.

45. X. Twitter Api. (2023). Available at: https://developer.twitter.com/en/docs/twitter-api. (Accessed January 26, 2024).

46. X. Developer Agreement and Policy. (2023). Available at: https://developer.twitter.com/en/developer-terms/agreement-and-policy.

47. YouTube. *Youtube researcher program*. (2023). Available at: https://research.youtube/. (Accessed January 01, 2024).

48. YouTube. *Google Researcher Program Application*. (2023). Available at: https://requestrecords.google.com/researcher/form. (Accessed March 08, 2024).

49. Meta. *Digital Services Act-Information on Average Monthly Active Recipients in the European Union*. (2023). Available at: https://transparency.fb.com/sr/dsa-report-aug2023/. (Accessed January 26, 2024).

50. LinkedIn. *Monthly Active Recipients of Linkedin Ireland Unlimited Company's Services in the European Union*. (2024). Available at: https://www.linkedin.com/help/linkedin/answer/a1441790/monthly-active-recipients-of-linkedin-ireland-unlimited-company-s-services-in-the-european-union?lang=en-US (Accessed March 18, 2024).

51. Snap. *Average Monthly Active Recipients*. (2024). Available at: https://values.snap.com/en-GB/privacy/transparency/european-union.

52. TikTok. *Europen Union (Eu) - Monthly Active Recipients Report*. (2023). Available at: https://www.tiktok.com/transparency/en/eu-mau-2023-07 (Accessed March 18, 2024).

53. X. Amars in the Eu. Available at: https://transparency.twitter.com/en/reports/amars-in-the-eu.html. (Accessed March 18, 2024).

54. Google. *Information about monthly active recipients under the digital services act (Eu)*. (2023) Available at: https://storage.googleapis.com/transparencyreport/report-downloads/pdf-report-24_2023-7-1_2023-12-31_en_v1.pdf (Accessed March 18, 2024).

55. Stokel-Walker C. *Twitter's $42,000-per-month Api prices out nearly everyone: WIRED*. (2023). Available at: https://www.wired.co.uk/article/twitter-data-api-prices-out-nearly-everyone.

56. European Commission. Regulation (Eu) 2022/2065 of the European Parliament and of the council of 19 October 2022 on a single market for digital services and amending directive 2000/31/Ec (digital services act) (text with Eea relevance). *Off J Eur Union*. (2022) 1:1–102.

57. European Commission. *The digital services act* Available at: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/digital-services-act_en (Accessed January 26, 2024).

58. European Commission. *Very large online platforms and search engines to publish first transparency reports under the Dsa*. (2023). Available at: https://digital-strategy.ec.europa.eu/en/news/very-large-online-platforms-and-search-engines-publish-first-transparency-reports-under-dsa.

59. European Commission. *Commission opens formal proceedings against X under the digital services act*. (2023). Available at: https://ec.europa.eu/commission/presscorner/detail/en/ip_23_6709. (Accessed January 26, 2024).

60. Euopean Commission. *Commission opens formal proceedings against Tiktok under the digital services act*. (2024). Available at: https://ec.europa.eu/commission/presscorner/detail/en/ip_24_926 (Accessed March 18, 2024).

61. European Commission. *Digital services coordinators* (2024). Available at: https://digital-strategy.ec.europa.eu/en/policies/dsa-dscs. (Accesssed March 07, 2024).

62. European Commission. *The cooperation framework under the digital services act*. (2023) Available at: https://digital-strategy.ec.europa.eu/en/policies/dsa-cooperation (Accessed January 29, 2024).

63. European Commission. *Digital services act starts applying to all online platforms in the Eu*. (2024). Available at: https://ec.europa.eu/commission/presscorner/detail/en/ip_24_881 (Accessed March 07, 2024).

64. European Centre for Algorithmic Transparency. *Faqs: Dsa data access for researchers*. (2023). Available at: https://algorithmic-transparency.ec.europa.eu/news/faqs-dsa-data-access-researchers-2023-12-13_en (Accessed March 28, 2024).

65. European Commission. Directive (Eu) 2019/790 of the European Parliament and of the council of 17 April 2019 on copyright and related rights in the digital single market and amending directives 96/9/Ec and 2001/29/Ec (text with Eea relevance.). *Off J Eur Union*. (2019) 90:92–125.

66. Robert Koch Institute. *Promoting Research and Evidence, Sharing Knowledge, Protecting and Improving Health: Mission Statement*. (2023). Available at: https://www.rki.de/EN/Content/Institute/Mission_Statement/Mission_Statement_node.html. (Accessed March 07, 2024).

67. European Commission. *Delegated Regulation on Data Access Provided for in the Digital Services Act*. Available at: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13817-Delegated-Regulation-on-data-access-provided-for-in-the-Digital-Services-Act_en (Accessed March 07, 2024).

68. Euopean Commission. *Digital services act: Summary report on the call for evidence on the delegated regulation on data access*. (2023). Available at: https://digital-strategy.ec.europa.eu/en/library/digital-services-act-summary-report-call-evidence-delegated-regulation-data-access (Accessed January 26, 2024).

69. Schmid P. Using behavioral science for Infodemic preparedness: the case of vaccination misinformation. *Policy Insights Behav Brain Sci*. (2023) 11:93–101. doi: 10.1177/23727322231219684

70. Machiri S, Purnat T, Nguyen T, Ho C, Ballalai I, Biller-Andorno N, et al. An ethics framework for social listening and Infodemic management. *Eur J Pub Health*. (2023) 33:661. doi: 10.1093/eurpub/ckad160.661

71. Kearney MD, Chiang SC, Massey PM. *The twitter origins and evolution of the Covid-19 "Plandemic" conspiracy theory*. Harvard Kennedy School Misinformation Review (2020).

72. Feuerriegel S, DiResta R, Goldstein JA, Kumar S, Lorenz-Spreen P, Tomz M, et al. Research can help to tackle Ai-generated disinformation. *Nat Hum Behav*. (2023) 7:1818–21. doi: 10.1038/s41562-023-01726-2

73. President von der Leyen of the European Commission. *Special Address by President Von Der Leyen at the World Economic Forum*. (2024). Available at: https://ec.europa.eu/commission/presscorner/detail/en/speech_24_221. (Accessed January 24, 2024).

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 18 April 2024
DOI 10.3389/fpubh.2024.1351820

OPEN ACCESS

EDITED BY
Selen Yeğenoğlu,
Hacettepe University, Türkiye

REVIEWED BY
Yuan Wang,
University of Maryland, United States
Songül Vaizoğlu,
Near East University, Cyprus

*CORRESPONDENCE
Bobo Feng
✉ milk_bravo@163.com

RECEIVED 07 December 2023
ACCEPTED 01 April 2024
PUBLISHED 18 April 2024

CITATION
Feng B (2024) Gaming with health misinformation: a social capital-based study of corrective information sharing factors in social media.
Front. Public Health 12:1351820.
doi: 10.3389/fpubh.2024.1351820

Gaming with health misinformation: a social capital-based study of corrective information sharing factors in social media

Bobo Feng*

School of Journalism and Media, Chongqing Normal University, Chongqing, China

Correction is an important tool to reduce the negative impact of health misinformation on social media. In the era of "I share, therefore I am" social media, users actively share corrective information to achieve the "anti-convincing" effect of health misinformation. Focusing on the local Chinese context, this study constructs a structural equation model using social capital as a mediating variable to explore whether usage of Chinese users' social media can promote corrective information sharing by influencing the structural, cognitive, and relational dimensions of social capital and the role of health literacy in corrective information sharing. It was found that social media use did not significantly affect corrective information share willingness but significantly influenced share willingness through social interaction connections, trust, and shared experiences, and share willingness significantly influenced sharing behavior. The moderating effect showed that health literacy played a significant moderating effect in the influence of corrective information share willingness on sharing behavior. This study introduces the three dimensions of social capital at the theoretical level and finds that users will share corrective information for the purpose of social capital accumulation. It also provides empirical evidence for specific practices, including improving users' health literacy and actively mobilizing them to participate in the blocking and management of health misinformation in social media.

KEYWORDS

social media, social capital, health misinformation, corrective information, health literacy

Introduction

In recent years, online users have increasingly used social media to seek and share health information (1). However, the emergence of social media has also opened the door to the proliferation of health risks, and the rapid spread of a large amount of unconfirmed and misinformation has dismantled the authenticity and scientific validity of health information (2). Health misinformation is "a claim, opinion, or content that is currently proven to be false in relation to health due to a lack of scientific evidence" (3) and may spread faster and more easily on social media than scientific information (4). The rapid proliferation of health misinformation can lead to misunderstanding and anxiety among users (5), reduces trust in health professionals, delays or hinders the adoption of individual treatment behaviors, and, in

some cases, even threatens life safety (6). How to curb the spread of health misinformation on social media and defend against is an important issue concerning the health of the Chinese people.

Correction that designed to refute inaccurate claims and misleading information is an important tool to combat health misinformation. While numerous studies have recognized the efficacy of corrective messages in debunking misinformation, limited research has been conducted on Chinese samples. A considerable amount of foreign research has noted the role of correction in counteracting the proliferation of health misinformation on social media. For example, providing coherent alternative explanations for misinformation and making timely corrections can be effective in reinforcing correct information and reducing people's misconceptions (7). Again, algorithmic correction can be used to dispel people's misconceptions (8). Further research suggests that relying on physicians (9), experts (3), health agencies (8), and relevant authorities (10) to correct health misinformation in order to prevent backfire effects could results better.

Considering the reality of "how to correct health misinformation on social media," the United Nations (UN) saw the "human sharing potential" and encouraged people to share real health information and correct misinformation on social media (11). In the age of "I share, therefore I am" social media, users' likes, retweets, comments, and other sharing behaviors encourage the proliferation of health misinformation. This study focuses on whether the power of sharing can be used to achieve the "anti-convincing" effect of corrective information (12). Whether in weak or strong relationships, individuals are always a key part of reducing the spread of misinformation (13) and have great potential to correct health misinformation on social media (14).

Chinese society is a relationship-based society, where individual behavior starts with interpersonal relationships and human exchange occurs within the relationships (15). The term "relationship" in Chinese society can be included in the study of social networks and social capital. It is only that social networks emphasize the structural study of relationships, while social capital emphasizes the operation of relationships. In China, individuals' information-sharing behaviors are not only for entertainment but also for maintaining relationships with others and acquiring social capital (16). It has been shown that the structural, relational, and cognitive dimensions of social capital all have varying degrees of influence on motivation to share personal information (17). Moreover, in the social media information interaction environment, social capital can significantly influence people's information sharing behavior (18). For example, people will decide whether to retweet medical crowdfunding information based on favor exchange rules with the goal of gaining social capital (19). Lin believes that social capital is an important resource embedded in social networks. Then, it is worthwhile to pay attention to how to make good use of this resource in social media and construct sharing relationships with social capital as the core (20).

Based on the above discussion, this study attempts to construct an integrated model using social capital as a mediating variable to explore the factors influencing social media use and corrective information sharing. The value of this study lies in the following: first, it is based on Chinese society and considers the role of "relationship" in corrective information sharing, which expands the scope of rational behavior theory and social capital theory and adds empirical evidence. Second, given the increasing prevalence of health misinformation in social media, this study discusses how to maximize the effectiveness of corrective information in terms of specific sharing dimensions and thus provides targeted suggestions for mobilizing users to participate in corrective information sharing.

Literature review and research hypothesis

Social media use

Social media (social networking or Web 2.0) is a broad concept that refers to a variety of web-based platforms and services that allow users to post public or semi-public profiles and/or content and connect to other users' profiles and/or content (21). Bolton et al. (22) believe that users can create and share a variety of contents online through the use of social media. As a result, social media use has become an essential information interaction action in citizens' daily lives. Correa et al. (23) suggest that social media use is a special form of consumption of digital media or the Internet that is not unlike traditional media use. Within the past decade, research on social media has become a major focus of academic attention. Scholars have explored the effects of social media use on citizen participation in political life (24), information seeking and sharing behavior (25), consumer engagement (26), public perception of disease risk (S.-H (27).), worry, anxiety, and fatigue psychological mood (28) from a variety of disciplines including communication, information science, management, medical science, and psychology.

Social media use affects users' willingness to share both positive and negative information. On the one hand, social media use can lead to the viral spread of negative information such as fake news (29), misinformation (30), and rumors (31). On the other hand, social media use can also promote the sharing of positive information such as health information (32) and corrective information (33). Because social media exacerbates the proliferation of negative information, there is tremendous value in studying the impact of social media use on positive information. Bode studied the experience of correction on social media during COVID-19 and found that most people who shared misinformation not only saw observed misinformation corrected but also potentially shared the corrective information (34). By studying how individuals deal with misinformation and corrective information about genetically modified food safety on social media, Wang found that using social media can enhance individuals' acceptance and sharing of corrective information (35). Based on this, this study will explore the effects of social media on corrective information sharing intentions at the positive information sharing level and propose hypotheses.

This study examines the impact of social media on the willingness and behavior of corrective information sharing at the level of positive information sharing and proposes the following hypotheses:

> *H1*: Social media use has a positive influence on corrective information share willingness.

Behavior and intention as important correlated variables in the theory of rational behavior and the theory of planned behavior have long been confirmed by numerous studies. Existing studies have shown that intentions effectively predict the adoption of behaviors such as health knowledge adoption (36) and social media use (37).

However, it has also been shown that intention is not a significant predictor of behavior. For example, social media content may increase users' intentions and knowledge related to Human Papilloma Virus (HPV) but do not improve behavioral outcomes (38). In the study of social media information sharing, Chen explored people's motivation to share social crisis information through WeChat and found that there was a positive influence of willingness of WeChat users' social crisis information sharing on behavior (16). As social crisis messages, people share corrective information to get positive comments from others, socialize, or complete their social activities. To explore what relationship actually exists between corrective information sharing intentions and behaviors, the following hypothesis was proposed:

> *H2*: Corrective information sharing willingness has a positive influence on sharing behavior.

Based on the above discussion, this study asks research question Q1: Does social media use positively influence corrective information sharing behavior through corrective information sharing intentions?

Social capital and three dimensions

As one of the first scholars to propose social capital, L.J. Hanifan defined it as "the goodwill, friendship, mutual sympathy, and social interactions among individuals and families that constitute the social unit" [(39), p. 130]. Scholars have subsequently offered different explanations for social capital, but all agree on the importance of social relationships and resources. Pierre Bourdieu considers social capital as the sum of the real or potential resources possessed by a society or group, consisting mainly of the network of relationships that define the identity of the members of the society or group [(40), p. 249]. Putnam proposed that social capital depends on the relationships between people and distinguished between bridging and bonding social capital, arguing that both forms of social capital have strong positive effects [(41), p. 23]. Nahapiet and Ghoshal (42) integrated previous research on different aspects of social capital, defined social capital as relational resources embedded in interpersonal, group, and social networks, and proposed to measure social capital in terms of structural, relational, and cognitive dimensions. Following the above framework, this study examined the influence of social capital on correct information sharing willingness using the structural dimension—social interaction ties and the cognitive dimension—shared experience and the relational dimension—trust, respectively.

Social interaction ties

Network ties, a key concept in the structural dimension of social capital, affect both the parties that combine and exchange resources, and the expected value obtained through the exchange (42). Developed from network ties, social interaction ties refer to connections between network members that act as a medium for information flow and resource exchange and provide individuals with access to the resources of others (43). In the field of behavioral research, the more frequently social interactions are connected, the higher the intensity, depth, and frequency of information exchange, the stronger the willingness of individuals to share or contribute certain content, such as information or knowledge (44). Thus, social interaction ties are considered a key concept for measuring willingness to share and behavior.

Trust

Trust is the core of the relational dimension of social capital (45) and is a dynamic cohesive factor that influences the achievement of the goals of both partners (46). Sociologists define trust as a set of expectations held by those involved in an exchange (47) that encompasses beliefs about the competence, integrity, and reliability of others (48). It is the existence of trust that makes it possible to maintain stable social relationships (K (49).). Research shows that trust, whether between acquaintances or strangers, leads to higher benefits and lower exchange costs for both parties to the exchange (50). Similar to face-to-face interactions, trust is also a major factor influencing online interaction behavior (51). In terms of virtual community knowledge sharing, trust involves the emotional connection between individuals and group members, which can reduce the uncertainty and risks associated with communication and coalesce identity (52) and thus inspire more information sharing behavior.

Share experience

According to Habermas' lifeworld theory, the cognitive dimension emphasizes culturally shared attributes and can refer to the similar attitudes, perceptions, and understandings that network members have about the "context" in which they live together (53). Common experience is the existence of similar experiences of social network members about something, and the more common points the more conducive to internal communication and cooperation, which, in turn, generates higher social capital (54). This is similar to McPherson' formulation of "homogeneity," i.e., people interact socially and transmit information based on the principle of homogeneity (55). Communicating with people who are different can lead to cognitive dissonance and distorted information while communicating with people who are similar tends to be more fluid and efficient (56). For example, interactions between people with similar cultures, religions, and ideologies occur more frequently than unrelated individuals (57).

The intermediary role of social capital

Social media use and social capital

Media interactions influence and shape interpersonal relationships, and the use of both traditional mass media and new media has positive implications for the accumulation of social capital among audiences (58). Social media, with the original intention of creating connections, not only deepens the maintenance of strong relationships but also provides a new ground for the establishment of weak relationships (59), becoming an important way for people to maintain social connections. In addition to building relationships, using social media for social interactions such as liking, commenting, and sharing can increase social capital (60). As confirmed by the study, there is a positive correlation between the usage behavior of social media users such as Instagram and WeChat to social capital (61).

Specific to particular groups, such as college students (62) and older adults (63), social media use similarly shows a significant effect on social capital. This is because the longer and more frequently the medium is used, the more likely it is to engage in social capital building activities (64). Based on the above discussion, the following hypotheses are proposed:

> *H3*: Social media use has a positive influence on social interaction ties of structural social capital.
>
> *H4*: Social media use has a positive influence on trust of relational social capital.
>
> *H5*: Social media use has a positive influence on shared experience of cognitive social capital.

Social capital and corrective information sharing willingness

Social interaction ties can positively influence knowledge acquisition (65), as well as the quality (66) and quantity (17) of knowledge sharing. In social media contexts, social interaction ties not only increase users' willingness to continue using WeChat (67) but also have a direct impact on social media information dissemination behavior (68). As a result, those who have good relationships and strong connections with others are more likely to share thought-provoking and valuable information, such as corrective information. Trust can encourage social media users to engage in more disclosure behaviors and share more information with trusted people (69). When trust is higher, the tendency to share information also rises (70). In addition, a study investigated the factors influencing the sharing of cancer experiences among fathers of children with cancer and found that although these fathers did not know each other, they experienced support for each other in the sharing of common cancer experiences (71). Experiencing the same negative emotional event together can promote cooperative behavior among individuals compared with experiencing negative emotional events alone (72). In addition, research on social media information sharing behavior has found that users seek out and share news and information in similar networks (73). Based on this, this study argues that people who have been exposed to or misled by health misinformation about such similar experiences are more likely to develop corrective information sharing behaviors. Moreover, the following hypotheses are proposed:

> *H6*: Social interaction ties of structural social capital have a positive influence on corrective information sharing willingness.
>
> *H7*: Trust of relational social capital has a positive influence on corrective information sharing willingness.
>
> *H8*: Shared experience of cognitive social capital has a positive influence on corrective information sharing willingness.

At the same time, this study raises the research question Q2: What is the mediating role of social capital social interaction ties, trust, and shared experiences between social media use and corrective information sharing willingness?

The moderating role of health literacy

Exploring health information sharing intentions and behaviors from the perspective of health literacy has become a focus of health communication research. Previous research has found that people with higher health literacy are more likely to receive more adequate health information from multiple sources. Health information literacy is positively associated with various health promotion behaviors, i.e., health literacy positively influences health information behaviors (74). Yang investigated the health information literacy of older adults and their intention to spread health rumors and found that health information literacy and the purpose of knowledge acquisition was negatively associated with the willingness of older adults to share health rumors (75). Oh and Lee confirmed the interaction between health literacy and perceived information importance in predicting willingness to verify and share health information by examining when people verify and share health rumors on social media (76). Fleary systematically reviewed and analyzed the literature on the relationship between adolescent health literacy and health behaviors. Functional and media health literacy was found to have a significant positive effect on the adoption of adolescent health behaviors (77). From the above, it can be observed that there is a significant effect of health literacy on both health intention and health behavior. However, Brittani Crook found that while health literacy positively influenced share willingness, people with higher health literacy tended to share less information about heart health than those with lower health literacy (78). Moreover, what role does health literacy play in the relationship between share willingness and behavior? To explore this question, the following hypothesis was proposed:

> *H9*: Higher health literacy is associated with a stronger relationship between corrective information share willingness and behavior.

Based on the literature review, this study constructed a structural equation model of social media corrective information sharing factors (Figure 1).

Research design

Data collection and implementation

The survey population of this study is users who use social media in China. It mainly includes WeChat, Weibo, QQ, Zhihu, Douban, Douyin, and Kuaishou short video social media platforms. Questionnaire Star was utilized to sketch the questionnaire and distribute it via WeChat moments on 10 August 2022 and 10 October 2022. A total of 601 subjects responded to the survey, excluding 66 invalid subjects and responses. A total of 527 subjects remained, with a sample qualification rate of 87.7%. Table 1 shows the demographic information of the respondents.

Measurement development

This study contains seven measurement dimensions, six of which were designed with options using a seven-point Likert scale ("1–7" for

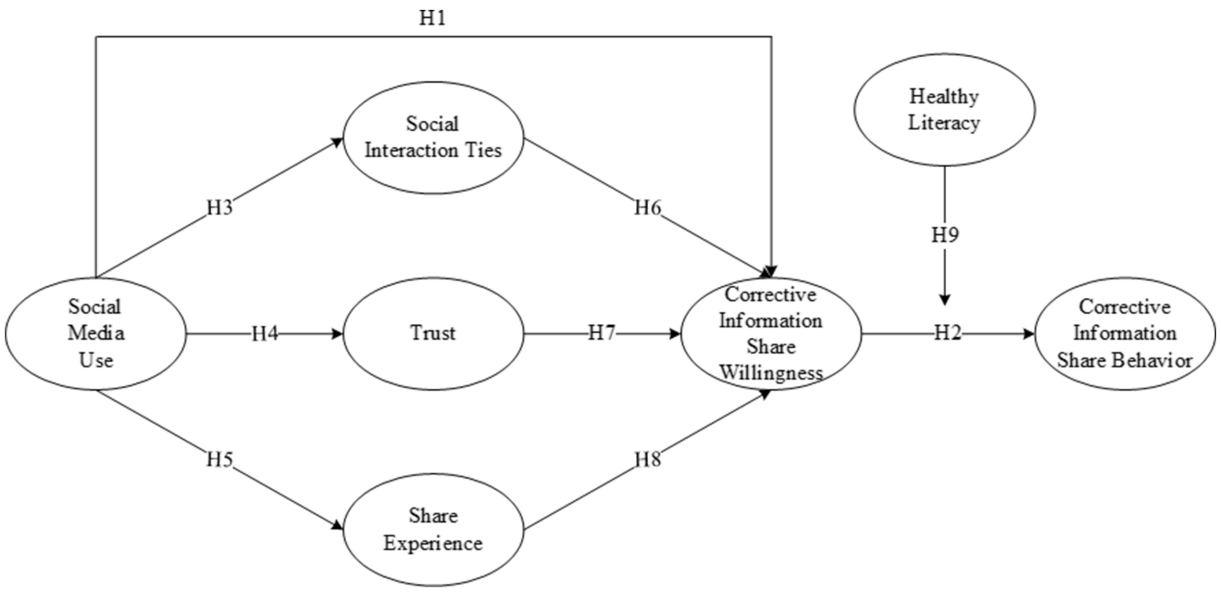


FIGURE 1
Research model for corrective information sharing in social media.

"strongly disagree" to "strongly agree"). to ensure the reliability and validity of the questionnaire, a small-scale test was conducted on the subjects in the pre-testing stage to listen to their opinions, and the questions, statements, and wording of the relevant questions were modified. After that, we invited experts and scholars to review the questionnaire and gradually revised it to improve it. The variables, measurements, and sources are shown in Table 2.

Statistical analysis and hypothesis test

This study adopted SPSS23.0 for descriptive analyses, and Partial Least Square (PLS) was used for confirmatory factor analyses and research hypotheses testing. PLS is considered "the most complete and versatile system" in structural equation modeling (86), and PLS-SEM can be used for principal component analysis, path analysis, testing for mediation and moderating effects and produces more robust results for non-constant data situations. The structural equation model evaluation and analysis for this study were carried out using SmartPLS 4.0.

Measurement model

The measurement model must pass the reliability test before structural model analysis can be performed. According to the statistical test, the standardized factor loading (STD) of the measurement model should be higher than 0.50, the composite reliability (C.R.) higher than 0.60, and the average variance extracted (AVE) higher than 0.50. As shown in Table 3, the STD of all items is greater than 0.8, Cronbach's alpha and C.R. are greater than 0.8, and AVE is greater than 0.7, all of which meet the criteria suggested by scholars and prove that all variables and items in the measurement model and question items have good reliability and validity.

Average variance extracted, as an important indicator to test whether variables are distinguishable, is crucial to the construction of models and the success of research hypotheses. In this study, the international Fornell–Larcker criterion was used to measure the discriminant validity between variables (87). As shown in Table 4, the square root of AVE of the variables in the measurement model is greater than the correlation coefficient between the variables, indicating that all variables have good discriminant validity between them.

Structural model

There are four main model fit metrics in PLS-SEM are standardized root mean square residual (SRMR), bootstrap-based test for the exact overall model fit (d_ULS and d_G),[1] and normed fit index (NFI). In this study, SRMR = 0.038 (<0.08), d_ULS = 0.437(<0.95), d_G = 0.327 (<0.95), and NFI = 0.911(>0.90) all meet the PLS model fitting standards recommended by scholars (88, 89). Therefore, the model of this study has a good degree of fit and can be analyzed in the next step.

Path analysis and hypothesis testing

As shown in Table 5, varying degrees of support for all seven research hypotheses, except for social media use, on corrective information sharing willingness did not receive support. There was a

1 The bootstrap-based test for the exact overall model fit tests the statistical (bootstrap-based) inference of the discrepancy between the empirical covariance matrix and the covariance matrix implied by the composite factor model. d_ULS (i.e., the squared Euclidean distance) and d_G (i.e., the geodesic distance) represent two different ways to compute this discrepancy.

TABLE 1 Demographics (number of subjects = 527).

Measure	Items	Number	Percentage(%)
Gender	Male	216	41.0
	Female	311	59.0
Education	High school or below	7	1.3
	College	42	8.0
	University	247	46.9
	Graduate school or above	231	43.8
Work	Public institutions/ Civil Servant	79	15.0
	Private enterprise	83	15.7
	State Owned Enterprises	49	9.3
	Pupil	237	45.0
	Freelancers	46	8.7
	Others	33	6.3
Age	<25 year	239	45.3
	26-35 year	170	32.3
	36-45 year	69	13.1
	46-55 year	40	7.6
	>55 year	9	1.7
Monthly Salary (RMB)	<3000RMB	233	44.2
	3,001–8,000	176	33.4
	8,001–13,000	77	14.6
	13,001–16,000	18	3.4
	>16,000	23	4.4

positive and significant effect of corrective information sharing willingness (CISW) ($\beta = 0.173$, $p < 0.001$) on corrective information sharing behavior (CISB). Social media use (SMU) ($\beta = 0.286$, $p < 0.001$) significantly influenced social interaction ties (SIT), social media use (SMU) ($\beta = 0.203$, $p < 0.001$) significantly influenced trust (TRU), and social media use (SMU) ($\beta = 0.171$, $p < 0.001$) significantly influenced share experience (SHE). There was a positive and significant effect of social interaction ties (SIT) ($\beta = 0.175$, $p = 0.012$), trust (TRU) ($\beta = 0.182$, $p = 0.007$), and share experience (SHE) ($\beta = 0.334$, $p < 0.001$) on corrective information sharing willingness (CISW). Therefore, the research hypothesis H1 is not valid and H2, H3, H4, H5, H6, H7, and H8 are valid.

Mediation effect test

In this study, the PLS-Bootstrapping 5,000 was used to test the mediating effect. As shown in Table 6, the mediation effect of corrective information sharing willingness between social media use and corrective information sharing behavior ($\beta = 0.002$, $p = 0.769$) was not significant, answering Q1. Among the simple mediation effects, social interaction ties ($\beta = 0.050$), trust ($\beta = 0.037$), and share experience ($\beta = 0.057$) each played a significant mediating effect between social media use on corrective information sharing willingness, answering Q2. In addition, this study also found that social interaction ties ($\beta = 0.030$), trust ($\beta = 0.032$), and share experience ($\beta = 0.058$) each positively influenced corrective information sharing behavior through corrective information sharing willingness.

In the chain mediation effects, social media use through social interaction ties, trust, share experience, and corrective information sharing willingness played a weak role in influencing corrective information sharing behavior. The chain mediation effect through share experience had the largest effect ($\beta = 0.010$).

Moderating effect of healthy literacy

As shown in Table 7, the interaction term between share willingness and health literacy had a positive and significant effect on sharing behavior ($p < 0.01$). When health literacy is higher, the degree of influence of share willingness on behavior is stronger. Therefore, for every 1 unit increase in health literacy, the degree of influence of willingness on behavior will increase by 0.131 units (Figure 2).

Conclusion and discussion

This study developed a structural equation model with social capital as a mediating variable and health literacy as a moderating variable. It is used to predict whether social media use can construct social capital through relational connection between users to promote

TABLE 2 Summary of measurement scales.

Construct	Measure	Source
Social Media Use(SMU)		
SMU1	Number of times you use SM per day	(67)
SMU2	Number of chats with others in SM per day	
SMU3	Number of times you retweet content from SM per day	
Social Interaction Ties(SIT)		
SIT1	I have close relationships with SMM	(43, 79)
SIT2	I spend a lot of time interacting with SMM	
SIT3	I have frequent communication with SMM	
SIT4	I have established a steady connection with SMM	
Trust(TRU)		
TRU1	My SMM are sincere with each other	(43, 79)
TRU2	My SMM do not try to use people in any way	
TRU3	My SMM keep their promises to each other	
TRU4	My SMM do not interrupt people's conversations with malicious intent	
TRU5	My SMM are consistent with their words	
Share Experience(SHE)		
SHE1	My SMM and I have had the experience of being misled by HM	(70, 80)
SHE2	My SMM and I have similar views on HM	
SHE3	My SMM and I have similar attitudes to HM	
SHE4	My SMM and I handle HM in a similar way	
Corrective Information Share Willingness(CISW)		
CISW1	I want to share CI to others	(81, 82)
CISW2	I wish to share CI with others	
CISW3	I look forward to sharing CI with others	
CISW4	I will continue to share CI to others	
Corrective Information Share Behavior(CISB)		
CISB1	Number of times per week I have shared CI with my family in the last three months	(17, 83)
CISB2	Number of times per week I have shared CI with friends in the last three months	
CISB3	Number of times per week I have shared CI with colleagues in the last three months	
CISB4	Number of times per week I have shared CI with others in the last three months	
Health Literacy(HEL)		
HEL1	I know where to seek health information	(84, 85)
HEL2	I like to get health information from diverse sources	
HEL3	Assessing the reliability of health information on diverse websites is easy for me	
HEL4	Assessing the reliability of health information on social media is easy for me	
HEL5	I apply diverse health knowledge to my daily life	

SM, Social Media; SMM, Social Media Members; HM, Health Misinformation; CI, Corrective information.

the dissemination of corrective information to combat health misinformation.

Conclusion

In terms of direct effects, first, social media use positively influence social interaction ties, trust, and share experiences in social capital. This result demonstrates that use social media can enhance an individual's status, resources (social interaction ties), and interpersonal relationships (trust) within the social network structure and can increase the sense of identity (share experiences) among other members. In the structural dimension, social media use can maintain the communication and sharing of information, knowledge, and experience, such as the dissemination of corrective information. In the relational dimension, social media use can develop positive and good interpersonal relationships, such as affectionate relationships, friendship relationships, and trust relationships. In the cognitive

TABLE 3 Reliability and convergent of the research model.

Variables	Items	Factor Loadings	Cronbachs α	C.R.	AVE
SMU	SMU1	0.924	0.907	0.918	0.842
	SMU2	0.912			
	SMU3	0.916			
SIT	SIT1	0.908	0.931	0.932	0.828
	SIT2	0.902			
	SIT3	0.926			
	SIT4	0.903			
TRU	TRU1	0.882	0.939	0.942	0.804
	TRU2	0.899			
	TRU3	0.909			
	TRU4	0.907			
	TRU5	0.886			
SHE	SHE1	0.828	0.896	0.903	0.762
	SHE2	0.887			
	SHE3	0.917			
	SHE4	0.857			
CISW	CISW1	0.929	0.953	0.953	0.876
	CISW2	0.944			
	CISW3	0.935			
	CISW4	0.935			
CISB	CISB1	0.929	0.952	0.953	0.874
	CISB2	0.944			
	CISB3	0.928			
	CISB4	0.938			
HEL	HEL1	0.817	0.902	0.914	0.719
	HEL2	0.812			
	HEL3	0.890			
	HEL4	0.900			
	HEL5	0.816			

C.R., composite reliability; AVE, average variance extracted; SMU, Social Media Use; SIT, Social Interaction Ties; TRU, Trust; SHE, Share Experience; CISW, Corrective information share Willingness; CISB, Corrective information Share Behavior; HEL, Health Literacy.

TABLE 4 Discriminant validity of measurement models (AVE).

Variables	AVE	SMU	SIT	TRU	SHE	CISW	CISB
SMU	0.842	0.918					
SIT	0.828	0.286	0.910				
TRU	0.804	0.203	0.611	0.897			
SHE	0.762	0.171	0.476	0.521	0.873		
CISW	0.876	0.156	0.448	0.465	0.514	0.936	
CISB	0.874	0.103	0.209	0.155	0.321	0.344	0.935

The diagonal values are the square root of each variable AVE and the others are the correlation coefficients between the variables.

dimension, social media use can enhance the level of understanding among members and share common aspirations, goals, and experiences. Second, social capital positively and significantly affects the corrective information sharing willingness. In terms of social interaction ties, the more frequent the interaction between social media members, the deeper the connections are. The more information is shared, the more knowledge and experience is exchanged, such as the sharing of corrective information. In terms of

TABLE 5 Path analysis and hypothesis test.

Hypothesis	Path	Unstd.	Std.	*p*-value	Results
H1	SMU → CISW	0.016	0.012	0.761	Reject
H2	CISW→CISB	−0.325	0.173***	0.000	Accept
H3	SMU → SIT	0.333	0.286***	0.000	Accept
H4	SMU → TRU	0.206	0.203***	0.000	Accept
H5	SMU → SHE	0.171	0.171***	0.000	Accept
H6	SIT→CISW	0.194	0.175*	0.012	Accept
H7	TRU → CISW	0.236	0.182**	0.007	Accept
H8	SHE→CISW	0.427	0.334***	0.000	Accept

Unstd., Unstandardization coefficient; Std., Standardization coefficient; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

TABLE 6 Mediation effect test.

Intermediate Path	Indirect effect	*T*-value	*P*-value	Bias-corrected 95%		Results
				Lower bound	Upper bound	
SMU → CISW→CISB	0.002	0.294	0.769	−0.021	0.031	Reject
SMU → SIT→CISW	0.050*	2.349	0.019	0.011	0.095	Accept
SMU → TRU → CISW	0.037*	2.277	0.023	0.010	0.073	Accept
SMU → SHE→CISW	0.057**	3.056	0.002	0.025	0.098	Accept
SIT→CISW→CISB	0.030*	2.097	0.036	0.013	0.112	Accept
TRU → CISW→CISB	0.032*	2.351	0.019	0.017	0.111	Accept
SHE→CISW→CISB	0.058**	3.115	0.002	0.071	0.169	Accept
SMU → SIT→CISW→CISB	0.009*	1.965	0.049	0.004	0.034	Accept
SMU → TRU → CISW→CISB	0.006*	2.028	0.043	0.003	0.026	Accept
SMU → SHE→CISW→CISB	0.010*	2.192	0.028	0.008	0.036	Accept

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

TABLE 7 Moderating effect of healthy literacy.

Path	Path Factor	Standard error	*T*-value	*P*-value	Result
CISW→CISB	0.175***	0.042	4.206	0.000	Accept
HEL → CISB	0.345***	0.042	8.129	0.000	
CISW×HEL → CISB	0.131**	0.048	2.720	0.006	

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

trust, the higher the level of trust among social media members, the greater the willingness to generate knowledge and information exchange, so trust can significantly influence the corrective information sharing willingness. In terms of share experience, when social media members identify with each other, the opportunity for information exchange is increased. For example, when social media members have experienced being misled by health misinformation, this experience increases the motivation of individuals to share corrective information. Third, corrective information sharing intention has a positive and significant effect on sharing behavior. It proves that when social media users generate willingness, they may generate behaviors.

In terms of indirect effects, first, social capital of social interaction ties, trust, and shared experience played a significant mediating effect on social media use to corrective information sharing willingness. It is noteworthy that social media use has no direct effect on share willingness but has an indirect effect on it through the mediating variable of social capital. The social capital of social ties, trust, and share experiences were shown to influence people's corrective information share willingness and behavior by building social network relationships. Second, corrective information share willingness mediated the effect of social capital of social interaction ties, trust, and share experience on corrective information sharing behavior. Third, the mediating effect of share willingness on social media use to sharing behavior was not significant.

In terms of moderating effect, health literacy plays a positive moderating role between corrective information share willingness and behaviors. Therefore, it can be understood that health literacy increases the influence of corrective information share willingness on behavior, which is more conducive to the proliferation of corrective information and helps to reduce the negative impact of health misinformation.

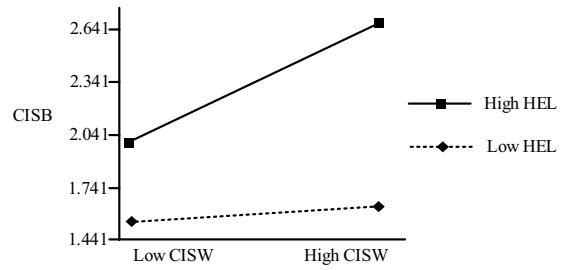


FIGURE 2
Moderating effect interaction plot of healthy literacy.

Discussion

Theoretical contributions

The impact of social media use on social capital has been demonstrated in many studies covering a wide range of disciplines, including news media, sociology, psychology, education, and economics. In this study, social media use was used as the independent variable, and the interactive connection, trust, and common experience of social capital were used as the mediator variables, and health literacy was added as a moderator variable to explore the sharing behavior of corrective health information, which expands the scope of application of social capital theory. First, the results of this study respond to previous research on social media use for social interaction connections (63, 90, 70). This suggests that social media use promotes interactive connection relationships among members, which facilitates the generation of information flow and exchange. Second, in terms of trust, distinguishing from previous study, this study found that social media use could positively influence the level of trust among members. In virtual social relationships, due to frequent communication and interaction between network members, social media use allows them to share more information, thus continuously increasing the level of trust between each other. This trust formed by continuous connection can significantly gather social capital in network relationships, and at the same time, social capital will be continuously expanded due to the deepening of trust among network members. Finally, in terms of share experiences, some studies have found that media use enhances an individual's identity and local identification, resulting in similarities with other members, such as the same background, the same context (91). Social media use can form stable networks of relationships and maintain positive and stable connections within the network with people who share common values and ideas and promote common interests (92).

This study confirms that social interaction ties, trust, and shared experiences have a significant effect on corrective information share willingness. Similar to the finding by Chiu, social interaction ties and share experiences can significantly influence individuals' information sharing behavior (17). Furthermore, consistent with the finding by Chen, trust significantly affects corrective information share willingness (16). In terms of structural dimensions, social interaction ties, as an important channel for information and resource flow, have an important role in correcting the wrong effects of health misinformation. Second, in terms of the relationship dimension, trust had a positive and significant effect on the corrective information share willingness, echoing the findings by Chen. Voluntary-focused trust behaviors are particularly important for exploring social media users' corrective information share willingness. Finally, to some extent, share experiences are reflected in homogeneity among social media members, i.e., whether they have all been exposed to health misinformation or whether their attitudes and perceptions about health misinformation are consistent with other members. Individuals are more likely to interact with members with whom they have something in common and are more likely to engage in corrective information sharing behavior when they believe that social media members may have similar experiences or encounters with them.

Although the findings confirm a positive and significant effect of share willingness on sharing behavior, the extent of the effect is not high. Information sharing is the act of information exchange and collaboration between two parties with a connected relationship, based on individual interests or common interests. The occurrence of behavior is influenced not only by intention but also by many factors such as individual ability, motivation, habit, cost, and convenience (93). First, information sharing requires certain costs, such as time, energy, and even privacy, to maintain an active state of communication and discussion with those being shared. Second, corrective information sharers also need to "gatekeep" the information to determine whether it is of good quality, and if they have difficulty ensuring the quality of the information, they may hesitate to share it. Especially when corrective information is published after health misinformation, many corrective information is not strictly verified, which not only does not help to correct health misinformation but also increases people's false beliefs. Third, information sharing requires certain resources and environmental conditions for the sharers, such as network conditions and device sensitivity. Therefore, future research needs to focus on how to stimulate users' willingness so as to cultivate and maintain their sharing behavior.

Correction measures in China's relational society

There have been many studies pointing to correction as an important means of addressing misinformation. In previous studies, scholars have attempted to reform the operation of news organizations in social networks to correct misinformation through fact-checking recommendations, information warnings, and growing a team of fact-checkers (94). However, this study argues that the spread of misinformation is shaped by social networks, and that to address misinformation, any corrective measures need to take social and interpersonal factors into account, or they may not achieve the corrective purpose at all. In a relational society, individuals' behavior starts with relationships, and information is often shared and interacted with the purpose of exchanging benefits and constructing social capital. First, relationships in social capital become an important variable in predicting corrective information sharing. Psychologists believe that the three main motivations for people to create and spread rumors are to discover facts and expand interpersonal relationships and self-improvement (95). Similar to the motivation of rumor spreading, the spread of corrective information is also aimed at increasing mutual understanding and maintaining relationships. To

enhance the exchange of information and benefits with members, individuals often share information in order to promote lasting relationships. Second, social capital connections are important for predicting the spread of corrective information. People often rely on informal relationships and word-of-mouth to obtain advice about health, especially when formal sources of information are not trusted. Thus, when members of a social network are subjected to health misinformation, individuals will communicate with other members and build connections and trust. In addition, the closeness of the relationship affects the persuasive effect of corrective messages, corrections from close people being more acceptable than strangers. Therefore, facilitating connections and interactions among social media members becomes a key element in the dissemination of corrective messages.

The importance of health literacy

The "Health China 2030" plan clearly states that "the health literacy level of the population will reach 30% by 2030. Among them, health literacy is mainly reflected in the screening and understanding of health information by individuals, as well as at the level of individuals' perception of whether health information will be threatened, their concern for health information protection, and the adoption of protective behaviors. As an important finding of this study, health literacy was a positive predictor of increased individual corrective information sharing behavior. When health literacy is higher, individuals have greater motivation and ability to transform their intentions into behaviors and thus take actual actions to convey authentic information. Therefore, developing public health literacy not only enhances individuals' health knowledge and skills but also their behavioral intention to corrective information forwarding and spreading. On the one hand, individuals should enhance their consciousness of protection in their daily use of the Internet and try not to spread or proliferate information with uncertainty. On the other hand, individuals should actively participate in online health literacy training to improve their health literacy.

This study has some shortcomings. The assessment of health literacy was derived from self-reported data from social media users, which may overestimate the results of health literacy. In addition, follow-up studies should focus on the key role that medical experts, healthcare workers, and health agencies play in addressing health misinformation in the Chinese cultural context and which types of corrective information have better corrective effects.

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 approval was not required for the study involving humans in accordance with the local legislation and institutional requirements. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was not required from the participants in accordance with the national legislation and the institutional requirements.

Author contributions

BF: Conceptualization, Data curation, Investigation, Methodology, Software, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

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.

Publisher's note

References

1. Suarez-Lledo V, Alvarez-Galvez J. Prevalence of health misinformation on social media: systematic review. *J Med Internet Res*. (2021) 23:e17187. doi: 10.2196/17187

2. Gong H. Struggling toward dialogue: health communication research in Chinese social media context. *Chin J J Commun*. (2019) 41:6–25. doi: 10.13495/j.cnki.cjjc.2019.06.001

3. Bautista JR, Zhang Y, Gwizdka J. Healthcare professionals' acts of correcting health misinformation on social media. *Int J Med Inform*. (2021) 148:104375. doi: 10.1016/j.ijmedinf.2021.104375

4. Vosoughi S, Roy D, Aral S. The spread of true and false news online. *Science*. (2018) 359:1146–51. doi: 10.1126/science.aap9559

5. Budak C, Agrawal D, Abbadi AE. Limiting the spread of misinformation in social networks. *Proceedings of the 20th international conference on world wide web, WWW 2011, Hyderabad, India, march 28–April 1, 2011*. (2011).

6. Wang Y, McKee M, Torbica A, Stuckler D. Systematic literature review on the spread of health-related misinformation on social media. *Soc Sci Med*. (2019) 240:112552. doi: 10.1016/j.socscimed.2019.112552

7. Walter N, Murphy S. How to unring the bell: a meta-analytic approach to correction of misinformation. *Commun Monogr*. (2018) 85:423–41. doi: 10.1080/03637751.2018.1467564

8. Bode L, Vraga EK. In related news, that was wrong: the correction of misinformation through related stories functionality in social media. *J Commun*. (2015) 65:619–38. doi: 10.1111/JCOM.12166

9. Sturgill A. Health care providers can help combat harmful misinformation about the pandemic. *N C Med J*. (2021) 82:68–70. doi: 10.18043/ncm.82.1.68

10. Lamberty P. Die Ursachen des Glaubens an Verschwörungserzählungen und Empfehlungen für eine gelungene Risikokommunikation im Gesundheitswesen.

Bundesgesundheitsbl Gesundheitsforsch Gesundheitsschutz. (2022) 65:537–44. doi: 10.1007/s00103-022-03524-z

11. Stephenson J. (2020). Available at: *United Nations seeks to counter COVID-19 misinformation with digital first responders*.

12. Vraga EK, Bode L. I do not believe you: how providing a source corrects health misperceptions across social media platforms. *Inf Commun Soc*. (2018) 21:1337–53. doi: 10.1080/1369118X.2017.1313883

13. Zubiaga A, Ji H. Tweet, but verify: epistemic study of information verification on twitter. *Soc Netw Anal Min*. (2014) 4:1–12. doi: 10.1007/s13278-014-0163-y

14. Tully M, Bode L, Vraga EK. Mobilizing users: does exposure to misinformation and its correction affect users' responses to a health misinformation post? *Soc Med Soc*. (2020) 6:2056305120978377. doi: 10.1177/2056305120978377

15. Bian Y. *Guanxi, how China works*. New York: John Wiley and Sons (2019).

16. Chen Y, Liang C, Cai D. Understanding WeChat users' behavior of sharing social crisis information. *Int J Hum Comput Interact*. (2018) 34:356–66. doi: 10.1080/10447318.2018.1427826

17. Chiu C-M, Hsu M, Wang ETG. Understanding knowledge sharing in virtual communities: an integration of social capital and social cognitive theories. *Decis Support Syst*. (2006) 42:1872–88. doi: 10.1016/j.dss.2006.04.001

18. Chang C-M, Hsu M-H. Understanding the determinants of users' subjective well-being in social networking sites: an integration of social capital theory and social presence theory. *Behav Inform Technol*. (2016) 35:720–9. doi: 10.1080/0144929X.2016.1141321

19. Aleksina A, Akulenka S, Lublóy Á. Success factors of crowdfunding campaigns in medical research: perceptions and reality. *Drug Discov Today*. (2019) 24:1413–20. doi: 10.1016/j.drudis.2019.05.012

20. Lin N, Erickson B. *Social capital: An international research program*. Oxford, UK: Oxford University Press (2008).

21. Blank G, Reisdorf BC. The participatory web. *Inf Commun Soc*. (2012) 15:537–54. doi: 10.1080/1369118X.2012.665935

22. Bolton RN, Parasuraman A, Hoefnagels A, Migchels N, Kabadayi S, Gruber T, et al. Understanding generation Y and their use of social media: a review and research agenda. *J Serv Manag*. (2013) 24:245–67. doi: 10.1108/09564231311326987

23. Correa T, Hinsley AW, de Zúñiga HG. Who interacts on the web?: the intersection of users' personality and social media use. *Comput Hum Behav*. (2010) 26:247–53. doi: 10.1016/j.chb.2009.09.003

24. Boulianne S. Social media use and participation: a meta-analysis of current research. *Inf Commun Soc*. (2015) 18:524–38. doi: 10.1080/1369118X.2015.1008542

25. Gil de Zúñiga H, Weeks B, Ardèvol-Abreu A. Effects of the news-finds-me perception in communication: social media use implications for news seeking and learning about politics. *J Comput-Mediat Commun*. (2017) 22:105–23. doi: 10.1111/jcc4.12185

26. Goh K-Y, Heng C-S, Lin Z. Social media Brand Community and consumer behavior: quantifying the relative impact of user-and marketer-generated content. *Inf Syst Res*. (2013) 24:88–107. doi: 10.1287/isre.1120.0469

27. Oh S-H, Lee SY, Han C. The effects of social media use on preventive behaviors during infectious disease outbreaks: the mediating role of self-relevant emotions and public risk perception. *Health Commun*. (2021) 36:972–81. doi: 10.1080/10410236.2020.1724639

28. Dhir A, Yossatorn Y, Kaur P, Chen S. Online social media fatigue and psychological wellbeing—a study of compulsive use, fear of missing out, fatigue, anxiety and depression. *Int J Inf Manag*. (2018) 40:141–52. doi: 10.1016/j.ijinfomgt.2018.01.012

29. Apuke OD, Omar B. Fake news and COVID-19: modelling the predictors of fake news sharing among social media users. *Telematics Inform*. (2021) 56:101475. doi: 10.1016/j.tele.2020.101475

30. Chadwick A, Vaccari C, O'Loughlin B. Do tabloids poison the well of social media? Explaining democratically dysfunctional news sharing. *New Media Soc*. (2018) 20:4255–74. doi: 10.1177/1461444818769689

31. Bae SY. The social mediation of political rumors: examining the dynamics in social media and belief in political rumors. *Journalism*. (2020) 21:1522–38. doi: 10.1177/1464884917722657

32. Li Y, Wang X, Lin X, Hajli M. Seeking and sharing health information on social media: a net valence model and cross-cultural comparison. *Technol Forecast Soc Chang*. (2018) 126:28–40. doi: 10.1016/j.techfore.2016.07.021

33. Walter N, Brooks JJ, Saucier CJ, Suresh S. Evaluating the impact of attempts to correct health misinformation on social media: a Meta-analysis. *Health Commun*. (2021) 36:1776–84. doi: 10.1080/10410236.2020.1794553

34. Bode L, Vraga EK. Correction experiences on social media during COVID-19. *Soc Med Soc*. (2021) 7:8829. doi: 10.1177/20563051211008829

35. Wang Y. Engaging with misinformation and misinformation corrective messages on social media: examining the role of source cues, social endorsement cues, and prior attitudes. *Atl J Commun*. (2023) 1:1–13. doi: 10.1080/15456870.2023.2291200

36. Chaoguang H, Feicheng M, Yifei Q, Yuchao W. Exploring the determinants of health knowledge adoption in social media: an intention-behavior-gap perspective. *Inf Dev*. (2018) 34:346–63. doi: 10.1177/0266666917700231

37. Jiang C, Zhao W, Sun X, Zhang K, Zheng R, Qu W. The effects of the self and social identity on the intention to microblog: an extension of the theory of planned behavior. *Comput Hum Behav*. (2016) 64:754–9. doi: 10.1016/j.chb.2016.07.046

38. Ortiz RR, Smith A, Coyne-Beasley T. A systematic literature review to examine the potential for social media to impact HPV vaccine uptake and awareness, knowledge, and attitudes about HPV and HPV vaccination. *Hum Vaccin Immunother*. (2019) 15:1465–75. doi: 10.1080/21645515.2019.1581543

39. Hanifan LJ. The rural school community center. *Ann Am Acad Pol Soc Sci*. (1916) 67:130–8. doi: 10.1177/000271621606700118

40. Bourdieu P. *The forms of capital*. Readings in Economic Sociology (1986). Available at: https://xueshu.baidu.com/usercenter/paper/show?paperid=7ce14ff2ee682062af2b762982aae777&site=xueshu_se.

41. Putnam RD. *Bowling alone:the collapse and revival of American community*. ACM Conference on Computer Supported Cooperative Work (2000). Available at: https://xueshu.baidu.com/usercenter/paper/show?paperid=27b94aae4262c782f303a184aaada832&site=xueshu_se.

42. Nahapiet J, Ghoshal S. Social capital, intellectual capital, and the organizational advantage. *Acad Manag Rev*. (1998) 23:242–66. doi: 10.5465/amr.1998.533225

43. Aslam MMH, Shahzad K, Syed AR, Ramish A. Social capital and knowledge sharing as determinants of academic performance. *J Behav Appl Manag*. (2013) 15:25–41. doi: 10.21818/001c.17935

44. Mu J, Peng G, Love E. Interfirm networks, social capital, and knowledge flow. *J Knowl Manag*. (2008) 12:86–100. doi: 10.1108/13673270810884273

45. Paxton P. Social capital and democracy: an interdependent relationship. *Am Sociol Rev*. (2002) 67:254–77. doi: 10.2307/3088895

46. Blau PM. *Exchange and power in social life*. New York: Wiley (1964).

47. Zucker LG. Production of trust: institutional sources of economic structure, 1840–1920. *Res Organ Behav*. (1986) 8:53–111.

48. Ganzha M, Paprzycki M, Lirkov I. Trust management in an agent-based grid resource brokering system-preliminary considerations. *AIP Conf Proc*. (2007) 946:35–46. doi: 10.1063/1.2806037

49. Newton K. Trust, social capital, civil society, and democracy. *Int Polit Sci Rev*. (2001) 22:201–14. doi: 10.1177/0192512101222004

50. Riegelsberger J, Sasse MA, Mccarthy JD. The mechanics of trust: a framework for research and design. *Int J Hum Comput Stud*. (2005) 62:381–422. doi: 10.1016/j.ijhcs.2005.01.001

51. Chen Y, Yan X, Fan W, Gordon M. The joint moderating role of trust propensity and gender on consumers' online shopping behavior. *Comput Hum Behav*. (2015) 43:272–83. doi: 10.1016/j.chb.2014.10.020

52. Joia LA, Lemos B. Relevant factors for tacit knowledge transfer within organisations. *J Knowl Manag*. (2010) 14:410–27. doi: 10.1108/13673271011050139

53. Sitton JF, Ebrary I. *Habermas and contemporary society*. Habermas and contemporary society. (2003). Available at: https://xueshu.baidu.com/usercenter/paper/show?paperid=a6d52bbad63ab2a49b45cfa0510b8f91&site=xueshu_se.

54. Bae SJ, Lee H, Suh E-K, Suh K-S. Shared experience in pretrip and experience sharing in posttrip: a survey of Airbnb users. *Inf Manag*. (2017) 54:714–27. doi: 10.1016/j.im.2016.12.008

55. McPherson M, Smith-Lovin L, Cook JM. Birds of a feather: Homophily in social networks. *Annu Rev Sociol*. (2001) 27:415–44. doi: 10.1146/annurev.soc.27.1.415

56. Phua J, Jin SV, Kim J. Gratifications of using Facebook, twitter, Instagram, or snapchat to follow brands: the moderating effect of social comparison, trust, tie strength, and network homophily on brand identification, brand engagement, brand commitment, and membership intention. *Telematics Inform*. (2017) 34:412–24. doi: 10.1016/j.tele.2016.06.004

57. Steffes EM, Burgee LE. Social ties and online word of mouth. *Internet Res*. (2009) 19:42–59. doi: 10.1108/10662240910927812

58. Ellison NB, Steinfield C, Lampe C. Connection strategies: social capital implications of Facebook-enabled communication practices. *New Media Soc*. (2011) 13:873–92. doi: 10.1177/1461444810385389

59. Newman MW, Lauterbach D, Munson SA, Resnick P, Morris ME. *It's not that i don't have problems, i'm just not putting them on facebook: challenges and opportunities in using online social networks for health*. Proceedings of the ACM 2011 Conference on Computer Supported Cooperative Work, pp. 341–350. (2011).

60. Burke M, Kraut R, Marlow C. *Social capital on facebook: differentiating uses and users*. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 571–580. (2011).

61. Shane-Simpson C, Manago A, Gaggi N, Gillespie-Lynch K. Why do college students prefer Facebook, twitter, or Instagram? Site affordances, tensions between privacy and self-expression, and implications for social capital. *Comput Hum Behav*. (2018) 86:276–88. doi: 10.1016/j.chb.2018.04.041

62. Liu D, Brown BB. Self-disclosure on social networking sites, positive feedback, and social capital among Chinese college students. *Comput Hum Behav*. (2014) 38:213–9. doi: 10.1016/j.chb.2014.06.003

63. Pfeil U, Arjan R, Zaphiris P. Age differences in online social networking – a study of user profiles and the social capital divide among teenagers and older users in MySpace. *Comput Hum Behav*. (2009) 25:643–54. doi: 10.1016/j.chb.2008.08.015

64. Kavanaugh AL, Patterson SJ. The impact of community computer networks on social capital and community involvement. *Am Behav Sci*. (2001) 45:496–509. doi: 10.1177/00027640121957312

65. Yli-Renko H, Autio E, Sapienza HJ. *Social capital, knowledge acquisition, and knowledge exploitation in young technology-based firms*. (2001).

66. Chua A. The influence of social interaction on knowledge creation. *J Intellect Cap*. (2002) 3:375–92. doi: 10.1108/14691930210448297

67. Zhang C-B, Li Y-N, Wu B, Li D-J. How WeChat can retain users: roles of network externalities, social interaction ties, and perceived values in building continuance intention. *Comput Hum Behav*. (2017) 69:284–93. doi: 10.1016/j.chb.2016.11.069

68. Chai S, Kim M. A socio-technical approach to knowledge contribution behavior: an empirical investigation of social networking sites users. *Int J Inf Manag*. (2009) 32:118–26. doi: 10.1016/j.ijinfomgt.2011.07.004

69. Chen X, Pan Y, Guo B. The influence of personality traits and social networks on the self-disclosure behavior of social network site users. *Internet Res*. (2016) 26:566–86. doi: 10.1108/IntR-05-2014-0145

70. Apuke OD, Omar B. What drives news sharing behaviour among social media users? A relational communication model from the social capital perspective. *Int Sociol*. (2021) 36:339–61. doi: 10.1177/0268580920961323

71. Neil-Urban S, Jones JB. Father-to-father support: fathers of children with Cancer share their experience. *J Pediatr Oncol Nurs*. (2002) 19:97–103. doi: 10.1177/104345420201900304

72. Xiaoyan M, Xin SUN, Yi K, Zuojun W. Co-experiencing the same negative emotional events promotes cooperation. *Acta Psychol Sin*. (2021) 53:81–94. doi: 10.3724/SP.J.1041.2021.00081

73. Sun R, Li C, Millet B, Ali KI, Petit J. Sharing news with online friends: a study of network homophily, network size, and news type. *Telematics Inform*. (2022) 67:101763. doi: 10.1016/j.tele.2021.101763

74. Hirvonen N, Enwald H, Mayer A-K, Korpelainen R, Pyky R, Salonurmi T, et al. Screening everyday health information literacy among four populations. *Health Inf Libr J*. (2020) 37:e12304:192–203. doi: 10.1111/hir.12304

75. Yang M. Health information literacy of the older adults and their intention to share health rumors: an analysis from the perspective of socioemotional selectivity theory In: J Zhou and G Salvendy, editors. *Human aspects of IT for the aged population. Social media, games and assistive environments*. Berlin: Springer International Publishing (2019). 97–108.

76. Oh HJ, Lee H. When do people Verify and Share health rumors on social media? The effects of message importance, health anxiety, and health literacy. *J Health Commun*. (2019) 24:837–47. doi: 10.1080/10810730.2019.1677824

77. Fleary SA, Joseph P, Pappagianopoulos JE. Adolescent health literacy and health behaviors: a systematic review. *J Adolesc*. (2018) 62:116–27. doi: 10.1016/j.adolescence.2017.11.010

78. Crook B, Stephens KK, Pastorek AE, Mackert M, Donovan EE. Sharing health information and influencing behavioral intentions: the role of health literacy, information overload, and the internet in the diffusion of healthy heart information. *Health Commun*. (2016) 31:60–71. doi: 10.1080/10410236.2014.936336

79. Koranteng FN, Wiafe I. Factors that promote knowledge sharing on academic social networking sites: an empirical study. *Educ Inf Technol*. (2019) 24:1211–36. doi: 10.1007/s10639-018-9825-0

80. Ma L, Sian Lee C, Hoe-Lian Goh D. Understanding news sharing in social media: an explanation from the diffusion of innovations theory. *Online Inf Rev*. (2014) 38:598–615. doi: 10.1108/OIR-10-2013-0239

81. Fishbein M, Ajzen I. Belief, attitude, intention and behaviour: an introduction to theory and research. Addison-Wesley, Reading MA. *Philos Rhetor*. (1977) 41:842–4. doi: 10.2307/4393175

82. Lin H-F. Effects of extrinsic and intrinsic motivation on employee knowledge sharing intentions. *J Inf Sci*. (2007) 33:135–49. doi: 10.1177/0165551506068174

83. Davenport TH, Prusak L. *Working knowledge: How organizations manage what they know*. Brighton, MA: Harvard Business School Press (2000).

84. Niemelä R, Ek S, Eriksson-Backa K, Huotari M-L. A screening tool for assessing everyday health information literacy. *Libri*. (2012) 62:125–34. doi: 10.1515/libri-2012-0009

85. Reychav I, Najami I, Raban DR, McHaney R, Azuri J. The impact of media type on shared decision processes in third-age populations. *Int J Med Inform*. (2018) 112:45–58. doi: 10.1016/j.ijmedinf.2018.01.004

86. McDonald RP. Path analysis with composite variables. *Multivar Behav Res*. (1996) 31:239–70. doi: 10.1207/s15327906mbr3102_5

87. Fornell C, Larcker DF. Evaluating structural equation models with unobservable variables and measurement error. *J Mark Res*. (1981) 18:39–50. doi: 10.1177/002224378101800104

88. Bentler PM, Bonett DG. Significance tests and goodness of fit in the analysis of covariance structures. *Psychological bulletin*. (1980) 88:588.

89. Henseler J, Hubona G, Ray PA. Using PLS path modeling in new technology research: updated guidelines. *Industrial management & data system*. (2016) 116:2–20.

90. Haythornthwaite C. Social networks and internet connectivity effects. *Inf Commun Soc*. (2005) 8:125–47. doi: 10.1080/13691180500146185

91. Li M, Li J, Yasin MAI, Hashim NB, Ang LH, Li F. Where do I belong? A study of associations between guanxi capital and local identity through WeChat use among Chinese youth. *Technol Forecast Soc Chang*. (2023) 187:122198. doi: 10.1016/j.techfore.2022.122198

92. Loss J, Lindacher V, Curbach J. Online social networking sites–a novel setting for health promotion? *Health Place*. (2014) 26:161–70. doi: 10.1016/j.healthplace.2013.12.012

93. Deshpande S, Basil MD, Basil DZ. Factors influencing healthy eating habits among college students: an application of the health belief model. *Health Mark Q*. (2009) 26:145–64. doi: 10.1080/07359680802619834

94. Nyhan B, Reifler J. Does correcting myths about the flu vaccine work? An experimental evaluation of the effects of corrective information. *Vaccine*. (2015) 33:459–64. doi: 10.1016/j.vaccine.2014.11.017

95. DiFonzo N, Bordia P. *Rumor psychology: Social and organizational approaches*. Washington, DC: American Psychological Association (2007). 292 p.

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 25 April 2024
DOI 10.3389/fpubh.2024.1362009

OPEN ACCESS

EDITED BY
Fatjona Kamberi,
University of Vlorë, Albania

REVIEWED BY
Tanay Maiti,
Black Country Partnership NHS Foundation Trust, United Kingdom
Hafiz Shahbaz,
University of Veterinary and Animal Sciences, Pakistan

*CORRESPONDENCE
Sujin Choi
✉ schoi77@sch.ac.kr

RECEIVED 27 December 2023
ACCEPTED 12 April 2024
PUBLISHED 25 April 2024

CITATION
Choi S (2024) The coronavirus disease 2019 infodemic: a concept analysis.
Front. Public Health 12:1362009.
doi: 10.3389/fpubh.2024.1362009

The coronavirus disease 2019 infodemic: a concept analysis

Sujin Choi*

Department of Nursing, College of Medicine, Soonchunhyang University, Asan-si, Republic of Korea

Aim: This study aimed to analyze the coronavirus disease 2019 (COVID-19) infodemic phenomenon in the medical field, providing essential data to help healthcare professionals understand it.

Methods: This study utilized a hybrid model for concept analysis. In the theoretical phase (first phase), a literature review was conducted using ScienceDirect, PubMed, CINAHL, ProQuest, Scopus, Web of Science, DBpia, RISS, and KISS. Semi-structured interviews, involving eight physicians and six nurses, were used in the fieldwork phase (second phase). In the final analysis phase (third phase), the results of the preceding phases were combined.

Results: Based on the findings of these phases, the COVID-19 infodemic can be defined as "the phenomenon of information flood, reproduction, dissemination, and asymmetry, which occurred during the pandemic through social networks among the public lacking essential knowledge of infectious disease, and is associated with negative and positive effects."

Conclusion: Our findings can help the Ministry of Health and Welfare and healthcare professionals to understand the phenomenon of the infodemic and prepare necessary strategies and education programs for the public. Therefore, the provision of basic data is important for developing influential roles for healthcare professionals during infectious disease outbreaks.

KEYWORDS

infodemic, overload, asymmetry, reproduction, dissemination

1 Introduction

According to the World Health Organisation (WHO), the information tsunami during the coronavirus disease 2019 (COVID-19) pandemic resulted in the generation of fake news that lacked scientific evidence and conveyed misunderstandings and misinformation about health (1). After WHO declared COVID-19 as a pandemic in March 2020 (1), an accompanying phenomenon called the "information pandemic" emerged, which refers to the rapid spread of misinformation or fake news through social media platforms and other mass media (2). Previous research has indicated that the information pandemic during the COVID-19 period which has called "COVID-19 infodemic" caused an invisible disaster with serious and widespread harmful effects (3, 4). Additionally, WHO defined an infodemic as a state in which correct and incorrect health information is mixed and proclaimed their combat against the infodemic (1).

Moon and Lee (5) analyzed the 200 most-viewed Korean YouTube videos about the COVID-19 virus in 2020, and identified that YouTube users created most videos, and that 37.13% of the videos contained incorrect information, with each video reflecting up to 68.09% of misinformation. Examples of misinformation included that boiling water, snake oil, silver, and burning incense could treat COVID-19 (6), and conspiracy theories suggesting that the government put microchips in the COVID-19 vaccine to track citizens (7).

The infodemic phenomenon negatively affected individuals and the approaches of healthcare professionals and government policies in managing COVID-19. The infodemic during the

COVID-19 pandemic also worsened the emotional problems of the public (8). A study conducted in China revealed that frequent exposure to social media containing COVID-19-related content increased depression and the prevalence of hyper-anxiety (9). The phenomenon of people trusting misinformation more than medical staff was also reported (10). Owing to the spread of misleading news, governments worldwide faced challenges in preventing and managing infectious diseases, as the public exhibited reluctance to follow COVID-19 guidelines during the pandemic (11, 12).

While, studies on the causes (13, 14), impacts (8, 14–16), and preventive strategies (14, 17) of the COVID-19 infodemic have been actively conducted, no research has identified to reveal the concept of the COVID-19 infodemic. Conducting a concept analysis enhances the practicality of the concept by providing a clear and transparent definition, thus serving as a foundation for planning, implementing, and assessing the utilization of the concept (18). Pope et al. (19) conducted a concept analysis study on the concept of "health misinformation" during the COVID-19 pandemic, but did not include correct health information. Therefore, it is necessary to conduct analytical research on the entire concept of infodemic, including correct information, as WHO (1) suggested.

Additionally, the need to identify the concept of the COVID-19 infodemic through a concept analysis study in medical settings has been raised. This is because healthcare professionals in medical settings have been at front-line of COVID-19 patients during the pandemic. During the COVID-19 pandemic, healthcare professionals communicated with each other constantly to stay informed amidst the flood of information and make medical decisions (20). However, there is no clear and concise concept of COVID-19 infodemic which is necessary for them to strategically respond to infodemic for a future pandemic. Thus, this study aimed to analyze the concept of the COVID-19 infodemic through identifying its antecedents, attributes, and consequences in the medical setting, providing basic data to help healthcare professionals understand the phenomenon of the COVID-19 infodemic.

2 Methods

This study analyzed the concept of the COVID-19 infodemic, targeting physicians and nurses working in medical settings, using a hybrid model. The hybrid model can clarify concepts and understand them in a situational context (21). Concept analysis through a hybrid model combines inductive and deductive analysis approaches and is used to specify concepts because it can subdivide widely applied concepts (18). The hybrid model is based on a literature review and individual interviews; thus, it can provide detailed data and clear analysis findings about concepts depending on context and situation (22). The hybrid model comprises theoretical, fieldwork, and final analysis phases (21).

2.1 The theoretical phase

A literature review was conducted on the infodemic in nursing and healthcare. The literature search included papers published from January 2020 to September 2023 in domestic and international databases such as ScienceDirect, PubMed, CINAHL, ProQuest, Scopus, Web of Science, DBpia, RISS, and KISS. Search terms included "infodemic," "misinformation," "information," "health information," and "COVID*." The search strategy incorporated "COVID*" and combined the remaining search terms. The inclusion criteria for papers in the analysis were: (a) inclusion of keywords in the text, (b) publication in English and Korean, (c) availability of full text, and (d) peer-reviewed articles. Editorials, conference discussions, and posters were excluded. Figure 1 illustrates the process of selected studies. A total of 48 eligible articles were included in the study. Following data collection, the content of the selected studies was analyzed, and a detailed definition of the COVID-19 infodemic, along with its antecedents, characteristics, and consequences, was derived.

2.2 The fieldwork phase

In this phase, a qualitative study was conducted to explore the first-hand experiences of participants. Eight physicians and six registered nurses were interviewed about the COVID-19 pandemic, its characteristics, antecedents, and consequences. Convenient sampling was employed, ensuring maximum variation in participants' age, gender, work experience, and healthcare institutions (Table 1). The mean age of the participants was 32 ± 5.3 years.

Interviews were conducted to explore the experiences of healthcare professionals in medical settings until theoretical data saturation was reached (23). The researcher directly conducted the interviews. The interview questions were: (a) Please tell me about an experience in which patients asked questions about COVID-19 during the COVID-19 pandemic, or an experience in which patients believed nonsensical knowledge; (b) Why has so much information (including misinformation) emerged about COVID-19? What do you think as a healthcare professional; (c) As healthcare professionals, why do you think the public accepts nonsensical knowledge about COVID-19; and (d) Please tell me about any experiences you remember about how patients were later affected positively or negatively by information. The interviews lasted an average of 30 min, and all interviews were recorded using a digital recorder after obtaining consent from the participants. Data analysis was conducted immediately after data collection using Graneheim and Lundman's content analysis method (24). Each interview data was transcribed into a transcript, read several times to identify keywords and meaning units, and coded to recognize them. Similar codes were grouped to derive themes. The researcher, having extensive experience in qualitative research, wrote reflection notes on the researcher's biases and preconceptions before the interview and utilized them in data analysis to improve the quality of the research results and avoid possible bias. Furthermore, the researcher employed a rigorous process to cross-verify responses from participants whose interview data carried ambiguous meanings. Through this iterative approach, data saturation was attained.

2.3 Final analysis phase

The results from the preceding two phases were combined. Subcategories were constructed by comparing and merging the codes

Abbreviations: COVID-19, coronavirus disease 2019; SNS, social networking services.

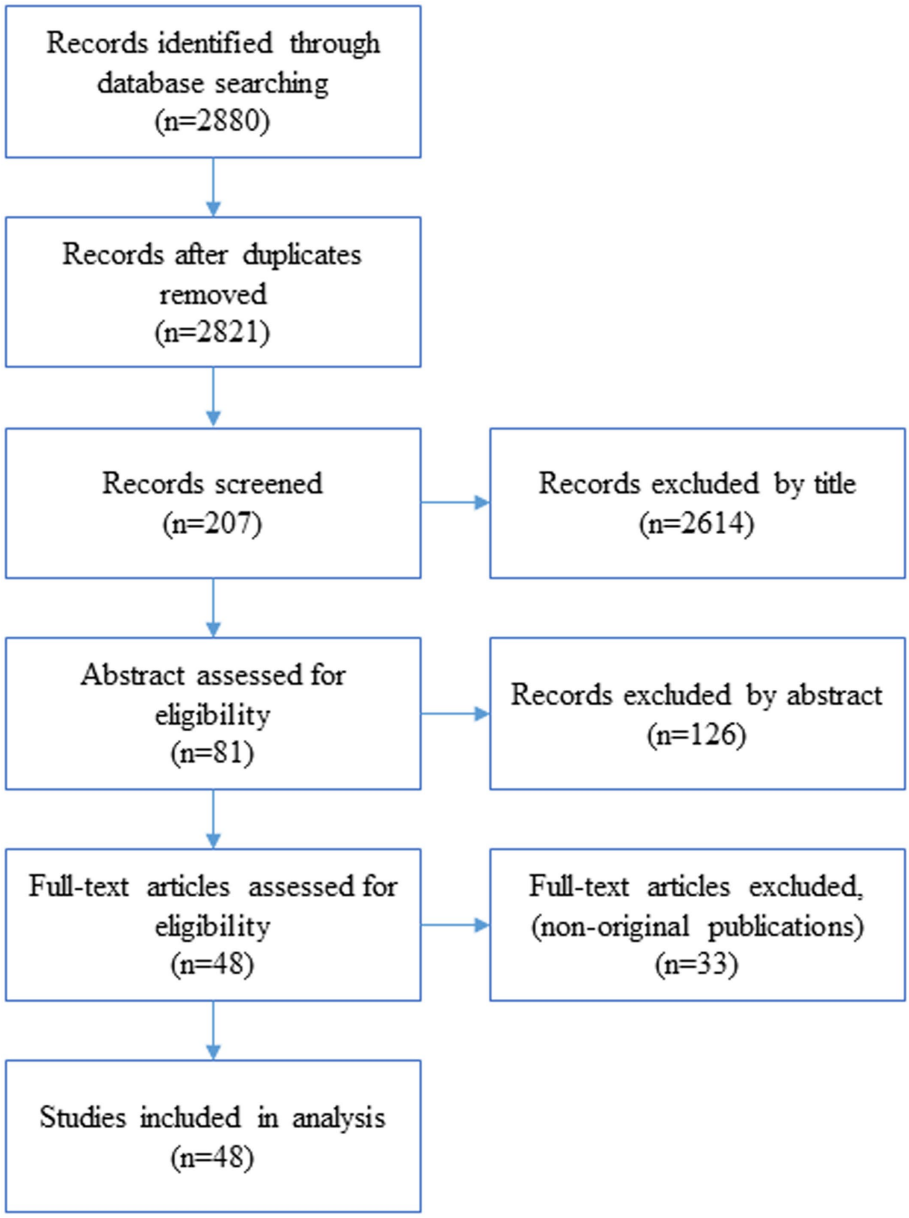


FIGURE 1
Flow diagram of the selection process.

extracted from the two phases. Finally, attributes, antecedent factors, and consequent factors were identified to provide a comprehensive definition of the concept.

3 Results

3.1 Findings of the theoretical phase

3.1.1 Definition of an infodemic

At the beginning of the COVID-19 pandemic, WHO announced the term and defined an "infodemic" as "too much information, including false or misleading information, in digital and physical environments during a disease outbreak" (1). This term has been used to describe the rapid spread of information, both online and offline (25), covering various aspects such as the virus, disease, treatment, standard operating procedures, lockdowns, and vaccines (26). Before the COVID-19 pandemic, such unverified and inaccurate information encompassed misinformation, disinformation, and malinformation (27).

3.1.2 Antecedents of the infodemic

The antecedents of the infodemic were categorized into environment-related and public-related.

3.1.2.1 Environment-related

A pandemic is defined as "an epidemic occurring worldwide or over a wide area, crossing international boundaries and usually

TABLE 1 Participant demographics ($n = 14$).

Characteristics		n (%)
Age range (years)	20 ~ 29	7
	30 ~ 39	5
	40 ~ 49	2
Gender	Female	9
	Male	5
Occupation	Physician	8
	Registered nurse	6
Education background	Undergraduate	13
	Graduate	1
Work experience (years)	1 ~ 3	5
	3 ~ 6	4
	6 ~ 9	4
	10~	1

affecting numerous people" (28). The pandemic resulted in an infodemic (26). Research has revealed that misinformation can foster an atmosphere of panic and discrimination in pandemics (29). The dissemination and consumption of information have spiked since the COVID-19 pandemic (30). At the onset of the pandemic, consumption of news among the public increased by 62% (31), with many being exposed to significant amounts of misinformation and fake news while seeking information related to COVID-19 pandemic (32, 33). Pandemics have resulted in infodemic even before COVID-19. For example, a rumor claiming that lack of iodine caused severe acute respiratory syndrome led to panic buying of salt during that pandemic in China (34).

Social media affects infodemic. A rapid integrative review study on infodemic during the COVID-19 pandemic reported social media as a direct source of quickly disseminating misinformation (4, 35). Another systemic review on health misinformation on social media identified high levels of misinformation on vaccines and disease on Twitter (36). Social media and private unfiltered networks such as WhatsApp, Facebook, Twitter, YouTube, and TikTok spread information much faster than the virus (37). A retrospective analysis of the COVID-19 infodemic in Saudi Arabia identified three sources of rumors social paths (through talking with friends and family), (2) traditional media such as television and newspapers, and (3) social media platforms such as Twitter and Facebook which were reported as the most common source of rumors, as these platforms are now the go-to media for information (25). Additionally, a study analyzing data on the COVID-19 social media infodemic reported that information from reliable and questionable sources does not present different spreading patterns (4).

3.1.2.2 Public-related

People with a low level of knowledge about COVID-19, low health/media literacy (17), and low trust in government/news media, particularly those with lower education, males, and younger individuals (26), tend to be more susceptible to the infodemic. Another study revealed that people with high levels of health literacy experienced difficulties dealing with the infodemic during the COVID-19 pandemic (38). This contrasts with research findings suggesting that people with low awareness (26) are more likely to be exposed to infodemic.

3.1.3 Characteristics of the infodemic

The characteristics of the infodemic were identified as quantitative volume of information and qualitative pattern of information.

3.1.3.1 Quantitative volume of information

A survey among healthcare professionals in India reported that 67% of respondents either agreed or strongly agreed about information overload (39). The types of information include unreliable information, rumors, and gossip (39), and false news, conspiracy theories, magical cures, and racist news (35, 40). Misinformation and disinformation about the virus, its origin, the vaccines, and potential treatment proliferated throughout the COVID-19 pandemic (41). Compared with that a decade ago, access to the internet and smartphones, as well as the availability of laptops at much cheaper rates, has facilitated the collection and real-time sharing of data, collaboration across different continents, live video conferences to share experiences, uploading of educational videos, and the accessibility of scientific information as soon as it becomes available (40).

3.1.3.2 Qualitative pattern of information

Wardle and Derakhshan discussed the three elements involved in the creation, production, distribution, and reproduction of misinformation (42). The created information is reproduced through the combination of social media and personal experiences. Social media users interpret the reproductive information and distribute it, with many regular users contributing to most retweets of content sourced from fake news websites (43). WHO also detected the production of fake news from the tsunami of information during the COVID-19 pandemic (1). A survey among healthcare professionals in India reported that 75% of respondents either agreed or strongly agreed about inaccurate information. Fifty percent of the respondents agreed or strongly agreed that differentiating correct from incorrect information is challenging (39).

Studies have documented the global spread of information and misinformation in the context of COVID-19 (39). The term "infodemic" has been used to describe the rapid spread and sharing of information (39, 40, 44). A rapid review study on misinformation during public health emergencies due to pandemics identified the sources of information from social media, friends and family, healthcare providers, religious leaders, and word of mouth (35). Some researchers evaluated the spreading pattern of news on COVID-19. Cinelli et al. revealed that the spread of information is motivated by the interaction paradigm set by the specific social media platforms and/or by the interaction patterns of users engaged in the topic (4). Pennycook et al. discovered that people shared false news about COVID-19 partially because they did not adequately consider the accuracy of the content before deciding to share (45).

3.1.4 Consequences of the infodemic

3.1.4.1 Impact on wellbeing

An infodemic causes confusion, panic attacks (29, 46), and fear and anxiety among citizens (37, 44). The fear of the virus created by social

TABLE 2 Hybrid data analysis in COVID-19 infodemic.

The phase of the study	Codes	Subcategories	Categories
Theoretical phase	Information overload	Quantitative volume of information	Characteristics of COVID-19 infodemic
	Reproduction of information	Qualitative pattern of information	
	Rapid spread of information		
	The pandemic	Environment-related	Antecedents of COVID-19 infodemic
	The development of social network services (SNS) The use of SNS		
	Being unprepared to disease outbreak among the public	Public-related	
	Anxiety, fear, suicide, vaccination hesitance, information avoidance	Impact on wellbeing	Consequences of COVID-19 infodemic
	Not responding to health policies Mistrust in healthcare authorities	Impact on healthcare policy	
Field work phase	Information flood	Quantitative volume of information	Characteristics of COVID-19 infodemic
	Reproduction of information	Qualitative pattern of information	
	Dissemination of information		
	Asymmetry of information		
	Usage of social network services Limited access to healthcare professional for home-based treatment	Environment-related	Antecedents of COVID-19 infodemic
	Absence of essential understanding on infectious disease	Public-related	
	An increase in interests in the COVID-19 virus among the public Practicing preventive measures cautiously	Positive impacts	Consequences of COVID-19 infodemic
	A decrease in trust in healthcare professionals Creation of anxiety and confusion among patients	Negative impacts	

media is more contagious to the general population than COVID-19 itself (37). For example, a man in India who was hospitalized for treatment by healthcare professionals committed suicide because of unclear information (47). Vaccination hesitance, which is the refusal of vaccines when access is not a limiting factor, has also been reported (48). In addition, information avoidance was reported. An overabundance of COVID-19 information can harm mental wellbeing and lead to a discontinuation of information-seeking behavior, as people deliberately avoid information that threatens their wellbeing (49).

3.1.4.2 Impact on healthcare policy

An infodemic triggers discrimination and stigma of disease and hinders the rapid response policies of health officials and policymakers (50). Infodemic can cause confusion and risk-taking behavior, which can harm an individual's health, and cause mistrust in healthcare authorities (51), lengthening the outbreak (52). An infodemic makes it challenging for the public to comply with public health measures, as it can debilitate individuals' ability to distinguish mis- and disinformation from fact and cause false perceptions of true risk, including a higher perceived risk and a false sense of safety (38, 53).

3.2 Findings of the fieldwork phase

In this phase, 185 primary codes were generated and grouped into three main categories: dimensions, antecedents, and consequences of the infodemic (Table 2).

3.2.1 Characteristics of infodemic

The subcategories of the characteristics of the COVID-19 infodemic were identified, consistent with the findings of the theoretical work. A code for the subcategory "asymmetry of information" under the category of "qualitative pattern of information" was additionally derived.

3.2.1.1 Quantitative volume of information

Most participants recalled the COVID-19 pandemic period, identifying an overload of unnecessary information, such as all the movement routes of people with the COVID-19 virus, newsletters regarding treatments from reporters who did not fully understand the medical information, and information on late complications of the COVID-19 virus (Participants 3, 6 and 12). They mentioned that the quantity of other types of information was overwhelming compared

with the information provided by healthcare professionals (Participant 5). Furthermore, much information was available but tended to be repetitive (Participant 9).

> *As you know, they now announce the number of confirmed cases every day, and we receive several messages. It is so overwhelming to the point that it feels like a trauma, with so much information. At first, when there were not many initial confirmed cases, they disclosed all the movement routes* (Participant 12).

3.2.1.2 Qualitative pattern of information

Most participants highlighted that the public reproduced information. The reasons for the reproduction of information included a lack of basic understanding of medical articles, purposefully creating provocative news to gain more "likes," and political motives (criticizing the current government's actions). The phenomenon of information reproduction has become most prominent in the social media space.

> *In the case of the media, information is directly linked to profitability based on the number of views, so there have been some indiscriminate articles published, competing with provocative titles and phrases. Someone made claims about things that have not been proven, and when encountering such internet articles, it is easy to be deceived because the internet articles seem more credible than friends or acquaintances* (Participant 6).

Dissemination of information refers to the same characteristic, "rapid spread of information," drawn from the theoretical work. According to our participants, stopping the dissemination of information through social network services online is impossible. Information spreads within social networking services (SNS) platforms, and family members in a family, coworkers in the workplace, and friends, who also share news they encounter on SNS. This pattern of information dissemination is even faster.

> *Nowadays, in a situation where anyone can freely create videos and access information, the creation and dissemination of any information itself has become possible from anyone, anywhere. While it is true that the spread of information has been fast, when I thought about whether it could be controlled, I actually believe that control is impossible* (Participant 8).

Most participants highlighted the asymmetry of information, mostly among healthcare professionals, patients, and healthcare institutions. The amount and quality of information about COVID-19 between healthcare professionals and patients may vary. However, healthcare professionals have expressed deep concerns about the variances in the amount and quality of information among themselves and between primary, secondary, and tertiary healthcare facilities. The deep concern regarding the asymmetry of information mentioned by healthcare professionals indicates their inability, as healthcare providers, to provide accurate information to healthcare recipients consistently.

> *There is information asymmetry, and information asymmetry exists between healthcare professionals and patients. I also believe that it exists among healthcare professionals themselves. Additionally, it exists among primary, secondary, and tertiary healthcare institutions* (Participant 3).

3.2.2 Antecedents of the infodemic

Antecedents of the infodemic included environment-related and public-related factors.

3.2.2.1 Environment-related

Most participants mentioned SNS development as an antecedent to the COVID-19 infodemic. Additionally, the characteristics of the COVID-19 virus bolstered the use of SNS among the public. Owing to the high transmission rate and low fatality rate of the COVID-19 virus, most of the patients with mild infection underwent home-based treatment. In the home treatment environment, patients were isolated from other family members and did not have healthcare professionals constantly available, as in the hospital setting. Consequently, patients who underwent home-based treatment relied on social media platforms, which are easily accessible and allow for easy communication to ask questions and seek information.

> *It seems that when I was admitted to the hospital because I was sick, there were always healthcare professionals available to ask questions. However, in the case of COVID-19, there are no healthcare professionals available in real-time nearby. As a result, I started searching immediately and accumulated knowledge through platforms like YouTube or Naver blogs* (Participant 6).

3.2.2.2 Public-related

Most participants highlighted the absence of basic knowledge of infectious diseases among the public as a key factor affecting the COVID-19 infodemic. According to them, basic knowledge of infectious disease includes the necessity of vaccination, side effects of vaccines, transmission path, and daily health promotion activities during the pandemic. As such, the public, lacking basic knowledge about infectious diseases, would have had difficulty discerning accurate information from inaccurate information and would have unquestioningly accepted what was said on social media or by acquaintances.

> *Now, the general public does not have much medical knowledge and it may not be easy for them to get correct information. Even if they are exposed to something stimulating or incorrect, it may be worse* (Participant 11).

3.2.3 Consequences of the infodemic

The participants stated that the most important consequences of the infodemic were divided into positive and negative effects on the public.

3.2.3.1 Positive impacts

The abundance of information generated interest among the public (Participant 1). With accumulated experience in discerning information (Participant 13), infection prevention measures were practiced cautiously and frequently (Participant 4).

TABLE 3 Categories, subcategories, and codes determined on analytic phase.

Categories	Subcategories	Codes
Characteristics of COVID-19 infodemic	Quantitative volume of information	Information flood
		Information overload
	Qualitative pattern of information	Reproduction of information
		Dissemination of information
		Asymmetry of information
Antecedents of COVID-19 infodemic	Environment related	The pandemic
		Usage of social network services
		Limited access to healthcare professional for home-based treatment
	The public related	Being unprepared to disease outbreak among the public
		Absence of essential understanding on infectious disease
Consequences of COVID-19 infodemic	Positive impacts	An increase in interests in the COVID-19 virus among the public
		Practicing preventive measures cautiously
	Negative impacts	A decrease in trust in healthcare professionals
		Creation of anxiety, confusion, fear, panic attack, information avoidance, vaccination hesitance among patients
		Not responding to health policies

3.2.3.2 Negative impacts

The participants mentioned a decrease in trust in healthcare professionals (Participant 13) and the creation of anxiety and confusion among patients (Participant 14), causing suicide (Participant 1).

3.3 Findings of the final analysis phase

A comparison of the findings of the theoretical and fieldwork phases revealed similarities and differences in some subcategories and codes. Most of the literature defined an infodemic as a phenomenon of overloading, reproducing, and spreading information, consistent with those of the fieldwork phase. However, the participants in the fieldwork phase introduced an aspect of the COVID-19 infodemic that was not well-addressed in the literature: the asymmetry of information that occurred between healthcare professionals and healthcare institutions. Based on these findings, the concept of the COVID-19 infodemic can be defined as "the phenomenon of information flood, reproduction, dissemination, and asymmetry that occurred during the pandemic using social networks among the public lacking essential knowledge of infectious diseases. It is associated with negative effects such as confusion, anxiety, fear, vaccination hesitance, information avoidance, low trust in healthcare professionals, and suicide among the public, and positive effects such as generating great interest in infectious diseases, leading to the practice of prevention measure cautiously and the ability to discern information among the public."

4 Discussion

This study analyzed the concept of the COVID-19 infodemic from the perspectives of healthcare professionals. The findings revealed that the COVID-19 infodemic has diverse characteristics and should be considered as a whole, encompassing accurate information and false information.

The antecedents of the COVID-19 infodemic identified in the theoretical work of this study were the pandemic, SNS use, and the public being unprepared for an infectious disease outbreak. The use of SNS was reiterated as an antecedent in the fieldwork phase. This finding was in line with the systematic review of COVID-19 infodemic (14) which identified the causes of COVID-19 infodemic as social media usage. Owing to the development and use of various SNS platforms and the increase in the age range of users, SNS is becoming a means of providing and sharing information further and faster (54). SNS has become a major source of information not only for the general public but also for healthcare providers due to the lack of information caused by COVID-19 co-affected by the novel disease and the initial state of research (55). In the fieldwork phase of this study, healthcare professionals stated that the spread of information through SNS is not preventable. Additionally, the reproduction and dissemination of information, prominently manifested through SNS (36, 37). Thus, exploring effective ways to use SNS to manage the infodemic in the event of an infectious disease outbreak following the COVID-19 virus is necessary (Table 3).

The fieldwork phase in this study revealed that in South Korea, most cases of mild COVID-19 viral infection symptoms were treated at home. However, accessibility to healthcare professionals was lower at home than in hospitals, and patients, therefore, searched for information about symptoms using easily-accessible SNS. This is because although a call center or telemedicine system has been established for patients receiving treatment at home, its' healthcare professionals and facility resources are insufficient (56, 57). Furthermore, remote sessions for patient-healthcare professionals cannot fully replicate in-person sessions (17). This highlights the problem of resource support, where home treatment patients were unable to receive information in a timely manner in situations where information was needed. These structural factors should be improved.

Our findings also revealed the absence of an essential understanding of infectious diseases among the public. In the theoretical phase, the public's low level of education and health literacy (26) were mentioned. Similarly, in the fieldwork phase, the lack of basic knowledge about how the public should behave in an infectious disease epidemic situation was also mentioned. This finding paralleled Pian et al.'s systematic review (14). The public, lacking basic knowledge about infectious diseases, may indiscriminately accept inaccurate information, which may lead to negative health outcomes (26, 48, 49). Gabarron et al.'s systematic review on COVID-19 related misinformation on social media (58) conveyed the same message. To prevent the COVID-19 infodemic, the public needs to have basic knowledge about behavior tips, treatment methods, and infectious diseases (including transmission routes).

In this study, the characteristics such as information overload, reproduction of information, and dissemination of information were identified from both theoretical analysis and fieldwork. Brennen et al. supported these findings and highlighted an intriguing observation from their analysis of fake news instances (59), noting that a small percentage of fake news can reach a large audience due to the amplifying influence of influential figures such as politicians, celebrities, and public figures. Additionally, a WHO technical consultation on infodemic management proposed the necessity of strategic partnerships across various sectors, including social media, technology, academia, and civil society (54). Therefore, securing the involvement of influential healthcare professionals in medical academia is crucial as a countermeasure for managing infodemic from other disease outbreaks.

Asymmetry of information is a characteristic derived from the fieldwork phase. This implies that the public lacks the same information and that disparity exists in the quantity and quality of information among healthcare professionals working in primary, secondary, and tertiary healthcare institutions. A previous study (60) revealed that healthcare professionals are not immune to the impact of infodemic. Doctors, especially primary health care doctors, faced tremendous difficulties as they lacked accurate information about the pathogenesis and treatment of diseases caused by the newly emerged COVID-19. The differences in information among healthcare professionals working in different types of medical institutions may lead to public distrust or hinder legitimate actions of governments requiring public cooperation to control the pandemic (50, 51). This suggests that a channel for providing and rapidly sharing accurate information for healthcare professionals is necessary when responding to an infectious disease pandemic.

The consequences identified in this study, such as confusion, panic attacks, anxiety, fear, and suicide, were consistent in the theoretical and fieldwork phases. Positive effects such as disease prevention, cautious practice of measures, and information discerning were also presented. Besides, many previous studies have addressed the negative consequences of the COVID-19 infodemic such as depression and sleep disorders (61), trust loss, inappropriate protective measures (14), fear, panic, and death from panic purchase (58); however, few studies have suggested positive effects. Such positive consequences were also derived during the fieldwork phase of this study. This may be affected by the data collection which was conducted using a retrospective approach after the end of the COVID-19 pandemic. Moreover, in a study investigating the impacts of misinformation, negative effects were reported as mentioned above. In this study, considering the definition provided by the WHO (1), which encompasses both misinformation and information within the concept of the infodemic, it is inferred that positive effects were also addressed.

Regarding the positive effects on the public (including healthcare professionals) who can discern information, a large amount of information broadens their options, increases interest, and encourages cautious behavior (17). Similarly, a recent study revealed that those who perceived higher risk at the individual and societal levels were more likely to seek information on the Zika virus, demonstrating mobilized preventive intention (62). Systematically investigating and examining the differences in infodemic according to the general characteristics of the public is necessary; however, previous studies have identified that low-educated groups are easily exposed to infodemic (26), leading to information avoidance (49) and vaccination hesitance (48). These findings indicate that in the context of an infectious disease pandemic, providing accurate information to the public and ensuring their understanding of the information can prevent extreme and negative outcomes. The most integral step to minimize the adverse effects of the COVID-19 infodemic is education and the provision of authentic, transparent information from reliable sources (17, 37). A large-scale survey targeting the public is needed to determine what information was and was not needed during the past COVID-19 infodemic. These results should be reflected in preparing measures to enhance the public's knowledge of infectious diseases.

The limitations of this study deserve attention. This concept analysis only considered articles written in English and Korean. However, it is crucial to incorporate relevant articles in other languages related to the COVID-19 infodemic. Considering that English functions as the international language for scholarly communication and publication, the goal of this study is to encompass the majority of the literature on the COVID-19 infodemic. Furthermore, during the fieldwork phase, interviews were conducted with physicians and nurses who shared their experiences based on the situation in South Korea. Therefore, the findings of this study should be interpreted with caution. Future researches should consider reflecting the perspectives of COVID-19 patients, health officials, and policy makers in terms of infodemic.

5 Conclusion

In conclusion, this study revealed that a wide range of characteristics, antecedents, and consequences should be considered in defining the COVID-19 infodemic. The findings contribute to the understanding of the infodemic phenomenon, enabling the Ministry of Health and Welfare and healthcare professionals to formulate necessary strategies and education programs for the public.

Improving access to the right information in a timely manner for patients undergoing home treatment, who often lack access to healthcare professionals, could be addressed by smartly utilizing SNS. Educational programs for the public are crucial for imparting basic knowledge about infectious diseases, including behavior tips,

treatment methods, and transmission routes. Such programs mitigate the adverse effects of the COVID-19 infodemic, balancing positive and negative consequences. The significance of this study is underscored by the identification of the asymmetry in COVID-19 information among healthcare professionals working in primary, secondary, and tertiary hospitals, which implies the need for future research to explore and measure the concept of asymmetry of COVID-19 information among these healthcare professionals.

Data availability statement

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

Ethics statement

The studies involving humans were approved by the Soonchunhyang University Institutional review board (1040875-202307-SB-077). 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

SC: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This work was supported by the Soonchunhyang University Research Fund (No. 20230660).

Acknowledgments

The author thank all participants for the interview.

Conflict of interest

The author reported receiving grants from the Soonchunhyang University during the conduct of the study.

Publisher's note

References

1. World Health Organization. (2020). *Call for action: managing the infodemic*. Available at: https://www.who.int/news/item/11-12-2020-call-for-action-managing-the-infodemic (Accessed November 12, 2022).

2. Centers for Disease Control and Prevention. (2020). *Coronavirus diseae (COVID-19): stigma and resilence*. Available at: https://www.cdc.gov/coronavirus/2019-ncov/about/related-stigma.html (Accessed December 8, 2022).

3. Hua J, Shaw R. Corona virus (COVID-19) "infodemic" and emerging issues through a data lens: the case of China. *Int J Environ Res Public Health*. (2020) 17:2309. doi: 10.3390/ijerph17072309

4. Cinelli M, Quattrociocchi W, Galeazzi A, Valensise CM, Brugnoli E, Schmidt AL, et al. The COVID-19 social media infodemic. *Sci Rep*. (2020) 10:16598. doi: 10.1038/s41598-020-73510-5

5. Moon H, Lee GH. Evaluation of Korean-language COVID-19-related medical information on YouTube: cross-sectional infodemiology study. *J Med Internet Res*. (2020) 22:e20775. doi: 10.2196/20775

6. Brewster T. (2020). *Coronavirus 'cure' claims get FTC warning, so maybe don't drink silver*. Forbes. Available at: https://www.forbes.com/sites/thomasbrewster/2020/03/09/teas-essential-oils-and-drinking-silverftc-warns-about-dubious-coronavirus-cures/?sh=7e05a8141cba (Accessed May 20, 2023).

7. Cassata C. (2021). *Doctors debunk 9 popular COVID-19 vaccine myths and conspiracy theories*. Healthline. Available at: https://www.healthline.com/health-news/doctors-debunk-9-popular-covid-19-vaccine-myths-and-conspiracy-theories (Accessed February 22, 2023).

8. Ying W, Cheng C. Public emotional and coping responses to the COVID-19 infodemic: a review and recommendations. *Front Psych*. (2021) 12:755938. doi: 10.3389/fpsyt.2021.755938

9. Gao J, Zheng P, Jia Y, Chen H, Mao Y, Chen S, et al. Mental health problems and social media exposure during COVID-19 outbreak. *PLoS One*. (2020) 15:e0231924. doi: 10.1371/journal.pone.0231924

10. Goyal K, Chauhan P, Chhikara K, Gupta P, Singh MP. Fear of COVID 2019: first suicidal case in India. *Asian J Psychiatr*. (2020) 49:101989. doi: 10.1016/j.ajp.2020.101989

11. Cellan-Jones R. (2020). Tech tent: is social media spreading the virus? *BBC News*. Available at: https://www.bbc.com/news/technology-51510196 (Accessed March 28, 2023).

12. Rohilla KK, Kalyani CV. COVID-19 emergency in India. *Natl J Community Med*. (2021) 12:449–51. doi: 10.5455/njcm.20211113124634

13. Khan AS, Khawaja R. Social media could be a of threat for an "Infodemic" throughout COVID-19 pandemic. *J Community Prev Med*. (2021) 3:1. doi: 10.33309/2638-7719.030201

14. Pian W, Chi J, Ma F. The causes, impacts and countermeasures of COVID-19 "Infodemic": a systematic review using narrative synthesis. *Inf Process Manag*. (2021) 58:102713. doi: 10.1016/j.ipm.2021.102713

15. Han JW, Park J, Lee H. Effect of exposure to COVID-19 infodemic on infection-preventive intentions among Korean adults. *Nurs Open*. (2022) 9:2665–74. doi: 10.1002/nop2.965

16. Sahithi B, Sharon K, Reddy MVR, Bhargav BP, Narayana G. Impact of infodemic on public perception on Covid-19 pandemic: web-based cross-sectional survey. *Int J Life Sci Pharma Res*. (2022) 12:87–95. doi: 10.22376/ijpbs/lpr.2022.12.6.P87-95

17. Choukou MA, Sanchez-Ramirez DC, Pol M, Uddin M, Monnin C, Syed-Abdul S. COVID-19 infodemic and digital health literacy in vulnerable populations: a scoping review. *Digit Health*. (2022) 8:205520762210769. doi: 10.1177/20552076221076927

18. Rodgers BL, Knafl KA. *Concept development in nursing: foundations, techniques, and applications*. Philadelphia: W.B. Saunders Company (2000).

19. Pope J, Byrne P, Devane D, Purnat TD, Dowling M. Health misinformation: protocol for a hybrid concept analysis and development. *HRB Open Res*. (2022) 5:70. doi: 10.12688/hrbopenres.13641.1

20. Choi K S. (2021). *Corona era, human resource management and leadership*. Hospital News. Available at: https://www.khanews.com/news/articleView.html?idxno=209532 (Accessed December 5, 2023).

21. Schwartz-Barcott D. An expansion and elaboration of the hybrid model of concept development In: *Concept development in nursing foundations, techniques, and applications*. Philadelphia: W.B. Saunders Company (2000). 129–59.

22. Walker LO, Avant KC. *Strategies for theory construction in nursing. 4th* ed. New Jersey: Pearson and Prentice Hall (2005).

23. Chun TY, Birks M, Francis K. Grounded theory research: a design framework for novice researchers. *SAGE Open Med*. (2019) 7:2050312118822927. doi: 10.1177/2050312118822

24. Graneheim UH, Lundman B. Qualitative content analysis in nursing research: concepts, procedures and measures to achieve trustworthiness. *Nurse Educ Today*. (2004) 24:105–12. doi: 10.1016/j.nedt.2003.10.001

25. Alasmari A, Addawood A, Nouh M, Rayes W, Al-Wabil A. A retrospective analysis of the COVID-19 infodemic in Saudi Arabia. *Future Internet*. (2021) 13:254. doi: 10.3390/fi13100254

26. Balakrishnan V, Ng WZ, Soo MC, Han GJ, Lee CJ. Infodemic and fake news - a comprehensive overview of its global magnitude during the COVID-19 pandemic in 2021: a scoping review. *Int J Disaster Risk Reduct*. (2022) 78:103144. doi: 10.1016/j.ijdrr.2022.103144

27. Allcott H, Gentzkow M. Social media and fake news in the 2016 election. *J Econ Perspect*. (2017) 31:211–36. doi: 10.1257/jep.31.2.211

28. Last JM ed. *A dictionary of epidemiology. 4th* ed. New York, NY: Oxford University Press (2001).

29. Akbar SZ, Panda A, Kukreti D, Meena A, Pal J. Misinformation as a window into prejudice: COVID-19 and the information environment in India. *Proc ACM Hum-Comput Interact*. (2021) 4:1–28. doi: 10.1145/3432948

30. Zarocostas J. How to fight an infodemic. *Lancet*. (2020) 395:676. doi: 10.1016/S0140-6736(20)30461-X

31. Casero-Ripollés A. Impact of Covid-19 on the media system: communicative and democratic consequences of news consumption during the outbreak. *Prof Inferm*. (2020) 29:e290223. doi: 10.3145/epi.2020.mar.23

32. Gruzd A, De Domenico M, Sacco PL, Briand S. Studying the COVID-19 infodemic at scale. *Big Data Soc*. (2021) 8:205395172110211. doi: 10.1177/20539517211021115

33. Greenspan RL, Loftus EF. Pandemics and infodemics: research on the effects of misinformation on memory. *Hum Behav Emerg Technol*. (2021) 3:8–12. doi: 10.1002/hbe2.228

34. Ding H. Rhetorics of alternative media in an emerging epidemic: SARS, censorship, and extra-institutional risk communication. *Tech Commun Q*. (2009) 18:327–50. doi: 10.1080/10572250903149548

35. Chowdhury N, Khalid A, Turin TC. Understanding misinformation infodemic during public health emergencies due to large-scale disease outbreaks: a rapid review. *Z Gesundh Wiss*. (2023) 31:553–73. doi: 10.1007/s10389-021-01565-3

36. Suarez-Lledo V, Alvarez-Galvez J. Prevalence of health misinformation on social media: systematic review. *J Med Internet Res*. (2021) 23:e17187. doi: 10.2196/17187

37. Patel MP, Kute VB, Agarwal SK. "Infodemic" COVID 19: more pandemic than the virus. *Indian J Nephrol*. (2020) 30:188–91. doi: 10.4103/ijn.IJN_216_20

38. Okan O, Bollweg TM, Berens EM, Hurrelmann K, Bauer U, Schaeffer D. Coronavirus-related health literacy: a cross-sectional study in adults during the COVID-19 infodemic in Germany. *Int J Environ Res Public Health*. (2020) 17:5503. doi: 10.3390/ijerph17155503

39. Datta R, Yadav AK, Singh A, Datta K, Bansal A. The infodemics of COVID-19 amongst healthcare professionals in India. *Med J Armed Forces India*. (2020) 76:276–83. doi: 10.1016/j.mjafi.2020.05.009

40. Rathore FA, Farooq F. Information overload and infodemic in the COVID-19 pandemic. *J Pak Med Assoc*. (2020) 70:S162–5. doi: 10.5455/JPMA.38

41. Gisondi MA, Chambers D, La TM, Ryan A, Shankar A, Xue A, et al. A Stanford conference on social media, ethics, and COVID-19 misinformation (INFODEMIC): qualitative thematic analysis. *J Med Internet Res*. (2022) 24:e35707. doi: 10.2196/35707

42. Wardle C, Derakhshan H. *Information disorder: toward an interdisciplinary framework for research and policymaking*. Strasbourg: Council of Europe (2017).

43. Huang B, Carley KM (2020). Disinformation and misinformation on twitter during the novel coronavirus outbreak arXiv preprint arXiv:2006.04278.

44. Gupta A, Li H, Farnoush A, Jiang W. Understanding patterns of COVID infodemic: a systematic and pragmatic approach to curb fake news. *J Bus Res*. (2022) 140:670–83. doi: 10.1016/j.jbusres.2021.11.032

45. Pennycook G, McPhetres J, Zhang Y, Lu JG, Rand DG. Fighting COVID-19 misinformation on social media: experimental evidence for a scalable accuracy-nudge intervention. *Psychol Sci*. (2020) 31:770–80. doi: 10.1177/0956797620939054

46. Yu SC, Chen HR, Liu AC, Lee HY. Toward COVID-19 information: infodemic or fear of missing out. *Healthcare (Basel)*. (2020) 8:550. doi: 10.3390/healthcare8040550

47. Express News Service (2021). COVID-19 patient commits suicide in VIMS. *The New Indian Express*. Available at: https://www.newindianexpress.com/states/andhra-pradesh/2021/may/23/covid-19-patient-commitssuicide-in-vims-2306395.html (Accessed April 14, 2023).

48. Puri N, Coomes EA, Haghbayan H, Gunaratne K. Social media and vaccine hesitancy: new updates for the era of COVID-19 and globalized infectious diseases. *Hum Vaccin Immunother*. (2020) 16:2586–93. doi: 10.1080/21645515.2020.1780846

49. Soroya SH, Farooq A, Mahmood K, Isoaho J, Zara SE. From information seeking to information avoidance: understanding the health information behavior during a global health crisis. *Inf Process Manag*. (2021) 58:102440. doi: 10.1016/j.ipm.2020.102440

50. Shigemura J, Ursano RJ, Morganstein JC, Kurosawa M, Benedek DM. Public responses to the novel 2019 coronavirus (2019-nCoV) in Japan: mental health consequences and target populations. *Psychiatry Clin Neurosci*. (2020) 74:281–2. doi: 10.1111/pcn.12988

51. Apetrei C, Marx PA, Mellors JW, Pandrea I. The COVID misinfodemic: not new, never more lethal. *Trends Microbiol*. (2022) 30:948–58. doi: 10.1016/j.tim.2022.07.004

52. World Health Organization. (2021). *Health topics/Infodemic*. Available at: https://www.who.int/health-topics/infodemic#tab=tab_1 (Accessed December 14, 2023).

53. Van den Broucke S. Why health promotion matters to the COVID-19 pandemic, and vice versa. *Health Promot Int*. (2020) 35:181–6. doi: 10.1093/heapro/daaa042

54. Tangcharoensathien V, Calleja N, Nguyen T, Purnat T, D'Agostino M, Garcia-Saiso S, et al. Framework for managing the COVID-19 Infodemic: methods and results of an online, crowdsourced WHO technical consultation. *J Med Internet Res*. (2020) 22:e19659. doi: 10.2196/19659

55. Aharon AA, Ruban A, Dubovi I. Knowledge and information credibility evaluation strategies regarding COVID-19: a cross-sectional study. *Nurs Outlook*. (2021) 69:22–31. doi: 10.1016/j.outlook.2020.09.001

56. Central Accident Control Headquarters; Central Disaster and Safety Countermeasures Headquarters. (2021). *Guidelines for operating living treatment centers in response to COVID-19*. Available at: https://policy.nl.go.kr/search/searchDetail.do?rec_key=SH2_PLC20210259443 (Accessed April 12, 2023).

57. Alanzi T, Al-Yami S. Physicians' attitude towards the use of social media for professional purposes in Saudi Arabia. *Int J Telemed Appl*. (2019) 2019:1–6. doi: 10.1155/2019/6323962

58. Gabarron E, Oyeyemi SO, Wynn R. COVID-19-related misinformation on social media: a systematic review. *Bulle World Health Organ*. (2021) 99:455–463A. doi: 10.2471/BLT.20.276782

59. Brennen JS, Simon FM, Howard PN, Nielsen RK. *Types, sources, and claims of COVID-19 misinformation*. [dissertation]. Oxford: University of Oxford (2020).

60. Sharma R, Kumar M. A word about Infodemic during COVID-19 pandemic among healthcare professionals. *J Postgrad Med Edu Res*. (2022) 56:149–50. doi: 10.5005/jp-journals-10028-1582

61. Jung S, Jung S. The impact of the COVID-19 infodemic on depression and sleep disorders: focusing on uncertainty reduction strategies and level of interpretation theory. *JMIR Formative Res*. (2022) 6:e32552. doi: 10.2196/32552

62. Lee J, Kim JW, Chock TM. From risk butterflies to citizens engaged in risk prevention in the Zika virus crisis: focusing on personal, societal and global risk perceptions. *J Health Commun*. (2020) 25:671–80. doi: 10.1080/10810730.2020.1836089

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 12 June 2024
DOI 10.3389/fpubh.2024.1323543

OPEN ACCESS

EDITED BY
Christiane Stock,
Institute of Health and Nursing Science, Germany

REVIEWED BY
Tanvi Kiran,
Post Graduate Institute of Medical Education and Research (PGIMER), India
David Conversi,
Sapienza University of Rome, Italy

*CORRESPONDENCE
Saleha Shafie
✉ saleha_shafie@imh.com.sg

RECEIVED 20 October 2023
ACCEPTED 22 May 2024
PUBLISHED 12 June 2024

CITATION
Devi F, Tan BCW, Shafie S, Zhang YJ, Shahwan S, Satghare P, Chong SA and Subramaniam M (2024) Exploring the Singapore general population's trust in COVID-19 information from different sources and its association with perceived risk of infection during the pandemic.
Front. Public Health 12:1323543.
doi: 10.3389/fpubh.2024.1323543

Exploring the Singapore general population's trust in COVID-19 information from different sources and its association with perceived risk of infection during the pandemic

Fiona Devi*, Bernard Chin Wee Tan, Saleha Shafie*, Yun Jue Zhang, Shazana Shahwan, Pratika Satghare, Siow Ann Chong and Mythily Subramaniam

Research Division, Institute of Mental Health, Singapore, Singapore

Background: The degree of public trust in the government's competence is crucial in preventing the spread of misinformation and reducing psychological distress during a pandemic. The study aimed to (i) explore the trust in COVID-19 information from different sources and trust in the ability of the World Health Organization (WHO), government departments and related institutions in handling the epidemic in Singapore and (ii) its association with perceived risk of infection among Singapore residents.

Methods: A total of 1,129 participants (aged 21 and above) were recruited from a cross-sectional study examining the well-being and resilience of Singapore's population between May 2020 to June 2021. Trust in COVID-19 information from different sources was measured on a 10-point scale and an ordinal 7-point scale was used for perceived risk of infection. Descriptive statistics and multivariate logistic regression model were conducted.

Results: 85.5% reported high trust in COVID-19 information from the government and their ability in handling the pandemic. Participants also reported high trust in COVID-19 information from local public health or infectious disease experts (84.4%) and traditional media (77.2%). Low trust in the ability of government departments and related institutions was associated with higher future (1 month) perceived risk of infection (OR: 5.7, 95% CI 1.02–32.45) and low trust in social media was associated with higher current perceived risk of infection (OR: 2.4, 95% CI 1.09–5.24).

Discussion: The present study provided insight on the level of trust on COVID-19 information from different sources and its associated perceived risks of infection. Future qualitative studies are recommended to facilitate better understanding of public trust and identify strategies for how it can be effectively addressed to support future public health responses.

KEYWORDS

COVID-19, multi-ethnic, trust, perceived risks of infection, Asia

Background

The COVID-19 pandemic profoundly impacted societies and economies globally and was constituted as a public health emergency of international concern (1). In essence, governments and stakeholders in public health worldwide have been forced to develop and implement complex healthcare and public health policies to combat COVID-19 following the outbreak (2). During the pandemic, social media platforms were also key for social interactions and community building, especially at the early stage of the pandemic when lockdown orders were implemented (3). Given the multiple sources of information and misinformation across both traditional and social media platforms, the degree of trust in public health authorities defined public perception and reaction to the pandemic (4). Therefore, concern about misinformation on health advice has highlighted the need to understand individuals' risk perception and trust in information from different sources such as traditional media, social media, public health experts and government or related institutions during the COVID-19 pandemic (5).

Trust and credibility of information sources are considered important factors in risk communication. When an issue is new and complex, the majority lack the knowledge to directly assess the risks (6). Individuals become increasingly dependent upon information and risk assessment from experts where trust aids as a peripheral cue (6). Information presented across different media formats also varies in its quality. Traditional media typically relies on gatekeepers such as trained journalists, reporters, and editors to produce and deliver content (7). However, the emergence of online news, citizen journalism, and social media has disrupted the traditional news model. Throughout the COVID-19 pandemic, digital media played a crucial role in distributing health information, coordinating medical resources, and promoting public health campaigns. Nonetheless, digital platforms were also plagued by misinformation and conspiracy theories, undermining trust and impeding mitigation efforts (3, 8).

The COVID-19 pandemic coincided with a proliferation of sources providing health information and misinformation (9). These include alternative media platforms whose reach could cross geographical borders and social strata. This proliferation competes with institutional messaging, and research has shown that acceptance of heterodox COVID-19 narratives is associated with lack of trust in public health institutions and scientists (10). In addition, one prominent cause of resistance to public health measures which persisted throughout the COVID-19 pandemic (11), has been the lack of trust in established organizations such as the World Health Organization (WHO) (6) and traditional media organizations (12). Misinformation from credible sources compromises the efforts of public health officials in charge of administering the pandemic response efforts in the country (9).

Under these conditions, compliance with public health measures such as social distancing guidelines, movement restrictions and mask requirements has varied systematically with levels of trust in policy-makers during the COVID-19 pandemic (13, 14). Hence, higher level of trust toward certain health information sources and public trust based on perception of government competence, fairness and transparency may influence public compliance with advocated health behaviors, decreasing health risks and managing the crisis (15). For example, experiences from all over the world especially in China showed how people's risk perception of COVID-19 could directly affect their follow-up response behaviors (16). Higher levels of risk perception were found to be associated with higher intention to engage in preventive behavior, such that if they believed that the risk of COVID-19 was high and dangerous, they would cooperate with the government's pandemic control measures, and strictly adhere to the restrictions (16).

On the other hand, if they believed that COVID-19 was just like the influenza flu, they would ignore or delay adherence to the government's regulation and mingle in crowds in public places which could lead to further spread of the infection and cause a wider spread of the disease (16). Hence, it has been shown that the trajectory of an infectious disease could often be determined by the behavior of individuals, and the behavior in turn is related to individual's risk perception (17).

Other studies (18, 19) conducted during previous pandemics identified numerous psychosocial variables that potentially influenced individuals' protective behavior. However, one factor that was found to be a crucial predictor was the level of trust in the sources of the health information (16, 20, 21). As such, public trust in the government's competence is crucial in preventing the spread of misinformation and reducing psychological distress during the pandemic. Singapore is a small independent island situated in Southeast Asia with a multi-ethnic population of 5.6 million (74.1% Chinese, 13.6% Malay, 9.0% Indian and 3.3% others) (7). Despite being a small country, Singapore managed to contain the Covid-19 outbreak with minimum disruption to daily life largely due to their pandemic's taskforce that was established after the SARS (severe acute respiratory syndrome) outbreak in 2003 (22). Shortly after the WHO announced the COVID-19 outbreak, Singapore's government and related institutions acted quickly and took proactive measures such as mandatory 14-days quarantine for all residents returning from other countries, border control, contact tracing and self-isolation at home, consequently reducing community transmission (23). The present study aims to (i) explore the general population's trust in COVID-19 information from different sources and trust in the ability of the WHO, government departments and related institutions in handling the pandemic in Singapore and (ii) explore the different factors associated with perceived risk of infection among Singapore residents.

Methods

Participants

A total of 1,129 participants were recruited in a cross-sectional study examining the well-being and resilience of the Singapore population (17) between May 2020 to June 2021. Inclusion criteria of the study were: (1) those who had provided consent for re-contact during Singapore Mental Health Study (SMHS) 2016; (2) Singapore citizens or Permanent Resident residing in Singapore aged 21 years and above; (3) able to speak English, Chinese, or Malay language. Exclusion criteria were: (1) uncontactable due to change in contact details; (2) those on long-term hospitalization or institutionalization throughout the study period.

Procedure

Participants were recruited through phone calls by experienced study team members between May 2020 to June 2021. In line with

physical distancing measures, participants were encouraged to participate in the interviewer-administered survey through the Zoom videoconferencing platform. Electronic informed consent was obtained via 'Zoom' from all participants prior to their enrolment and appropriate measures were taken to ensure confidentiality and data privacy. For those participants who preferred a face- to -face session, they were re-contacted after the Circuit Breaker period when in-person contact with participants was allowed ($n = 122$). Likewise, written informed consent was obtained from these participants prior to their enrolment. Ethics approval (DSRB 2020/00462) was obtained from the Domain Specific Review Board of the National Healthcare Group, Singapore. Clinical psychologists and psychiatrists who were part of the team followed up with participants who reported any concrete suicide plan(s) or attempt(s) in the 2 weeks prior to the interview. A comprehensive description of this study has been published in an earlier article (24).

Upon completion of the questionnaires, participants were reimbursed with SGD 40 as an inconvenience fee either through cash or cashless payment methods.

Instruments

Sociodemographic questionnaire

Socio-demographic information (e.g., age, gender, ethnicity, marital status, religion, and highest education) were collected using a structured questionnaire.

Trust questionnaire

(i) *Trust in **COVID-19 INFORMATION** from different sources*

Participants were asked how much they trusted six sources namely traditional media, social media, governments and/or public health authorities, family doctor, local scientists, and the World. Health Organization (WHO) on COVID-19 related information. Responses were measured on a discrete scale of 1 to 10 whereby higher scores indicated higher trust (scores of 1–3 are classified as low trust, 4–7 as neutral, and 8–10 as high).

(ii) *Trust in **ABILITY** of the World Health Organization (WHO), government departments and related institutions in handling the pandemic in Singapore*

Participants were asked how much they trusted in the ability of government departments, related institutions, and the WHO, in the handling of the pandemic. Responses were measured on a discrete scale of 1 to 10 whereby higher scores indicated higher trust. The scale was locally developed by a multidisciplinary team comprising experts of the questionnaire methodology, experts in public health and preventions, and statisticians for the purpose of the study (25, 26).

Perceived risk of infection (self)

Participants were asked to rate their perceived risk of contracting COVID-19. This was addressed using two timeframes, where current risk was assessed by "What do you think is your current chance of getting infected with COVID-19?" and future (1 month) risk by "What do you think is your chance of getting infected with COVID-19 in the next month?" Responses were measured on a discrete scale of 1–7 whereby higher scores indicated certainty of getting infected with COVID-19 (score of 1–3 are classified as low perceived risk, 4 as neutral and 5–7 as high).

Statistical analysis

Descriptive statistics were conducted to determine the frequencies of each of the trust levels as well as the description of the sociodemographic characteristics of the sample. Associations between sociodemographic characteristics and level of trust in COVID-19 information with perceived risk of contracting COVID-19 were examined with the use of multiple logistic regressions by which current and one-month perceived risk was the dependent variable and sociodemographic characteristics and the level of trust in COVID-19 information were the independent variables. Adjusted odds ratios (^{a}OR) and 95% confidence intervals (CI) were reported to determine the associations between variables in the multivariate logistic regression model (27). Additionally, to determine if any specific demographic were more likely to trust a certain type of media, logistic regressions were run with sociodemographic characteristics as the independent variables and trust as the dependent variable. IBM SPSS Statistics software version 23 was used to run all analyses. Response rate was about 54.8%.

Results

Sample characteristics

Socio-demographic characteristics of the participants are shown in Table 1. A total of 1,129 participants with a mean age 42.20 (SD = 14.97) years participated in the study. The sample comprised majority of males (53.3%), Chinese (35.3%), married (60.3%), those with a tertiary education (i.e., 'A' Level/ITE/Diploma/ Pre-University/, Degree/Postgrad Degree and Others) (82%) and with a religion (86%).

Trust in information from different sources and ability of the WHO, government departments and related institutions in handling the pandemic

The level of trust in the information from different sources and the ability of the WHO, government departments and related institutions in handling the pandemic is presented in Table 2. A majority of 85.5% reported high trust in COVID-19 information from the government and related institutes like the Ministry of Health and Multi- Ministry Taskforce (to direct the national whole-of-government response to the COVID-19 outbreak). 85.4% reported high trust in the ability of government and related institutes like Ministry of Health and the Multi- Ministry Taskforce in handling the pandemic in Singapore. Participants also reported high trust in COVID-19 information from local public health or infectious disease experts (84.4%) and traditional media (77.2%). Out of all the sources of information, social media was rated the lowest (27.0%) for trust in COVID-19 information (Table 3).

Correlates of perceived risk of COVID-19 infection (to self)

Participants aged 35–64 (vs. 21–34) years were significantly associated with high current perceived risk of infection (^{a}OR: 2.70,

10.3389/fpubh.2024.1323543

TABLE 1 Socio-demographic characteristics of the sample.

Variables		Overall sample (n = 1,129)
Age		N (%)
	21–34	426 (37.7)
	35–64	580 (51.4)
	65+	123 (10.9)
Gender		
	Male	602 (53.3)
	Female	527 (46.7)
Ethnicity		
	Chinese	398 (35.3)
	Malay	263 (23.3)
	Indian	293 (26.0)
	Others	175 (15.5)
Marital status		
	Never married	363 (32.2)
	Married	681 (60.3)
	Divorced/Widowed/ Separated	85 (7.5)
Religion		
	Yes	971 (86.0)
	No	158 (14.0)
Highest education		
	Secondary and below	202 (17.9)
	'A' Level/ITE/Diploma/ Pre-university	396 (35.1)
	Degree/Postgrad Degree	481 (42.6)
	Others	50 (4.4)

TABLE 2 Trust in COVID-19 information from different sources and the ability of the WHO, government departments and related institutions in handling the pandemic.

Trust in the sources of COVID-19 information	Low		Neutral		High	
	N	%	N	%	N	%
1. Traditional media	57	5.0	197	17.4	872	77.2
2. Social media	316	28.0	487	43.1	305	27.0
3. Local public health and/or infectious disease experts	37	3.3	139	12.3	953	84.4
4. Government departments and/or related institutes	42	3.7	120	10.6	965	85.5
5. WHO	130	11.5	290	25.7	691	61.2
Trust in the ability to handle the pandemic						
6. Ability of government departments and related institutions to handle the pandemic	32	2.8	129	11.4	964	85.4
7. Ability of WHO to handle the pandemic	196	17.4	341	30.2	572	50.7

95% CI 1.26–5.80). Indians (versus Chinese) were significantly associated with low current perceived risk of infection ([a]OR: 0.41, 95% CI 0.18–0.93). Those with a religious affiliation (vs. those without) were significantly associated with high current perceived risk of infection ([a]OR: 3.87, 95 CI 1.27–11.81). Low trust in social media (versus high trust) was associated with high current perceived risk of infection ([a]OR: 2.39, 95% CI 1.09–5.24). As for the future (one-month) perceived risk of COVID-19 infection, participants with low trust in the ability of government departments and related institutions in handling the pandemic were associated with a high future (one-month) perceived risk of infection ([a]OR: 5.75, 95% CI 1.02–32.45) (Table 3).

Discussion

Our research investigated the association between the public's trust in COVID-19 information from different sources and the ability of the WHO, other government departments and related institutions in handling the pandemic in Singapore. Along with this, the current research investigated the factors associated with perceived risk of infection among Singapore residents. The study found that majority of the residents reported high trust in the government and related institutions' ability in handling the pandemic in Singapore. As mentioned previously in the literature review, perception of government competence and transparency may possibly influence management of the crisis (15). For example, as COVID-19 began to unfold in Singapore, key government officials openly addressed the scientific uncertainties around the virus, the search for a vaccine and detailed summary of contact tracing (4). In addition, frequent press conferences held by the Prime Minister speaking in the language of the targeted audience without the use of translators was key in building trust and promoting affective beliefs about the institutional behavior and competence especially in a multi-ethnic population like Singapore (4). As such, with all the meticulous contact tracing procedures and information communicated heavily through credible sources, it established a positive perception of the government's risk management and high level of trust in the Singapore government.

The findings of the current study also support the notion that those with a lower trust in the government's ability was associated with a higher level of perceived risk of infection. A local study (4), showed that those who had a very positive perception of the government's risk management and communication efforts, expressed a very high level of confidence in government and healthcare system. In turn, they

TABLE 3 Factors associated with the perceived risk of COVID-19 infection (self).

	Current perceived risk of COVID-19 infection				One-month perceived risk of COVID-19 infection			
Variables	[a]OR	95% CI		*p*-value	[a]OR	95% CI		*p*-value
		Lower	Upper			Lower	Upper	
Age								
65+	2.05	0.63	6.69	0.23	0.77	0.14	4.36	0.77
35–64	2.70	1.26	5.80	**0.01***	1.50	0.60	3.73	0.39
21–34	Ref.				Ref.			
Gender								
Female	0.68	0.39	1.21	0.19	0.59	0.29	1.21	0.15
Male	Ref.				Ref.			
Ethnicity								
Malay	1.26	0.61	2.61	0.53	1.74	0.68	4.44	0.25
Indian	0.41	0.18	0.93	**0.03***	1.01	0.38	2.70	0.99
Others	0.59	0.25	1.38	0.22	0.89	0.28	2.79	0.84
Chinese	Ref.				Ref.			
Religion								
Yes	3.87	1.27	11.81	**0.02***	2.03	0.61	6.71	0.25
No	Ref.				Ref.			
Education								
Secondary and below	1.31	0.57	3.00	0.52	1.53	0.52	4.55	0.44
'A' Level/ITE/ Diploma/Pre-University	1.14	0.60	2.18	0.69	1.84	0.83	4.08	0.13
Others	2.16	0.65	7.22	0.21	2.13	0.41	11.02	0.37
Degree/Postgrad degree	Ref.				Ref.			
Marital status								
Never married	1.96	0.93	4.10	0.08	1.72	0.68	4.35	0.25
Divorced/Widowed/ Separated	1.34	0.43	3.05	0.80	1.38	0.42	4.60	0.60
Married	Ref.				Ref.			
Trust in the COVID-19 information from social media								
Low	2.39	1.09	5.24	**0.03***	1.07	0.38	3.01	0.89
Neutral	1.59	0.74	3.39	0.23	1.68	0.71	4.00	0.24
High	Ref.				Ref.			
Trust in the COVID-19 information from government departments and/or related institutes								
Low	0.47	0.07	3.35	0.45	0.60	0.86	4.14	0.60
Neutral	1.59	0.67	3.81	0.30	1.88	0.69	5.12	0.22
High	Ref.				Ref.			
Trust in the ability of government departments and related institution in handling the pandemic								
Low	4.64	0.80	26.88	0.09	5.75	1.02	32.45	**0.05***
Neutral	1.87	0.80	4.36	0.15	2.75	1.08	7.04	**0.03***
High	Ref.				Ref.			

*Bold values indicate significant *p* value $p < 0.05$. [a]OR, adjusted odds ratio; 95% CI, 95% confidence interval; Ref., reference categories. The Nagalkerke R-Square value for current perceived risk (0.105) and one-month perceived risk (0.114) showed that the model explains 10.5 and 11.4% of the variation of perceived risk of COVID-19 infection, respectively. The Omnibus tests of model coefficients give a chi-square of 91.063 ($p < 0.001$) for current perceived risk and 91.522 ($p < 0.001$) for one-month perceived risk indicating good fit for both models. The analysis estimated the overall accuracy of 64.1% for current perceived risk and 72.6% for one-month perceived risk in correct prediction of the probabilities.

considered their risk of infection to be very low because they felt that the government had been transparent, highly competent, and effective. Whereas those who were more skeptical and found the government's approach to be confusing expressed higher level of anxiety and risk of infection.

We also established that the older participants in our sample had a higher current perceived risk of COVID-19 infection. We believe that objective information on infection rates might have misled younger individuals to be influenced by ageism and biased risk (28). Hence, given the high engagement of youth with multiple information sources such as medical sources and mass media coverage, younger individuals may have gathered the message that COVID-19 infection mostly concerns older individuals who are at higher risk of being infected or dying (29).

This study makes another interesting contribution to the literature. The results show that those with lower level of trust in social media was associated with higher current perceived risk of infection. During the early stages of an infectious diseases outbreak, traditional media platforms such as television news, newspaper, radio stations, governments and/or public health officials or institutions may not always provide the public sufficient information in a timely manner, due to the lack of disease-related information (30, 31). Hence, individuals may turn to social media platforms particularly Facebook, Instagram, Youtube or Twitter feeds as an effective and immediate information tool to communicate relevant information to others (28). Unsurprisingly, these sources are unverified and therefore, foster the spread of conspiracy theories, myths, and false information which can consequently fuel uncertainty and psychological problems for instance, fear and anxiety in the population (16, 25, 28). However, misinformation surrounding COVID-19 also involved downplaying the seriousness of the pandemic with several influential accounts stating that COVID-19 was not more severe than the ordinary flu and greatly discouraged the use of face masks and other preventive measures (32, 33). It is possible that the people who chose not to believe in such information, feared the virus and its impact on their wellbeing, and therefore, they may have perceived a higher degree of risk that they will be infected. Further research is needed to evaluate the association between risk perception and the use of social media platforms.

Interestingly, the study revealed that those of Indian ethnicity reported lower current perceived risk of infection as compared to Chinese ethnicity. One possible explanation could be related to beliefs regarding differences in COVID-19 infection rates across countries contributed by media and symptom reporting in hospitals. China was the first country to experience the initial phase of COVID-19 pandemic outbreak and adopted different safety measurements in different stages (2). During the initial phase of the pandemic outbreak in early 2020, China had higher COVID-19 infections rates and deaths as compared to India (2). However, though China's daily cases were high, it was mainly concentrated in the early phase; China quickly adopted active screening, tracking of cases and strict city closure measures which slowed the increase of COVID-19 cases (2). In contrast, daily infection cases were low in India during the early phase of the pandemic, however it continuously rose during the later stages (2). Thus, the media reporting and the study recruitment being in the early phase of the pandemic, could have resulted in biased risk perception among these ethnic groups in Singapore. However, further research is needed to better understand these ethnic differences in perceived risk of infection.

Limitations

There are some limitations in this study. Firstly, collection of data through videoconferencing was encouraged. A significant number of older adults were reluctant to participate as many were not comfortable with using and signing the consent form through the online platform. Secondly, the pandemic evolved through many stages corresponding to changes in health measures, infection rates and restrictions, and thus trust levels may have varied in the population. Thirdly, the validity and reliability of the questionnaires content used in the study were not formally assessed. Lastly, data collected for this study comprised a small sample size which may not be sufficiently representative of the population.

Conclusion

In summary, effective public health messaging during a pandemic is crucial as it influences public compliance, advocates health behaviors, decreases health risks and helps in the management of the crisis. The present study provides important insights into the level of trust on COVID-19 information from different sources, and the ability of the government and related institutions in handling the pandemic in Singapore. Future qualitative studies are recommended to facilitate better understanding of public trust and identify strategies on how it can be further strengthened in preparation for future public health responses to crises.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, upon reasonable request.

Ethics statement

The studies involving humans were approved by Domain Specific Review Board of the National Healthcare Group, Singapore (DSRB 2020/00462). 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

FD: Data curation, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. BT: Formal analysis, Software, Writing – review & editing. SaS: Conceptualization, Data curation, Investigation, Methodology, Project administration, Supervision, Writing – review & editing. YZ: Data curation, Investigation, Methodology, Project administration, Writing – review & editing. ShS: Conceptualization, Data curation, Investigation, Methodology, Writing – review & editing. PS: Conceptualization, Data curation, Investigation, Methodology, Writing – review & editing. SC: Funding acquisition, Supervision, Writing – review & editing. MS: Funding acquisition, Investigation, Project administration, Resources, Supervision, Validation, Visualization, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This study was funded by the Ministry of Health Singapore, National Centre for Infectious Diseases and Temasek Foundation. The funding source had no role in the study design and in collection, analyses, and interpretation of data and in writing this report.

Acknowledgments

The authors would like to thank all the participants for their time and efforts in the study.

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.

Publisher's note

References

1. Siegrist M, Zingg A. The role of public trust during pandemics implications for crisis communication. *Eur Psychol*. (2014) 19:23–32. doi: 10.1027/1016-9040/a000169

2. Xu T. Media, Trust in Government, and risk perception of COVID-19 in the early stage of pandemic: an analysis based on moderating effect. *Healthcare*. (2021) 9:1597. doi: 10.3390/healthcare9111597

3. Abdelrahman M. Personality traits, risk perception, and protective behaviors of Arab residents of Qatar during the COVID-19 pandemic. *Int J Ment Health Addict*. (2020) 20:237–48. doi: 10.1007/s11469-020-00352-7

4. Wong CM, Jensen O. The paradox of trust: perceived risk and public compliance during the COVID-19 pandemic in Singapore. *J Risk Res*. (2020) 23:1021–30. doi: 10.1080/13669877.2020.1756386

5. Woo JJ. Pandemic, politics and pandemonium: political capacity and Singapore's response to the COVID-19 crisis. *Policy Design Pract*. (2020) 4:79–93. doi: 10.1080/25741292.2020.1835212

6. Siegrist M, Luchsinger L, Bearth A. The impact of trust and risk perception on the acceptance of measures to reduce COVID-19 cases. *Risk Anal*. (2021) 41:787–800. doi: 10.1111/risa.13675

7. Monzani D, Marinucci M, Pancani L, Rusconi P, Mazzoni D, Pravettoni G. Thinking of future as an older individual increases perceived risks for age-related diseases but not for COVID-19. *Int J Psychol*. (2022) 57:96–106. doi: 10.1002/ijop.12789

8. Shang Y, Li H, Zhang R. Effects of pandemic outbreak on economies: evidence from business history context. *Front Public Health*. (2021) 9:632043. doi: 10.3389/fpubh.2021.632043

9. Vaughan E, Tinker T. Effective health risk communication about pandemic influenza for vulnerable populations. *Am J Public Health*. (2009) 99 Suppl 2:S324–32. doi: 10.2105/AJPH.2009.162537

10. Liao Q, Cowling B, Lam WT, Ng MW, Fielding R. Situational awareness and health protective responses to pandemic influenza a (H1N1) in Hong Kong: a cross-sectional study. *PLoS One*. (2010) 5:e13350. doi: 10.1371/journal.pone.0013350

11. Bults M, Beaujean DJMA, De Zwart O, Kok G, Van Empelen P, Van Steenbergen JE, et al. Perceived risk, anxiety, and behavioural responses of the general public during the early phase of the influenza a (H1N1) pandemic in the Netherlands: results of three consecutive online surveys. *BMC Public Health*. (2011) 11:2. doi: 10.1186/1471-2458-11-2

12. Blair RA, Morse BS, Tsai LL. Public health and public trust: survey evidence from the Ebola virus disease pandemic in Liberia. *Soc Sci Med*. (2017) 172:89–97. doi: 10.1016/j.socscimed.2016.11.016

13. Reynolds RM, Weaver SR, Nyman AL, Eriksen MP. Trust in COVID-19 information sources and perceived risk among smokers: a nationally representative survey. *PLoS One*. (2022) 17:e0262097. doi: 10.1371/journal.pone.0262097

14. Poortinga W, Pidgeon NF. Exploring the dimensionality of Trust in Risk Regulation. *Risk Anal*. (2003) 23:961–72. doi: 10.1111/1539-6924.00373

15. Bargain O, Aminjonov U. Trust and compliance to public health policies in times of COVID-19. *J Public Econ*. (2020) 1:104316. doi: 10.1016/j.jpubeco.2020.104316

16. Petretto DR, Pili R. Ageing and COVID-19: what is the role for elderly people? *Geriatrics*. (2020) 5:14. doi: 10.3390/GERIATRICS5020025

17. Subramaniam M, Abdin E, Vaingankar JA, Shafie S, Chua BY, Sambasivam R, et al. Tracking the mental health of a nation: prevalence and correlates of mental disorders in the second Singapore mental health study. *Epidemiol Psychiatr Sci*. (2020) 29:E29. doi: 10.1017/S2045796019000179

18. Chen H, Shi L, Zhang Y, Wang X, Jiao J, Yang M, et al. Comparison of public health containment measures of COVID-19 in China and India. *Risk Manag Healthc Policy*. (2021) 14:3323–32. doi: 10.2147/RMHP.S326775

19. Tasnim S, Hossain MM, Mazumder H. Impact of rumors and misinformation on COVID-19 in social media. *J Prev Med Public Health*. (2020) 53:171–4. doi: 10.3961/jpmph.20.094

20. Saechang O, Yu J, Li Y. Public trust and policy compliance during the COVID-19 pandemic: the role of professional trust. *Healthcare*. (2021) 9:151. doi: 10.3390/healthcare9020151

21. Agley J, Xiao Y. Misinformation about COVID-19: evidence for differential latent profiles and a strong association with trust in science. *BMC Public Health*. (2021) 21:89. doi: 10.1186/s12889-020-10103-x

22. DoS Singapore, Trends Populations (2022). *Department of statistics MoTI, Republic of Singapore* Report No. ISSN 2591–8028.

23. Hsu L.Y., Tan M.-H. *What Singapore can teach the U.S. about responding to Covid-19*. Available at: https://www.statnews.com/2020/03/23/singapore-teach-united-states-about-covid-19-response/ (Accessed April 12, 2020).

24. Chiew CJ, Li Z, Lee VJ. Reducing onward spread of COVID-19 from imported cases: quarantine and 'stay at home' measures for travellers and returning residents to Singapore. *J Travel Med*. (2020) 27:taaa049. doi: 10.1093/jtm/taaa049

25. Jang K, Baek YM. When information from public health officials is untrustworthy: the use of online news, interpersonal networks, and social media during the MERS outbreak in South Korea. *Health Commun*. (2019) 34:991–8. doi: 10.1080/10410236.2018.1449552

26. Wiederhold BK. Using social media to our advantage: alleviating anxiety during a pandemic. *Cyberpsychol Behav Soc Netwo*. (2020) 23:1–2. doi: 10.1089/cyber.2019.29171.bkw

27. Nicholls N, Yitbarek E. Trust in social media and COVID-19 beliefs and behaviours. *PLoS One*. (2022) 17:e0275969. doi: 10.1371/journal.pone.0275969

28. Du E, Chen E, Liu J, Zheng C. How do social media and individual behaviors affect epidemic transmission and control? *Sci Total Environ*. (2021) 761:144114. doi: 10.1016/j.scitotenv.2020.144114

29. Joseph AM, Fernandez V, Kritzman S, Eaddy I, Cook OM, Lambros S, et al. COVID-19 misinformation on social media: a scoping review. *Cureus*. (2022) 14:e24601. doi: 10.7759/cureus.24601

30. Mututwa W, Matsilele T. COVID-19 infections on international celebrities: self presentation and tweeting down pandemic awareness. *J Sci Common*. (2020) 19:A09. doi: 10.22323/2.19050209

31. Llewellyn S. Covid-19: how to be careful with trust and expertise on social media. (2020). doi: 10.1136/bmj.m1160

32. Feng S, Shen C, Xia N, Song W, Fan M, Cowling BJ. Rational use of face masks in the COVID-19 pandemic. *Lancet Respir Med*. (2020) 8:434–436. doi: 10.1016/S2213-2600(20)30134-X

33. Wismans A, van der Zwan P, Wennberg K, Franken I, Mukerjee J, Baptista R, et al. Face mask use during the COVID-19 pandemic: how risk perception, experience with COVID-19, and attitude towards government interact with country-wide policy stringency. *BMC Public Health* (2022) 22:1622. doi: 10.1186/s12889-022-13632-9

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 30 July 2024
DOI 10.3389/fpubh.2024.1370343

OPEN ACCESS

EDITED BY
Fatjona Kamberi,
University of Vlorë, Albania

REVIEWED BY
Alice Verticchio,
Icahn School of Medicine at Mount Sinai, United States
Yi Luo,
Montclair State University, United States

*CORRESPONDENCE
Eray Öntaş
✉ eontas@ankara.edu.tr

RECEIVED 14 January 2024
ACCEPTED 03 July 2024
PUBLISHED 30 July 2024

CITATION
Öntaş E, Bahar-Özvarış Ş and Şimşek B (2024) Creating, publishing, and spreading processes of health-related contents in internet news sites: evaluation of the opinions of actors in health communication.
Front. Public Health 12:1370343.
doi: 10.3389/fpubh.2024.1370343

Creating, publishing, and spreading processes of health-related contents in internet news sites: evaluation of the opinions of actors in health communication

Eray Öntaş[1]*, Şevkat Bahar-Özvarış[2] and Burcu Şimşek[3]

[1]Department of Public Health, Ankara University Faculty of Medicine, Ankara, Türkiye, [2]Department of Public Health, Hacettepe University Faculty of Medicine, Ankara, Türkiye, [3]Department of Communication Sciences, Hacettepe University Faculty of Communication, Ankara, Türkiye

Introduction: The accuracy and reliability of health information disseminated through news is crucial, as it directly impacts both individual and societal health outcomes. This study aims to analyze the publication process of health content in Türkiye and its implications for public health. By examining the perspectives of various health communication stakeholders, the study seeks to identify existing issues and propose potential solutions.

Methods: The research uses a mixed-methods approach, including baseline content analysis of 846 news by 133 criteria, quantitative research with 78 participants encompassing bureaucrats, academics, journalists, and health association members, and 15 in-depth interviews for comprehensive insights.

Results: The content analysis indicated that 23.2% of the analyzed news articles lacked credible sources, while 63% did not mention the author's name. A striking 96.2% of respondents stated that inaccurate health news poses a risk to public health, emphasizing the urgent need for standardized reporting practices. The majority (90.9%) pinpointed the media as the primary catalysts for infodemic spread, with 93.5% citing gatekeepers as barriers to accurate information. Eroding trust in media, fueled by unethical practices, harms both media credibility and effective public health interventions.

Discussion: The study underscores the necessity for a collaborative approach among public institutions, academia, and media, focusing on responsibility, regulation, and sanctions against the infodemic. The research advocates for a balanced approach that prioritizes health rights and press freedom within a stakeholder-driven framework, highlighting that legislation alone cannot fully enhance the digital information ecosystem.

KEYWORDS

public health, health communication, online news, misinformation, science communication, infodemic, infodemiology, internet

1 Introduction

World Health Organization (WHO) states, "The extension to all peoples of the benefits of medical, psychological and related knowledge is essential to the fullest attainment of health" (1). In the digital age, providing accurate, clear, unbiased, up-to-date, and evidence-based health information to the public is critical in all aspects of health (2). The lack of access to essential health information, significantly influences morbidity and mortality rates, particularly in low to middle-income countries and among vulnerable populations worldwide (3). This condition arises when individuals, healthcare professionals, or policymakers lack the necessary health information to protect their own health or that of others, leading to what is termed "health information poverty" (4). Its detrimental effects, in turn, have negative impacts on the health of populations, which include poor levels of health education, challenges in reaching or understanding vital health information, inadequate critical information literacy skills, and an increased susceptibility to misinformation. Digital platforms' health information is, more often than not, biased and not credible, possibly impacting public health intervention outcomes negatively (5, 6).

The use of information technology presents a paradoxical view in the context of improving health, as it is both a part of the problem and a component of the solution (7). Currently, 64.4% of the global population uses the Internet, and 59.4% are engaged in social media (8). Türkiye's digital landscape, where 71.4 million individuals are internet users (83.4% of the population), 62.6 million (73.1% of the population) engage actively on social media, and with a staggering 95.4% of the adult demographic using smartphones represents a critical juncture for examining health communication dynamics. The average time spent on the Internet on any device is 7 h and 57 min a day, while on social media, the average is 2.57 h a day, highlighting the pivotal role of digital platforms in both active and passive health information acquisition (9).

Due to its widespread use, information technology plays an important role in the active and passive information acquisition process: Information from these sources can be actively acquired as part of health information search behaviors for purposes such as obtaining information about a medical condition, medication, testing, treatment, understanding the cause of health-related changes, symptoms, changing behavior or daily routine, getting information on a doctor or health institution, and dealing with an existing medical condition; on the other hand, information on social media and internet news sites can be passed on to individuals by chance or incidental exposure, causing them to be passively informed (3, 4, 10, 11). Just as the lack of quality information, the quantitatively large amount of health-related misinformation spread from internet sources also deepens the health information poverty (12).

Today, digital mass media are used with increasing momentum to eliminate the information gap. As delineated by the Turkish Statistical Institute in its Household Information Technology Usage Survey (2023), over the past 3 months, a significant 61.4% of internet users accessed online news, while 66.3% sought health-related information (e.g., injury, disease, nutrition, improving health, etc.) (13). These figures underscore the internet's role as the preeminent source for news and health information in Türkiye, with an engagement rate for news access reaching 75% (14).

As delineated in the literature, the propagation of health-related misinformation on topics such as vaccines, medications, nutrition, cancer, HIV/AIDS, outbreaks pertinent to Ebola and H1N1, tobacco, and e-cigarettes, constitutes a menace to public health (6, 15, 16). During the COVID-19 pandemic, a significant crisis of trust in information has emerged. Individuals, caught in a state of "confusion" due to unclear information and uncertain sources, now approach even reputable sources with skepticism. Despite the vast availability of information, there is a noticeable decline in the acceptance of shared truths, which are crucial for societal decisions. This has led to the fragmentation of society into "truth publics," where parallel realities and narratives proliferate within echo chambers. Consequently, the burden of truth establishment has been shifted to organizations characterized by weak transparency and accountability bases. This unethical accountability tendency may in the end breed a long-lasting disinterest or apathy that will make it easy to experience alienation from society's norms and values (17, p. 10). Other research has shown that, compared to correct health information, this misinformation is more likely to spread and diffuse in online contexts, adding the urgency of countermeasures and difficulty in controlling it (18). The "dilemma of trust" around science, using media as the primary channel to reach the public, could significantly endanger the diffusion of correct health information based on evidence.

While information and communication technologies (ICT) represent essential ingredients of our modern societies and economies, at the same time, they have the potential to deepen digital inequalities. The fact that ICTs can be used to exclude particular populations from services based on new technologies, such as e-government, ICT-based health, or education, is actual indeed. Socioeconomic inequalities thus influence the type and quality of practical and scientific knowledge acquisition by different groups, particularly in the context of public health issues (19). For instance, it is shown by communication theories, including the "knowledge gap" hypothesis, that disparities in information access can mirror those in wealth, leading to unequal distributions of knowledge within society. According to this hypothesis, people who continuously access information through mass media or the internet are often better informed than those not accessing them, increasing their level of knowledge regarding social contrasts of expertise (20). During the development of digital technologies, this difference has not only remained between them but also increased (21). "Digital divide" is often segmented into three clearly defined levels in research of this phenomenon: access to technology, use of this access, and information literacy. Each of these levels directly influences the outcomes and effects of internet usage (22, 23). Future studies were also challenged to conduct further in-depth research into the impacts and effects of internet usage, especially in the domain of the health-related digital divide (22). Further, for this to occur, the overall social resources need to be determined to ensure the equitable provision of access to information technology and its contents by all persons and to foster the development of crucial information literacy skills (24).

The need for reliable and accurate health communication is more important than ever, given the urgent issues brought to light by the spread of infodemic and the crisis of trust. The digital divide and associated disparities in access to information exacerbate these challenges, demanding a focused response from both researchers and policymakers. Within this contextual framework, the study is structured with three primary objectives: First, to elucidate the

prevailing scenario through content analysis, this initial section evaluates the health-related content featured on designated internet news sites. Second, through quantitative research, this part aims to gauge the perspectives of chosen stakeholders from diverse sectors. It assesses their sociodemographic attributes, competencies in health communication, and views on the reliability and impact of health-related content, standard publishing criteria, resource, and medium control to mitigate infodemic, oversight, and sanctions, as well as their opinions on content creation, publication, and dissemination processes. Third, the study concludes with a qualitative analysis in its final section, providing a detailed exploration of the significance of health-related content on internet news sites regarding public health. This section delves into the challenges surrounding the accuracy, reliability, and legitimacy of information, integrating insights from the previous sections to propose solutions.

2 Methods

2.1 Type of research

This research, encompassing three sections, is a descriptive investigation employing a mixed-methods approach, integrating both quantitative and qualitative research methodologies. In the first section, content analysis is conducted on internet news sites to delineate the current scenario. In the second section, quantitative research techniques are utilized, and the views of stakeholders from diverse sectors are captured via an online data collection form. Following the insights garnered from the first and second sections, in-depth interviews with stakeholders from varied sectors have been carried out in the third section.

2.2 Setting

In the first section dedicated to content analysis, a scrutiny of health-related content has been carried out on the following internet news sites: Sözcü - sozcu.com.tr, Hürriyet - hurriyet.com.tr, Sabah - sabah.com.tr, Milliyet - milliyet.com.tr, Habertürk - haberturk.com; Voice of America Turkish (VOA TR) - amerikaninsesi.com, BBC News Turkish (BBC TR) - bbc.com/turkce, Sputnik Turkey (Sputnik TR) - tr.sputniknews.com, Deutsche Welle Turkish (DW TR) - dw.com/tr, Bianet - bianet.org, NTV - ntv.com.tr. In the subsequent sections, namely the Quantitative Research (2nd Section) and Qualitative Research (3rd Section), interviews have been administered both in-person and online, aligning with the COVID-19 pandemic precautions.

2.3 Quantitative and qualitative research sample

The section on content analysis was executed on 11 internet news sites identified above, selected through purposive sampling. These news sites were chosen based on their rankings provided on SimilarWeb's website, a proprietary firm inaugurated in 2007 offering internet analytics services to enterprises based on composite indices like visit frequency and duration spent on the site, showcasing the most popular sites in the news/media category in Türkiye as of May 2019. The sites sozcu.com.tr, hurriyet.com.tr, sabah.com.tr, milliyet.com.tr, and haberturk.com were designated as "mainstream" media. For alternative media, news outlets financed by the United States, the United Kingdom, Russia, Germany, and Sweden, delivering news in Turkish, namely amerikaninsesi.com, bbc.com/turkce, tr.sputniknews.com, dw.com/tr, and bianet.org were chosen. Lastly, as a good practice exemplar, ntv.com.tr was selected as an online news portal whose editor has garnered accolades from professional bodies and academic entities in the realm of health communication. These internet news sites were scrutinized over a 7-day span from 16.03.2020 to 22.03.2020, with all health-related shares in text and photo gallery format containing information, recommendations, and other relevant content published throughout each day being encompassed in the analysis.

The sample for the Quantitative Research section was purposively determined, encompassing five distinct stakeholder groups engaged in health communication: bureaucrats allocated in health communication-related units within the Republic of Türkiye's Ministry of Health ($n = 5$), two representatives each as endorsed by the Executive Boards of Professional Unions in the health sector, namely the Turkish Medical Association, Turkish Dental Association, Turkish Veterinary Medical Association, and Turkish Pharmacists Association ($n = 8$), journalists functioning as health editors or reporters in Internet News Media ($n = 22$), representatives from Medical Specialty Associations within the Coordination Board of Specialty Associations of the Turkish Medical Association ($n = 93$), and academicians who have served as advisors for theses concerning health misinformation over the last decade (2010–2020), as per the database of the Higher Education Council Presidency National Thesis Center ($n = 27$). From the envisaged total of 155 health communication actors, engagement was established with 84; amongst these actors, 78 have partaken in the research.

In the section of qualitative research, in-depth discussions were orchestrated with three individuals from each identified group, chosen predicated on their topical background and the responses they rendered to the quantitative inquiries, culminating in a total of 15 participants. Vasileiou, Barnett, et al., in their systematic analysis spanning 15 years, conducted in 2018 (18), scrutinized prevailing factors that dictate the sufficient sample size in qualitative explorations; it was discerned that saturation and pragmatic considerations were the most recurrently cited legitimacy rationales. Despite the pragmatic selection of three individuals from disparate groups within the delineated universe, saturation was perceived to have been attained nearing the culmination of the 15-participant discussions, attributed to the repetition of statements.

2.4 Data collection instruments and research procedure

In the Content Analysis section of our study, we implemented a comprehensive content assessment schema comprising 33 meticulously devised queries tailored to reflect both the literature and the research objectives. The schema included: 2 queries for recording the URL and headline of each news item; 13 queries for evaluating structural attributes (metadata); 7 queries for thematic analysis; and 11 queries for a holistic review of the internet news portals examined. Thematic evaluation was guided by Schema.org's health and medical types model, which provides a structured framework for categorizing

medical entities (25). Accordingly, content was thematically grouped and analyzed in relation to the Sustainable Development Goals' health-related targets (n = 29) and classified based on the Global Burden of Disease Study-2017 (GBD-2017) cause hierarchy and risk, impairment, etiology, and injury n-code (REI) hierarchy (26). The news platforms were then assessed using criteria developed based on Health on the Net (HON) Codes (27). Due to the lack of standardized criteria for classifying health-related content in the existing literature, we employed a variety of specific classification criteria. This approach allowed us to clearly identify the associations within the content, using a total of 133 distinct criteria to ensure a thorough and targeted analysis.

In the Quantitative Analysis section, the digital survey was designed in seven distinct segments comprising 41 questions, both multiple-choice and open-ended. These segments included: Sociodemographic Attributes (4 questions); Individual Proficiencies/Experiences in Health Communication (4 questions); Digital Media Engagement and Digital Health Literacy (13 questions); Perceptions concerning the Reliability/Legitimacy of Health-Oriented Content (4 questions); Perspectives on Health-Oriented Content within Internet News Portals (13 questions); Proposals for Resolutions (2 questions); Individual Contributions toward Resolutions (1 question). Regarding perceptions concerning the reliability and legitimacy of health-oriented content, respondents were asked to reflect on what constitutes the reliability and legitimacy of health information, characteristics that make health information accurate, what they consider to be incorrect health information, and whether they think there are verification mechanisms in place before the news is published. In terms of perspectives on health-oriented content within Internet news portals, participants were questioned on their thoughts about the risk posed by infodemic in health news, their sense of personal responsibility in combating such infodemic, and their views on whether specific standards should be maintained in health-related content on internet news sites. Additionally, the research also considered the sources that individuals believed to be the main factors of the infodemic and their opinions on whether it was necessary to have oversights and sanctions to curb the infodemic. The researchers designed the questions solely for this research purpose and were not selected from any existing scales. This approach will allow for conducting an in-depth analysis of numerous topics addressed in the seven different sections of the survey. The implementation of this approach will help capture the complex views and nuanced views about digital health communication that current scales may not be represented well. Again, with the explorative character of the survey, it aimed at collecting wide-ranging information concerning the dynamics of digital health information and not testing *a priori* hypotheses or hypotheses derived from considerations. From the insights acquired in sections 1 and 2, a semi-structured template with six key questions was applied to the Qualitative Analysis domain for open-ended discussions. These six key questions captured participants' perception of the current status of health-related information available on news internet sites, as well as the basis of its reliability and accuracy while illuminating potential solutions and their contributions. The flowchart of the research is summarized in Figure 1.

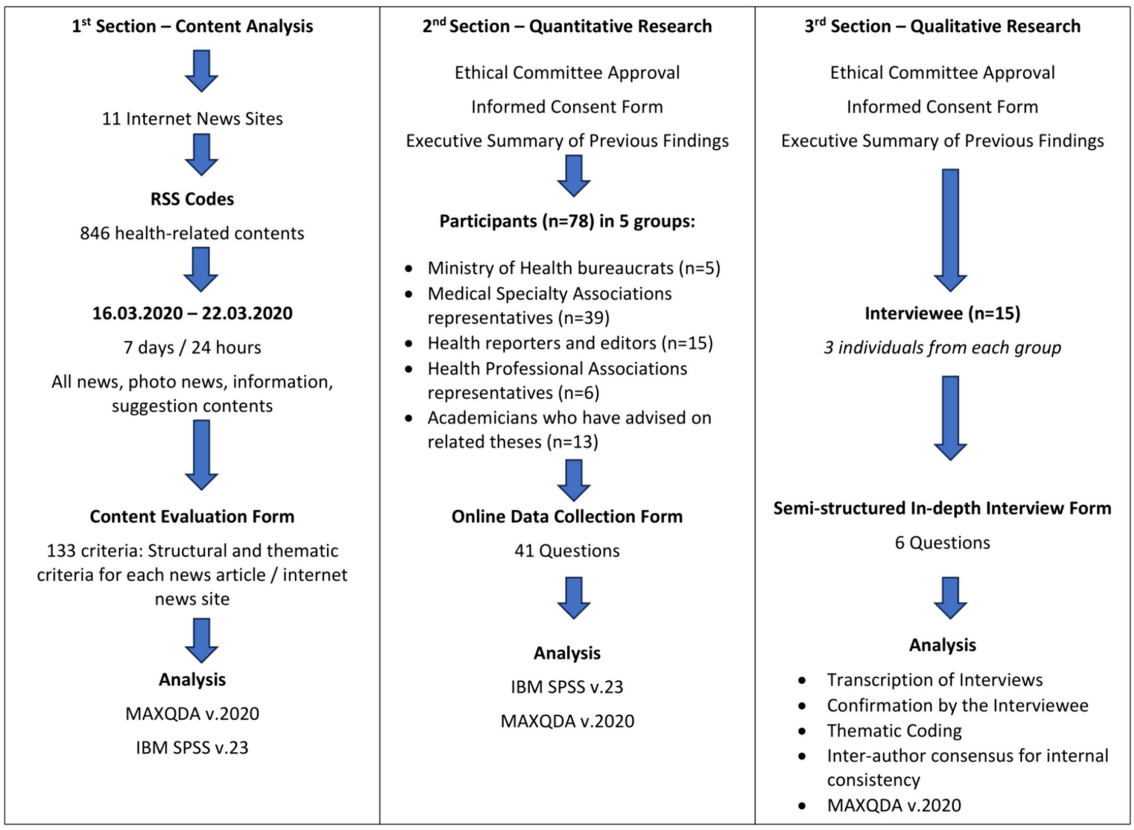


FIGURE 1
Flow diagram: overview of research methodology.

2.5 Data analysis framework

The content analysis was conducted using MAXQDA v.2020 for qualitative data analysis and SPSS v.23 for quantitative data analysis. The refined results are presented in descriptive tables, showing numerical and percentage divisions. The chi-square test facilitated the comparative analysis of mainstream versus alternative media content. The quantitative analysis was executed with IBM SPSS v.23, with findings represented as numerical and percentage distributions in descriptive tabulations. When scrutinizing the correlation between descriptive and described variables, continuous variables' distributions were probed through normality tests; the Mann Whitney-U test was employed amid determined categorical variables and those deviating from a normal distribution. Chi-square and Fisher's Exact tests underpinned the analyses among categorical variables, with a p-value <0.05 deemed statistically significant. Qualitative data inquiry was conducted through MAXQDA v.2020. To bolster the rigor of qualitative analyses, a preliminary pilot study was undertaken, and the findings accrued by the observer were vetted by other investigators, selecting a 5% sample for audit.

3 Results

In the preliminary section where content analysis was undertaken, 11 online news outlets were assessed against 133 criteria, unearthing that amongst 846 health-related pieces: the author/responsible party was undisclosed in 63%; in 24.5% solely news agency data was divulged. The transparency concerning author/agency/responsible entity is markedly lesser in mainstream media channels ($p < 0.05$). It was discerned that 23.2% of the contents lacked source attribution. In 43.7%, a minimum of one expert viewpoint was incorporated, affirming subject-matter competence via disclosed education and specialization details; in 22.7% at least one medical practitioner's opinion, and in 16.4% a scholarly article/report/book was cited as a source. Advisories to the readers were rendered in 71.4%. Merely in 3.5% were their open citations with web links, allowing universal access and appraisal concerning the disseminated information or data. Clickbait terminologies (cure, definitive solution, remedy, etc.) were employed in 4.4% of the headings. In thematic scrutiny, with respect to Sustainable Development Goals' 29 targets related to health, 65.5% are related with Communicable Diseases (SDG Target 3.3). Per the GBD-2017 cause hierarchy, 63.3% are Non-communicable diseases; (COVID-19 is not encompassed in this categorization) 13.6% pertain to communicable, maternal, neonatal, and nutritional diseases. As per the GBD-2017 REI hierarchy, 33.6% are tied to environmental/occupational risks, 15.7% to behavioral risks, and 8% to metabolic risks. In 31.2%, promotion of products and/or services was observed in one or more clusters (Clusters: pharmaceutical, therapeutic, or medical merchandize; botanical product, nutritional aid; examination, surgical procedure, investigation, or protocol). While nearly all promotional contents mentioned objectives and advantages, alternatives were discussed in 49.6%, risks and side effects in 31.1%, and the advisement of "seeking physician consultation prior to utilization" was merely articulated in 14.5% (Table 1).

In the segment encompassing quantitative analysis, the perspectives of 78 respondents hailing from five diverse sectors were appraised, with a staggering 96.2% concurring that the current proliferation of inaccurate health information within digital news platforms poses a palpable threat to public health. The predominant catalysts for this infodemic were identified as influential personalities within the media sphere (78.2%), news agencies (60.3%), groups harboring skepticism toward health services (53.8%), and health journalists and editors (51.3%). Participants pinpointed "Media" (90.9%), content generators (76.6%), internet users (66.2%), and the deficit of coherent and accurate health information disseminated by governmental entities (49.4%) as the fundamental drivers behind the online dissemination of erroneous health insights. A significant 93.5% acknowledged an interruption in the accurate health information generation and dissemination continuum; within this disruption, 67.5% underscored the predilection of "gatekeepers/decision-makers for speculative content driven by economic and political motives over factual information," while 53.2% accentuated the "inadequacy of adept individuals in generating accurate and publicly comprehensible information." The realms most plagued by the distribution of incorrect health data, as perceived by 91% of respondents, are "commercial internet platforms," followed by television productions (60.3%), and print media (51.3%). Education emerged as a paramount instrument in combatting infodemic, as endorsed by 55.1%, with 17.9% advocating for systemic alterations entailing deterrent sanctions by both public and private sectors to curb misinformation. The lack or insufficiency of verification mechanisms within publishing entities was acknowledged by 92.2%. A robust 93.6% championed the imperative of oversight to mitigate incorrect health information dissemination: the Ministry of Health (69.2%), the Turkish Medical Association (51.3%), and subject-specific Medical Specialty Associations (42.3%) were mooted as suitable overseers. The call for sanctions resonated with 92.2%, wherein 77.9% pinpointed the infodemic source, 72.7% the publishers, and 48.1% the sharers as liable entities. Upon a deeper analysis bifurcating media personnel from other stakeholders, a mere 20% of media professionals, contrasting with 54% of other actors, endorsed sanctions for misinformation purveyors, delineating a statistically substantial discrepancy ($p = 0.022$) (Table 2).

All participants exhibited consensus on the necessity of adhering to certain standards while generating health-related content on internet news platforms. The percentage of agreement concerning the delineated standards is documented in the Table 3.

In the third section wherein, the qualitative research was undertaken, through comprehensive discussions with 15 participants across five distinct groups, it was articulated that there necessitates a "collective responsibility, apportioned among readers, media, public authorities, and the academia." Within the media spectrum, the onus of responsibility is envisaged to reside within the "editorial chain." The paramount responsibility is underscored to vest with the "Public Authority" to orchestrate the process on society's behalf and to ensure the fulfillment of obligations by all societal individuals and establishments. It was highlighted that, given its direct bearing on health, media institutions should harbor a control mechanism imbued with a sense of responsibility. Apprehensions were aired regarding potential encroachments on press freedom in the presence of an external control mechanism, propelling the recommendation for the cultivation of an internal control mechanism. Pertaining to the extant scenario, foundational expectations from academia, media, public establishments, and legislators encompass a holistic approach at every juncture, meticulously delineated boundaries of health rights and

10.3389/fpubh.2024.1370343

TABLE 1 Key findings from comprehensive analysis of health-related content in 11 online news outlets (Türkiye, 2020).

Structural criteria	*n*	%
Authorship		
• Unknown author/responsible party	533	63.0
• Known author/responsible party	313	37.0
Content creator disclosure*		
• News agency name disclosed	207	24.5
• Author name disclosed/no competence declared	108	12.8
• Health journalist	13	1.5
• Expert with declared competence	9	1.1
Source attribution for content*		
• Expert opinion with declared competence	370	43.7
• Public institution/official statement	211	24.9
• No source attribution	196	23.2
• Scholarly articles/reports/books	139	16.4
• Opinion without declared competence	70	8.3
• Civil society official statement	51	6.0
• Private sector official statement	33	3.9
• Health-related Professional organizations' official statement	16	1.9
• Other websites	15	1.8

Thematic criteria	*n*	%
Health topics classification*		
• Disease or conditions	748	88.4
• COVID-19	645	76.2
• Risk factors	642	75.9
• Prevention	636	75.2
• Treatment/Therapies (including drugs and procedures)	257	30.4
• Signs and symptoms	232	27.4
• Studies and trials	181	21.4
• Diets	138	16.3
• Supplements	101	11.9
• Causes	91	10.8
• Tests	90	10.6
• Health infrastructure	56	6.6
• Exercise plans	52	6.1
• Devices	46	5.4
• Anatomy	31	3.7
• Guidelines	6	0.7
• Self diagnostic tools	5	0.6
• Legal issues	3	0.4
Promotion hidden within health-related content		
• **Promoted product/service group***	264	31.2
o Drug, treatment or medical product	138	16.3
o Herbal product, nutritional supplement, etc.	104	12.3
o Test, operation, research or procedure	27	3.2
Scope of promotional content* (*n* = 264)		
o Benefits	261	98.9
o Intended purpose	260	98.5
o Discussion of alternatives	131	49.6
o Risks and side effects	82	31.1
o Advice to physician consultation prior to utilization	38	14.5

*Multiple categories can be selected for each content.

press freedom, and engagement with all identified responsible stakeholders in all ensuing steps.

4 Discussion

A significant 96.2% of participants are of the view that the inaccurate health-related content present in today's internet news poses a public health risk; a minority of 3 participants (3.8%) acknowledge this assertion to be true in certain scenarios. The quality of health information available online has been substantially impacted by the transformation of the Internet into a participatory and social platform with the emergence of Web 2.0 (28, 29). Wardle and Derakhshan's paper offers a framework for analyzing information disorder, classifying it into three types: misinformation, disinformation, and malinformation, based on the accuracy of the information and the intent to harm (30). In the digital era, which is also defined by the "weaponization of mistrust" and "computational propaganda" (31), information disorder has become a serious public health concern due to the rapid increase in the speed, scale, and scope of information flow. The widespread use of the internet, social media, and mobile phones has fundamentally disrupted established business models in the news sector. New business models often grapple with budget constraints, infrastructure challenges, and a scarcity of resources, leading to a reduction in "on-the-ground," real-life news coverage (32). The pressure to continuously create content to feed the homepage and social media accounts, along with the speed of publication demands, has reduced the quality control processes such as verification, diversity of data, and content enhancement. The blending of news and commercial information, along with the risk of eroding reader trust through hidden advertisements and "clickbait" headlines, has increased information disorder. In an increasingly competitive online world, content produced to attract visitors to websites rather than inform the public is promoted to increase digital advertising sales, sometimes at the cost of excellence and viability in journalism practice. The demand for "real-time" content increases the potential for errors and the merging of all types of media blur expertise in specialized areas. This pressure often translates into a "publish first, check later" approach (33). It becomes desperately important to enforce robust internal controls within media organizations to check the spread of non-factual information. Overcoming these challenges is possible only when media organizations and journalists base the centrality of transparency on their practice of ethical journalism and chase down evidence-based reporting. The implementation of rigorous verification processes to identify the prevalence of misinformation and thorough validation of data, sources, and digital images are necessary. Furthermore, additionally, it is essential that the framing

10.3389/fpubh.2024.1370343

TABLE 2 Key findings from qualitative analysis of opinions on actors in health communication ($n = 78$).

Theme	Perception	Description	%
Impact of infodemic on public health	High risk to public health	Belief that inaccurate health information in news poses a risk to public health	96.2
	Risk to public health in certain conditions	Belief that inaccurate health information in news poses a risk to public health, in certain conditions	3.8
Sources of infodemic*	Media influencers	High-profile individuals in the media	78.2
	News agencies		60.3
	Healthcare skeptic groups		53.8
	Health reporters/editors		51.3
	Health professionals		17.9
	Public officials		14.1
	Civil society organizations		5.1
Catalysts for infodemic spread*	Media	Selective impact by media gatekeepers, economic concerns in supply due to demand	90.9
	Content creators	Inadequacy in producing public beneficial information by competent individuals and organizations, unmet demand	76.6
	Internet users	Need for health information search behavior, lack of critical skills due to unmet information gaps	66.2
	Public institutions	Insufficient accurate and understandable health information provided	49.4
	Healthcare services	Inadequate communication duration between service provider and receiver	41.6
	Social media companies		1.3
Barriers to accurate information*	Gatekeepers/decision-makers	Preference for speculative content over accurate information for economic and political reasons	67.5
	Competent individuals	Not producing enough correct and understandable information for the public	53.2
	Information not reaching gatekeepers/decision-makers		32.5
	Demand not met by users even if correct information is produced and published		32.5
	Inability to discern right from wrong		31.2
Media for infodemic spread*	Commercial internet platforms		91.0
	Television productions		60.3
	Press/Newspapers		51.3
	Internet forums		48.7
	Instant messaging applications		47.4
Countering health infodemic	Education	Emphasizing the need for health literacy to discern misinformation	55.1
	System change for deterrence	Need for deterrent sanctions by the private sector and public to prevent misinformation	17.9
	Verification mechanisms	Detecting and correcting misinformation	15.4
	System change for regulation	Need for regulatory actions by the private sector and public to prevent misinformation	7.7
	Tools	Helping users to discern misinformation	2.6

(Continued)

of news agendas is consistent with the public's requirements and benefits, thereby guaranteeing that the media act as a constructive force in society (31).

The digital shift, particularly the move to digital advertising dominated by giants like Google and Facebook, has not fully supported media organizations, compelling them to develop new business models. The research underscores social media corporations as pivotal conduits for the dissemination of health misinformation online, a viewpoint further enriched by Farkas and Schou's discourse on "digital capitalism" (34). Delving into the underlying causality with a holistic lens, beyond the "political power" deliberated in ensuing sections, the nexus between advertising revenue distribution and content formulation in media entities warrants scrutiny. In Türkiye, during 2021, a staggering 99.2% of internet users utilized search engines within the preceding month (35),

TABLE 2 (Continued)

Theme	Perception	Description	%
Oversight*	Ministry of health		69.2
	Turkish medical association		51.3
	Medical specialist associations		42.3
	Information technologies and communications authority		26.9
	An independent organization		24.4
	Radio and television supreme council		21.8
	Press/Journalists		15.4
	Civil society organizations		7.7
	The user themselves		6.4
	Commercial internet platforms		3.8
	Consumer arbitration boards		2.6
Sanctions for infodemic*	Against misinformation source		77.9
	Against publisher of misinformation		72.7
	Against sharer of misinformation		48.1
	No sanctions needed		7.8

*Multiple responses can be selected for this question.

TABLE 3 Proposed standards for health-related content on internet news sites.

Criteria	Frequency (*n*)	Percentage (%)
Author name and relevant expertise *(n = 78)*	78	**100.0**
Recency *(Date of information acquisition, last updated date) (n = 78)*	78	**100.0**
Citation and verifiability *Accessible references to data sources, provision of balanced evidence addressing different aspects of the topic (n = 78)*	77	98.7
Completeness statement *Declaration that the health information provided is to support, not replace, doctor-patient relationships, and consultation with a physician is necessary for the appropriateness of the information (n = 78)*	75	96.2
Readability *Simple and understandable expressions; explanatory infographics and tables (n = 77)*	73	94.8
Privacy statement *Transparency about the usage and security procedures of user-collected data (n = 76)*	71	93.4
Ethical declaration *Declaration of no vested interest by the author regarding the content (n = 77)*	71	92.2
Contact addresses and feedback mechanism *(n = 78)*	71	91.0
Guidance *Detailed resources or contact information for visitors seeking further support and current information regarding the content (n = 77)*	67	87.0
Responsibility statement *Declaration of author's responsibility for any adverse situations arising from the content (n = 77)*	65	84.4
Legal guidance *Basic guiding information for those wishing to pursue legal rights concerning publishing and current applicable laws (n = 77)*	62	80.5

with a dominant majority (over 80%) opting for Google (36). Anticipations are rife for Google, the online advertising vanguard, to steer 29% of the global digital ad outlays in 2021, with Facebook trailing at 24% (37). Peering into the European landscape, notably the UK, a presumed 'Duopoly' held by these behemoths commandeers nearly 70% of the market share (38), while a 'Digitalization and Competition Policy Report' initiated by Türkiye's Competition Authority in January 2021 could shed light on the analogous scenario locally (39). The year 2020 saw a purported investment of around 7.5 billion TL in digital media ventures in Türkiye. A dissection of the investment spread across ad modalities

unveils that paid ad campaigns ensuring prime search engine rankings (37.9%), impression or click-centric ads (35.2%), and video ads (20.5%) are poised to engulf a substantial portion of the nearly 7 billion TL investment (40). Yet, post the 7.5% digital service tax amendment in March 2020, the revenue accrued from April 2020 to March 2021 stood at 1.66 billion, with the implicated sector boasting a transaction girth of 22 billion TL (41, 42). A foray by the Reuters Institute, encompassing 234 digital media chieftains across 43 nations, revealed that a hefty 66 and 61% acknowledged impression-based and native ads, respectively, as significant revenue streams (43). Internet news outlets, in a bid to bolster ad revenues, are veering toward marketing "content" crafted to fuel site traffic over *bona fide* "news," employing SEO tactics like clickbait, content pagination, 'click to continue reading' prompts, and auto-refresh features (44). This paradigm of churning out "cheap" content, gauged by metrics like views, clicks, site duration, and shares, is embarking on a quality compromise journey, undermining public trust in securing timely, accurate, and comprehensible information. The 2021 Turkey Digital Media Report by the International Press Institute accentuates, through engagements with media moguls, that colossal platforms are swaying the publishing ecosystem by "propagating clickbait" (45). The prevailing revenue distribution algorithms are propelling large media houses with hefty SEO arsenals to eclipse other media entities in search engine visibility, thereby stifling the distribution share for outlets disseminating alternative viewpoints and local news narratives.

Media professionals, influenced by routine media practices, institutional goals, external pressures, and ideological influences - as outlined in the agenda-setting framework (46), which focuses on how media prioritize issues to shape public perceptions - actively engage in "marketing" health information. The communal benefits of disseminating critical public health information may be overshadowed by the prioritization of content that generates the most clicks, views, and shares. For instance, prevalent and often fatal diseases such as cardiovascular diseases, cancers, chronic respiratory disorders, diabetes, and chronic kidney diseases receive significant attention. Nevertheless, there is a significant inclination among internet news sites to prioritize sensationalist and ambiguous lifestyle advice over clear and actionable guidance on preventable risk factors, including the cessation of tobacco, the reduction of harmful alcohol consumption, the reduction of salt intake, the reduction of trans-fat and sugar-sweetened beverages, and the increase in physical activity (47). This method has the potential to diminish the effectiveness of disease prevention and management strategies and weaken the impact of critical public health messaging.

The research question onto the accountability for the accuracy and reliability of health-related information on internet news platforms introduces the notion of collective responsibility. In many cases, it is posited that responsibility is distributed among a number of different stakeholders, such as the reader, the source of the information, media entities, public authorities, and academic institutions, to varying degrees. In addition, a sizeable number of respondents emphasized that the public authorities bear the lion's share of this responsibility. This is because of the role that they play in orchestrating the processes that are involved.

In Türkiye, examining the governance of the Internet reveals that the Ministry of Transport and Infrastructure set up through Decree-Law No. 655, is designated with powers concerning the electronic communication sector under Law No. 5809. Additionally, an Internet Development Board operates under this ministry, is mandated to foster a conducive environment for internet growth through research and assessments, and is entrusted with shaping the national internet policy. The Information and Communication Technologies Authority (ICTA), affiliated with the ministry via Law No. 2813, is tasked with executing the board's decisions (48). The ICTA holds the regulatory reins in electronic communication, as outlined in Law No. 5651, which addresses the regulation of online publications and the combat against online crimes (49). Other pivotal legislations in the domain of Internet law include Law No. 5369 on Universal Service and Law No. 5809 on Electronic Communication (50, 51). At the time of this study, the outdated definitions and responsibilities in the Press Law for internet news sites, along with the lack of adherence to author identification in periodic publications, contribute to legislative gaps fostering information disorder (52).

This research discovered that 63% of the evaluated contents lacked author, agency, or responsible party identification, and some respondents pinpointed anonymous news as a significant misinformation catalyst. Unanimously, participants advocated for a standard requirement of disclosing the author's name, their subject-matter expertise, and the creation and last update dates of the content. The necessity of standardly presenting an author's name and credentials in every piece of content is partly driven by concerns around copyright issues. A study engaging news website editors revealed that they unanimously source information from "rival news outlets" and "social media" (53). The accountability of content providers is defined in Law No. 5651, and Law No. 5846 on Intellectual and Artistic Works extends this definition to digital transmissions in its additional article no.4 (54). However, the present regulation may fall short in deterrence, as it positions the "Notice-Takedown System" at the forefront, coupled with a 3-day timeframe allocated for the rights holder's request. Moreover, the practice of amplifying individuals' visibility—sometimes in sensitive scenarios—by featuring personal opinions from social media on news websites, brings the discussion of "usage permissions" and accurate attribution to the fore, a discourse evident not only in Türkiye but also in broader international dialogs (55).

Participants underscored two key considerations concerning the amendments needed for the current deficiencies: firstly, the necessity of accurately delineating the constitutional boundaries of press freedom, personal rights, and health rights while establishing legal frameworks for publications; secondly, ensuring that these legislative amendments are crafted in a collaborative manner, with extensive engagement from public, private, and civil society entities. Conversely, the global scenario paints a different picture, where many nations have faced criticism for infringing upon freedom of expression and press liberty, often justified by the ongoing pandemic (56). In the COVID-19 epoch, scrutinizing nations' legal battles against the surging "disinformation" tide, amplified by the infodemic, reveals a spectrum of responses. For instance, new legislation categorizing disinformation as a criminal offence has emerged in countries like Hungary, Bolivia, South Africa, Botswana, Zimbabwe, and the Philippines. Additionally, instances of detentions have been reported in Kenya, the Philippines, Sri Lanka, and Cambodia, triggered by critiques of governmental approaches toward COVID-19 containment. Meanwhile, Serbia and India have instituted "directive" frameworks permitting only official or government-sanctioned COVID-19 information to be disseminated. Lastly, notable restrictions on COVID-19-related information dissemination have been imposed by authorities in China, Belarus, and Kuwait (57, 58).

The notion of "responsibility" in internet news media naturally leads to the need to define oversight and accountability. According to quantitative research findings, a significant 93.6% of participants believe that oversight is crucial to prevent misinformation related to health; 92.2% mention the lack of or inadequacy of a verification mechanism as an internal oversight process in broadcasting institutions. On the flip side, when it comes to external oversight mechanisms, participants suggest that the Ministry of Health of the Republic of Türkiye (69.2%), Turkish Medical Association (51.3%), and relevant medical specialty associations (42.3%) could be responsible for oversight, depending on the subject matter. There is an expectation from the academic community to establish oversight mechanisms, while public institutions are anticipated to organize oversight and regulatory activities. Qualitative research findings collectively emphasize that due to the direct impact of health news on individual and community health, it should be carried out with a particular sensitivity. Therefore, a sense of responsibility throughout all stages of the publication process is vital within media organizations, necessitating an internal oversight mechanism. A heavily stressed point regarding internal oversight is "professional ethics." The ethical regulations and legislation concerning health professionals who could serve as sources have been defined by professional organizations: Law on the Practice of Medicine and Its Branches (Article 24) (59), Medical Deontology Regulation (Articles 8–9) (60), Guide on Shares of Physicians and Health Institutions in Electronic Media (61), Turkish Medical Association Principles on Physician and Drug Promotion (62), Guide on Publications of Dentists in All Communication Media (63), Turkish Dental Association and Chambers of Dentists Discipline Regulation (Article 8/a) (64) and the Regulation on Promotion and Information Activities in Health Services issued in 2023 (65).

A crucial component of internal oversight is the decision-makers at the pinnacle of the editorial chain. Research by Ioannidis highlights a shortfall in media coverage of significant public health issues and their modifiable risk factors, while individualized suggestions are prominently featured (47). Sezgin, critically examining health discourse in media, bases his assessments on the implications of neoliberal economy on healthcare systems (66). The investigation delves into the transformation in biotechnology, the pharmaceutical industry, health insurance, and the cosmetic industry under the banner of "for a healthier society," alongside the medicalization of everyday life and physiological concepts like birth, death, menopause, and aging. The impact of gatekeepers on content selection is explored in a study by Yalçınkaya (2019) involving news site editors (33), where it's found that editors' judgments are influenced by their institution's political stance, fears of political pressures, the publication policy, and the expectation of high click-through rates. Ayaz's study unveils the ideological influences on gatekeepers' decision-making processes, emphasizing the need for revisiting editorial independence (67, p. 278). Reports by Turkish Journalists Society (68), Turkish Journalists Union (69), Turkish Media and Law Studies Association (70), Freedom House (71), and European Commission (72, p. 37) have shed light on press freedom violations. In this context, legal frameworks should uphold press freedom, fostering a transparent structure to mitigate economic and political influences on editorial independence, and encouraging unionization (69) to rekindle a journalist's primary accountability toward the public and truth.

When examined through the lenses of information disorder, responsibility, and oversight, a notable "legal disorder" that potentially infringes on various rights is observed. Consequently, the interviewees frequently expressed reservations about the yet-to-be-defined external oversight and punitive mechanisms under the current legal conditions, fearing they might encroach upon fundamental rights and freedoms. They advocated for the promotion and endorsement of "good practice examples" as corrective measures. Participants are looking to legislators to delineate boundaries concerning the focus of sanctions (information source, publishing institutions, social media and internet service providers, health information communication tools, sharers, advertisements); the limits of sanctions (safeguarding public health for the common good, not impeding personal freedoms, and not hindering scientific advancements); and the conditions under which they will be applied (non-scientific, commercially-driven publications, those without clear references, unethical ones). They underscored the necessity for formulating regulations directed at oversight and demonstrating steadfastness in implementing these regulations.

When comparing Türkiye's response to the infodemic with global initiatives, certain similarities as well as distinctions become apparent. In recognition of the fact that misinformation is a substantial obstacle in the public health response to the pandemic, WHO has brought attention to the concept of an "infodemic" (73). It is important to note that WHO has established the WHO Information Network for Epidemics (EPI-WIN) in order to guarantee that communities receive trustworthy, timely, and easily understandable advice and information regarding public health events and outbreaks (74). A Public Health Research Agenda for Infodemics Management has been developed through the global collaboration of nations under the aegis of the World Health Organization (12, 75). Many contributions forming the process made by this agenda included Artificial Intelligence tools like WHO-EARS to guide social listening and identify information gaps (76).

As part of this strategy, there are numerous policies that the European Union has put in place to enhance accountability and transparency within digital communications. Some of these policies include the EU Code of Practice on Disinformation, the COVID-19 Disinformation Monitoring Programme, and the Digital Services Act, which is aimed at regulating online platforms to curb the spread of false information through strict monitoring and reporting mechanisms (77–79). Such measures are also part of the most recent legislation in Türkiye, even though it deviates significantly from the country's policy. However, it seems that Turkey, unlike the EU member states, has focused more on legal infrastructures and strict regulations meant to oversee the distribution of such content that is realized as harmful or false.

While in the EU, independent bodies and NGOs contribute to the multi-stakeholder, decentralized approach to information oversight and verification—this is seen, for example, with the European Digital Media Observatory (80)—recent Türkiye legislative changes, such as Law No. 7418 (81), bringing state mechanisms directly into the picture through monitoring and controlling online content (82).

In addition, Türkiye's regulations place a strong emphasis on the legal ramifications of infractions, including particular criminal penalties for disseminating false information. This goes beyond the administrative and civil remedies that are generally preferred in Western approaches (83). This divergence highlights a more stringent and controlled method in Türkiye, aiming to quickly stem the dissemination of disinformation,

whereas the EU and countries like Canada and the UK's strategies often emphasize long-term educational strategies and technological solutions to foster a more informed and resilient public (82).

4.1 Strengths and limitations

Our study is a pioneering investigation into the topic of "infodemic" before the WHO had formally defined the concept, thus laying the groundwork for future research in the critical area of accurate health information during a pandemic. It benefits from the collective insights of diverse fields, enhancing problem-solving and intervention strategies. Nevertheless, it has constraints. The data collection phase coincided with the announcement of the COVID-19 pandemic, overshadowing other health-related topics we intended to analyze. The pandemic also impeded direct access to health-related actors, which could potentially reduce the participation of health professionals. Due to the fact that we lacked the specialized expertise necessary to verify the factual accuracy or scientific validity of each health content, we relied on practical criteria to ensure the reliability of the information they contained. A purposive sampling approach was required due to resource constraints and the pandemic, which restricted the generalizability of our findings. Future research could resolve these limitations by incorporating broader actor participation and expanding the evaluative criteria for health-related content on internet sites.

5 Conclusion

This research brings forth the critical role of journalists in putting public health at the center of reporting. To effectively fight the infodemic and ensure the success of health interventions with the population, it is essential to regain trust in journalism as a sector that has always safeguarded the truth. Research shows that such efforts must be undertaken in collaboration with various stakeholders, including media, academic institutions, and regulators, to guide ethical standards and increase transparency. The paper suggests an integrative vision of health communication that brings forward the awareness of a public health agenda as fundamentally and increasingly interconnected with democratic processes, human rights, and social cohesiveness. In public health protection, public authorities play a crucial role in ensuring that all people have access to quality internet and accurate and dependable information. Supplementary Table S1 provides recommendations to the public authorities to assist the public authorities in fighting information disorder. Lastly, it is imperative for the state to undertake positive actions to facilitate the realization of the right to health and the enhancement of public health, thereby creating an environment where all members of the community can fulfill their responsibilities.

Data availability statement

The datasets presented in this article are not readily available because the second part of the study – the quantitative research, and the third part – the qualitative research, might reveal the participants' identities when the data is shared. Therefore, data can only be shared upon a reasonable request. Requests to access the datasets should be directed to eontas@ankara.edu.tr.

Ethics statement

The studies involving humans were approved by the Non-Interventional Clinical Research Ethics Committee of Hacettepe University, Ankara, Türkiye under the decree number GO20/129 (Evaluation Date: 27.01.2020), 2020/03–08. 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

EÖ: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Software, Validation, Writing – original draft, Writing – review & editing. ŞB-Ö: Conceptualization, Formal analysis, Methodology, Project administration, Supervision, Validation, Writing – review & editing. BŞ: Conceptualization, Formal analysis, Methodology, Project administration, Supervision, Validation, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Acknowledgments

This article is based on a thesis authored by EÖ.

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.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2024.1370343/full#supplementary-material

References

1. World Health Organization. Constitution of the World Health Organization. Geneva. (1948). Basic documents: forty-ninth edition, including amendments adopted up to 31 May 2019. Available at: https://apps.who.int/gb/bd/pdf_files/BD_49th-en.pdf

2. Tangcharoensathien V, Calleja N, Nguyen T, Purnat T, D'Agostino M, Garcia-Saiso S, et al. Framework for managing the COVID-19 Infodemic: methods and results of an online, crowdsourced WHO technical consultation. *J Med Internet Res*. (2020) 22:e19659. doi: 10.2196/19659

3. Longo DR. Understanding health information, communication, and information seeking of patients and consumers: a comprehensive and integrated model. *Health Expect*. (2005) 8:189–94. doi: 10.1111/j.1369-7625.2005.00339.x

4. Longo DR, Ge B, Radina ME, Greiner A, Williams CD, Longo GS, et al. Understanding breast-cancer patients' perceptions: health information-seeking behaviour and passive information receipt. *J Commun Healthc*. (2009) 2:184–206. doi: 10.1179/cih.2009.2.2.184

5. Lieneck C, Heinemann K, Patel J, Huynh H, Leafblad A, Moreno E, et al. Facilitators and barriers of COVID-19 vaccine promotion on social Media in the United States: a systematic review. *Healthcare*. (2022) 10:321. doi: 10.3390/healthcare10020321

6. Wang Y, McKee M, Torbica A, Stuckler D. Systematic literature review on the spread of health-related misinformation on social media. *Soc Sci Med*. (2019) 240:112552. doi: 10.1016/j.socscimed.2019.112552

7. Gunasekeran DV, Chew A, Chandrasekar EK, Rajendram P, Kandarpa V, Rajendram M, et al. The impact and applications of social media platforms for public health responses before and during the COVID-19 pandemic: systematic literature review. *J Med Internet Res*. (2022) 24:e33680. doi: 10.2196/33680

8. We Are Social & Meltwater. Digital. (2023). Global Overview Report 2023. Available at: https://datareportal.com/reports/digital-2023-global-overview-report.

9. We Are Social & Meltwater.Digital 2023: Turkey. (2023). Available at: https://datareportal.com/reports/digital-2023-turkey

10. Basic J, Erdelez S. Active and passive acquisition of health-related information on the web by college students. *Proc Am Soc Inf Sci Technol*. (2015) 51:1–5. doi: 10.1002/meet.2014.14505101149

11. Zhang D, Shi Z, Hu H, Han G(K). Classification of the use of online health information channels and variation in motivations for channel selection: cross-sectional survey. *J Med Internet Res*. (2021) 23:e24945. doi: 10.2196/24945

12. Calleja N, AbdAllah AH, Abad N, Ahmed N, Albarracin D, Altieri E, et al. A public Health Research agenda for managing Infodemics: methods and results of the first WHO Infodemiology conference. *JMIR Infodemiol*. (2021) 1:e30979. doi: 10.2196/30979

13. Turkish Statistical Institute. Household Information Technologies (IT) Usage Survey, 2023- in Turkish. 2023 30.08.2023. Available at: https://data.tuik.gov.tr/Bulten/Index?p=Hanehalki-Bilisim-Teknolojileri-(BT)-Kullanim-Arastirmasi-2023-49407

14. Newman N, et al. Digital news report 2023. Reuters Institute for the Study of Journalism. (2023). Available at: https://reutersinstitute.politics.ox.ac.uk/sites/default/files/2023-06/Digital_News_Report_2023.pdf

15. McKee M, Middleton J. Information wars: tackling the threat from disinformation on vaccines. *BMJ*. (2019) 365:l2144. doi: 10.1136/bmj.l2144

16. Krishna A, Thompson TL. Misinformation about health: a review of health communication and misinformation scholarship. *Am Behav Sci*. (2021) 65:316–32. doi: 10.1177/0002764219878223

17. LSE Truth Trust & Technology Commission. Tackling the information crisis: a policy framework for media system resilience. The London School of Economics and Political Science; (2018). Available at: https://www.lse.ac.uk/media-and-communications/assets/documents/research/T3-Report-Tackling-the-Information-Crisis.pdf

18. Vosoughi S, Roy D, Aral S. The spread of true and false news online. *Science*. (2018) 359:1146–51. doi: 10.1126/science.aap9559

19. Van Dijk JAGM. Closing the digital divide: the role of digital technologies on social development, well-being of all and the approach of the Covid-19 pandemic. UN Department of economic and social affairs. (2020) Expert Group Meetings, Panel Discussions and Seminars. Available at: https://www.un.org/development/desa/dspd/wp-content/uploads/sites/22/2020/07/Closing-the-Digital-Divide-by-Jan-A.G.M-van-Dijk-.pdf

20. Tichenor PJ, Donohue GA, Olien CN. Mass media flow and differential growth in knowledge. *Public Opin Q*. (1970) 34:159–70. doi: 10.1086/267786

21. Lyles CR, Wachter RM, Sarkar U. Focusing on digital health equity. *JAMA*. (2021) 326:1795–6. doi: 10.1001/jama.2021.18459

22. Scheerder A, van Deursen A, van Dijk J. Determinants of internet skills, uses and outcomes. A systematic review of the second- and third-level digital divide. *Telematics Inform*. (2017) 34:1607–24. doi: 10.1016/j.tele.2017.07.007

23. Jia X, Pang Y, Liu LS. Online health information seeking behavior: a systematic review. *Healthcare*. (2021) 9:1–15. doi: 10.3390/healthcare9121740

24. Robinson L, Schulz J, Blank G, Ragnedda M, Ono H, Hogan B, et al. Digital inequalities 2.0: legacy inequalities in the information age. *First Monday*. (2020):842. doi: 10.5210/fm.v25i7.10842

25. W3C Schema.org Community Group. Documentation for health/medical types. (2021). Available at: https://schema.org/docs/meddocs.html

26. Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2017 (GBD 2017) Cause, REI, and Location Hierarchies. Institute for Health Metrics and Evaluation (IHME). (2018). Available at: https://ghdx.healthdata.org/record/ihme-data/gbd-2017-cause-rei-and-location-hierarchies

27. Health On the Net Foundation. HONcode Principles. (2021). Available at: https://www.hon.ch/cgi-bin/HONcode/principles.pl?English

28. Blank G, Reisdorf BC. The participatory web. *Inf Commun Soc*. (2012) 15:537–54. doi: 10.1080/1369118x.2012.665935

29. Impicciatore P, Pandolfini C, Casella N, Bonati M. Reliability of health information for the public on the world wide web: systematic survey of advice on managing fever in children at home. *BMJ*. (1997) 314:1875–9. doi: 10.1136/bmj.314.7098.1875

30. Wardle C, Derakhshan H. Information disorder: Toward an interdisciplinary framework for research and policymaking 2ed. Council of Europe. (2017). Available at: https://rm.coe.int/information-disorder-toward-an-interdisciplinary-framework-for-researc/168076277c

31. UNESCO In: C Ireton and J Posetti, editors. Journalism, fake news & disinformation: Handbook for journalism education and training. France: UNESCO (2018) Available at: https://unesdoc.unesco.org/ark:/48223/pf0000265552

32. Martens B, et al. The digital transformation of news media and the rise of disinformation and fake news - an economic perspective; digital economy working paper 2018-02. European Commission, Joint Research Centre. (2018). JRC Technical Reports. Available at: https://joint-research-centre.ec.europa.eu/document/download/0843265e-f418-4b6e-94f7-61d2ba1cba1e_en?filename=jrc111529.pdf

33. Yalçınkaya ÜL. Information pollution in the post-truth era and the role of digital news editors: The case of Turkey - Master's thesis in Turkish. İstanbul, Türkiye: Galatasary University, Communication Sciences (2019).

34. Farkas J, Schou J. Fake news as a floating signifier: hegemony, antagonism and the politics of falsehood. *Javnost-the Public*. (2018) 25:298–314. doi: 10.1080/13183222.2018.1463047

35. Hootsuite & We Are Social. Digital (2021). Turkey. Available at: https://datareportal.com/reports/digital-2021-turkey

36. Stat Counter. Search Engine Market Share Turkey. (2021). Available at: https://gs.statcounter.com/search-engine-market-share/all/turkey

37. Graham M, Elias J. How Google's $150 billion advertising business works. *CNBC LLC*. (2021) Available at: https://cnb.cx/3eUElXG

38. eMarketer. UK Digital Ad Spending 2021. (2021). Available at: https://www.emarketer.com/content/uk-digital-ad-spending-2021.

39. Turkish Competition Authority. Competition Authority Started Work to Prepare "Digitalization and Competition Policy Report" (30.1.2020) - in Turkish. (2020). Available at: https://www.rekabet.gov.tr/tr/Guncel/rekabet-kurumu-dijitallesme-ve-rekabet-p-874d77d25943ea118119005056b1ce21

40. Advertisers Association (Turkey). Estimated Media and Advertising Investments in Turkey 2020 Report - in Turkish. (2021). Available at: http://rd.org.tr/Assets/uploads/1cc3c0b2-236d-4ada-9cbe-8a24420611c5.pdf

41. Official Gazette of the Republic of Türkiye. Digital Service Tax Application General Communiqué - in Turkish. (2020). Available at: https://www.resmigazete.gov.tr/eskiler/2020/03/20200320-4.htm

42. Republic of Türkiye Ministry of Treasury and Finance. Central Government Budget Statistics - in Turkish. (2021). Available at: https://muhasebat.hmb.gov.tr/merkezi-yonetim-butce-istatistikleri

43. Journalism Newman N., Media, and Technology Trends and Predictions. Reuters Institute for the Study of Journalism. (2021). Digital news project. Available at: https://reutersinstitute.politics.ox.ac.uk/sites/default/files/2021-01/Newman_Predictions_2021_FINAL.pdf

44. Cherubini F, Nielsen RK. Editorial analytics: how news media are developing and using audience data and metrics. *SSRN Electron J*. (2016). doi: 10.2139/ssrn.2739328

45. Kızılkaya E, Ütücü B. Türkiye Digital Media Report - in Turkish. International Press Institute. (2021). Available at: https://freeturkeyjournalists.ipi.media/wp-content/uploads/2021/03/TUR-IPI-Turkey-Digital-Media-Report-02032021-2nd-version.pdf

46. Shoemaker PJ, Reese SD. Mediating the message: Theories of influences on mass media content. *2nd* ed. Longman USA, NY: Longman Publishers USA (1996).

47. Ioannidis JPA. Neglecting major health problems and broadcasting minor, uncertain issues in lifestyle science. *JAMA*. (2019) 322:2069–70. doi: 10.1001/jama.2019.17576

48. Republic of Türkiye Legislation Information System. Law on establishment of the information technologies and communication authority no. 2813- in Turkish. (1983). Available at: https://www.mevzuat.gov.tr/MevzuatMetin/1.5.2813.pdf

49. Republic of Türkiye Legislation Information System. Law on regulating publications made on the internet and combating crimes committed through these

publications no. 5651- in Turkish. (2007). Available at: https://www.mevzuat.gov.tr/MevzuatMetin/1.5.5651.pdf

50. Republic of Türkiye Legislation Information System. Universal Service Law No. 5369- in Turkish. (2005). Available at: https://www.mevzuat.gov.tr/MevzuatMetin/1.5.5369.pdf

51. Republic of Türkiye Legislation Information System. Electronic Communications Law No. 5809- in Turkish. (2008). Available at: https://www.mevzuat.gov.tr/MevzuatMetin/1.5.5809.pdf

52. Republic of Türkiye Legislation Information System. Press Law No. 5187- in Turkish. (2004). Available at: https://www.mevzuat.gov.tr/MevzuatMetin/1.5.5187.pdf

53. Yalçınkaya ÜL. Information pollution in the post-truth era and the role of digital news editors: The case of Turkey-Master's thesis - in Turkish. Galatasaray Üniversitesi Sosyal Bilimler Enstitüsü İletişim Ana Bilim Dalı. (2019). Available at: https://tez.yok.gov.tr/UlusalTezMerkezi/TezGoster?key=FgmkGchPKo23qQqBeqzVZiMzd3fh6hOkBr7T71TL2aPMIp6ydCINh7AbLTxM-Cse

54. Republic of Türkiye Legislation Information System. Law on intellectual and artistic works no. 5846- in Turkish. (1951). Available at: https://www.mevzuat.gov.tr/MevzuatMetin/1.3.5846.pdf

55. Brown P. A global study of eyewitness media in online newspaper sites. Eyewitness Media Hub. (2015). Available at: http://eyewitnessmediahub.com/uploads/browser/files/Final%20Press%20Study%20-%20eyewitness%20media%20hub.pdf

56. Reporters Sans Frontières. World Press Freedom Index: Journalism, the vaccine against disinformation, blocked in more than 130 countries. (2021). Available at: https://rsf.org/en/2021-world-press-freedom-index-journalism-vaccine-against-disinformation-blocked-more-130-countries

57. Radu R. Fighting the 'Infodemic': legal responses to COVID-19 disinformation. *Social Media + Society*. (2020) 6:4819. doi: 10.1177/2056305120948190

58. Pomeranz JL, Schwid AR. Governmental actions to address COVID-19 misinformation. *J Public Health Policy*. (2021) 42:201–10. doi: 10.1057/s41271-020-00270-x

59. Republic of Türkiye Legislation Information System. Law on the proper practice of medicine and medicine arts - in Turkish. (1928). Available at: https://www.mevzuat.gov.tr/mevzuat?MevzuatNo=1219&MevzuatTur=1&MevzuatTertip=3

60. Turkish Medical Association. Code of Ethics for the Medical Profession - in Turkish. (1999). Available at: https://www.ttb.org.tr/mevzuat/index.php?option=com_content&id=65&Itemid=31

61. Turkish Medical Association. Guide on Sharing of Physicians and Health Institutions and Organizations in Electronic Environments - in Turkish. (2016). Available at: https://www.ttb.org.tr/mevzuat/index.php?option=com_content&view=article&id=1088:hekmler-le-salik-kurum-ve-kurulularinin-elektronk-ortamlardak-paylaimlarina-lkn-kilavuz&catid=26:etik&Itemid=65.

62. Turkish Medical Association. Turkish Medical Association Physician and Drug Promotion Principles - in Turkish. (1995). Available at: https://www.ttb.org.tr/mevzuat/index.php?option=com_content&view=article&id=658:hek-ve-atanitim-keler&catid=3:tebligenelge&Itemid=35.

63. Turkish Dental Association. Guide for Dentists to Broadcast in All Kinds of Communication Mediums - in Turkish. (2011). Available at: http://www.tdb.org.tr/mevzuat_goster.php?Id=30

64. Republic of Türkiye Legislation Information System. Disciplinary Regulation of the Turkish Dental Association and Chambers of Dentists - in Turkish. (1991). Available at: https://www.mevzuat.gov.tr/mevzuat?MevzuatNo=8106&MevzuatTur=7&MevzuatTertip=5

65. Official Gazette of the Republic of Türkiye. Regulation on Promotion and Information Activities in Health Services - in Turkish. (2023). Available at: https://www.resmigazete.gov.tr/eskiler/2023/07/20230729-29.htm

66. Sezgin D. Medicalized life, individualized health: contradictions, alternatives and health communication - in Turkish. Ayrıntı. (2011). 579.

67. Ayaz F. Commercial factors affecting heath related contents - PhD Thesis - in Turkish. Anadolu Üniversitesi Sosyal Bilimler Enstitüsü Basın ve Yayın Anabilim Dalı. (2019). Available at: https://tez.yok.gov.tr/UlusalTezMerkezi/TezGoster?key=4J_FzTwlrMCH4qBROpXPHyZTgXp8we-9sH2154DmaTZ8g4_RU9YbH7wwP3mc0ru4

68. Kanlı Y, Şener K. Media Monitoring Report. Journalists Association Press House, Ankara, Türkiye. (2021). Available at: https://media4democracy.org/public/uploads/reports_5835411.pdf

69. Coşkun I, Şahin Ü. TGS Press Freedom Report (2020-2021). Journalists' Union of Turkey (TGS), Ankara, Türkiye. (2021). Eds. İlyas Coşkun, Ülkü Şahin. Available at: https://tgs.org.tr/wp-content/uploads/2021/05/2020-2021-BASIN-%C3%96ZG%C3%9CRL%C3%9C%C4%9E%C3%9C-RAPORU.pdf

70. Media and Law Studies Association. End of the news: Internet censorship in Turkey - in Turkish. (2021). Available at: https://static.bianet.org/system/uploads/1/files/attachments/000/003/278/original/Free-Web-Turkey-2020-rapor.pdf?1611134449.

71. Freedom House. Freedom on wthe Net 2020: The Pandemic's Digital Shadow. (2021). Available at: https://freedomhouse.org/tr/country/turkey/freedom-net/2020

72. European Commission. Commission Staff Working Document - Turkey 2020 Report - in Turkish. (2020). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Available at: https://www.ab.gov.tr/siteimages/trkiye_raporustrateji_belgesi_2020/turkey_report_30.10.2020.pdf

73. Ghebreyesus TA. Munich security conference. Munich: World Health Organization (2020).

74. World Health Organization. An *ad hoc* WHO technical consultation managing the COVID-19 infodemic: call for action. (2020). Available at: https://iris.who.int/bitstream/handle/10665/334287/9789240010314-eng.pdf?sequence=1

75. Mahajan A, Czerniak C, Lamichhane J, Phuong L, Purnat T, Nguyen T, et al. WHO public Health Research agenda for managing Infodemics. *Eur J Pub Health*. (2021) 31:30. doi: 10.1093/eurpub/ckab164.030

76. Purnat TD, Wilson H, Nguyen T, Briand S. EARS-A WHO platform for AI-supported real-time online social listening of COVID-19 conversations. *Stud Health Technol Inform*. (2021) 281:1009–10. doi: 10.3233/SHTI210330

77. European Commission. Code of Practice on Disinformation. (2018). Available at: https://digital-strategy.ec.europa.eu/en/library/2018-code-practice-disinformation

78. European Commission. COVID-19 disinformation monitoring programme. (2020). Available at: https://digital-strategy.ec.europa.eu/en/policies/covid-19-disinformation-monitoring

79. Madiega AT, Franciosi M. Digital services act: application timeline. European Parliamentary Research Service. (2022). Available at: https://www.europarl.europa.eu/RegData/etudes/ATAG/2022/739227/EPRS-AaG-739227-DSA-Application-timeline-FINAL.pdf

80. European Commission. European Digital Media Observatory (EDMO). (2021). Available at: https://digital-strategy.ec.europa.eu/en/policies/european-digital-media-observatory

81. Oymak H. The Provisions of Law No. 7418- Amending the Press Law and Other Laws, Known by the Public as the 'Disinformation Law' - in Turkish. (2022). New Media. Available at: https://dergipark.org.tr/tr/download/article-file/2860682

82. Bontcheva K, Posetti J In: K Bontcheva, J Posetti, D Teyssou, T Meyer, S Gregory and C Hanotet al, editors. Balancing act: Countering digital disinformation while respecting freedom of expression. France: International Telecommunication Union & UNESCO (2020). Available at: https://unesdoc.unesco.org/ark:/48223/pf0000379015

83. Amnesty International. Amnesty International Public Statement: Türkiye's disinformation law tightens government control and curtails freedom of expression. (2022). Available at: https://www.amnesty.org/en/documents/eur44/6143/2022/en/

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 24 October 2024
DOI 10.3389/fpubh.2024.1404587

OPEN ACCESS

EDITED BY
Fatjona Kamberi,
University of Vlorë, Albania

REVIEWED BY
Julak Lee,
Chung-Ang University, Republic of Korea
Chen Li,
Shanghai University of Engineering Sciences, China

*CORRESPONDENCE
Qiangqiang Dong
✉ dqq_joyce@163.com

RECEIVED 21 March 2024
ACCEPTED 03 October 2024
PUBLISHED 24 October 2024

CITATION
Liu T, Hu X and Dong Q (2024) Generation paths of online public opinion impact in public health emergency: a fuzzy-set qualitative comparative analysis based on Chinese data.
Front. Public Health 12:1404587.
doi: 10.3389/fpubh.2024.1404587

Generation paths of online public opinion impact in public health emergency: a fuzzy-set qualitative comparative analysis based on Chinese data

Teng Liu[1], Xiangming Hu[2] and Qiangqiang Dong[3]*

[1]Tourism College, Hainan Normal University, Haikou, Hainan, China, [2]School of Public Administration, Beihang University, Beijing, China, [3]School of Marxism, Zaozhuang University, Zaozhuang, Shandong, China

Public health emergencies can quickly provoke alarm and shock in the society, as well as generate high-impact online public opinion through network fermentation. Analyzing the generation mechanism of online public opinion in public health emergencies helps to explain its characteristics and laws. Based on information ecology theory, seven indicators from the four dimensions of information person, information, information technology, and information environment are extracted, and the analysis framework of public opinion impact of public health emergencies is constructed. Taking 40 cases from China as samples, fuzzy set qualitative comparative analysis (fsQCA) is used to investigate the generation path and mechanism of online public opinion impact in public health emergency. The results suggest that: information person and information technology are the core conditions for the generation of high-impact online public opinion, but the harm level contained in the information itself is not sensitive to the generation of public opinion impact; there are four generation paths and three types that drive the generation of high-impact online public opinion in public health emergencies. This work enriches the cognition of the causality of public opinion impact in public health emergencies from the perspective of configuration, and clearly shows which combination of variables leads to high-impact online public opinion, and helps to prevent and reduce the risk of public opinion.

KEYWORDS

online public opinion, public health emergencies, generation mechanism, QCA, public opinion risk

1 Introduction

With the popularity of the internet and the expansion scale of internet users, the key role of online public opinion for the development of human society has been strengthened. According to the 50th China Statistical Report on Internet Development published by China Internet Network Information Center (CNNIC), up to June 2023, China had 1.079 billion internet users, and the internet penetration rate has reached 76.4%. The Internet brings scattered people together, which makes huge changes in the way of information dissemination. The trend of decentralization of online information dissemination is becoming obvious, while the dominant role of traditional media in public opinion is gradually declining. The new media based on the internet has become a new carrier of public opinion, represented by social media, live streaming and short video platforms. Compared to the traditional media, which has poor public opinion expression and low participation, the new media has become the public domain of public opinion expression because of its low communication threshold, fast speed and wide

range (1). The public space, which can form public opinions, allows free communication and debate, has emerged (2).

In the internet age, online public opinion covers all aspects of our lives. While according to the content of public opinion, it can be divided into positive and negative public opinion (3). Several studies question the effectiveness of public opinion. As the main body of public opinion, people are easily guided and confused by elite groups and opinion leaders, together with the obscurity and complexity of public opinion itself, which all harm the objectivity and authenticity of public opinion (4). On the contrary, public opinion is not useless, some rational cognition and judgment of the public can be formed through limited information. The goal of environmental governance by online public opinion is to create positive public opinion and remove negative public opinion, so that online public opinion environment is presenting in a new form (5), and there are still many challenges and problems associated with building an online public opinion environment. If the online public opinion is not reasonably managed and evacuated, it may hurt society and the internet environment. Given the dual influence of online public opinion, this paper examined the dominant factors influencing online public opinion and how to prevent and reduce public opinion risk.

Moreover, contemporary society has entered the risk society. As risk disasters accompany the process of human society, the western theoretical community has started to study risky societies at an early stage, and has developed a relatively sound theoretical system (6). Unfortunately, the risk society is further deepened by public health emergencies, public health diseases have been a major threat to human health development, but along with the entire human history process. In recent years, major public health emergencies such as SARS, monkeypox, avian influenza, H1N1, Ebola, Zika, and other have occurred frequently, the outbreak of COVID-19 is particularly serious (7). Unlike other types of emergencies, public health emergencies are unpredictable, rapidly spreading and socially threatening, with no fixed population, easy-to-occur areas and ways of occurrence, which aggravate social risks, and the superposition of online public opinion risks and social risks triggered by network communication, which in turn derives new risks (8). The risk amplification effect of the internet has been dramatically accentuated, and it is not uncommon for individual cases and regional events to ferment into national or even global public opinion events. As it involves the life safety and physical health of every member of the public, information related to epidemics will quickly dominate the hot searches on the internet platform, triggering public attention and discussion. As a new social power and public opinion space, internet platform has become a platform and carrier for the public to express their views on specific events. Especially when public health emergencies occur, a large amount of true and false public opinion information emerges instantly and geometrically fissions, forming group polarization phenomenon, and even triggering secondary public opinion and offline group events, which poses a serious threat to social harmony and stability (9).

Online public opinion is a recurring theme in academic research (10), with the research exploring the impact of different factors on online public opinion. Our study attempts to answer the following research questions: (1) what factors are primarily responsible for the impact of online public opinion in public health emergency? (2) What is the generation paths of high-impact online public opinion? (3) What are the unique characteristics of the evolution of online public opinion influence? and (4) How to prevent and reduce the risk of public opinion? To address these issues, in the context of frequent public health emergencies as well as the downward shift of the focus of information dissemination in the era of new media, where the public and the mass media play a dominate role in the cognition and discussion of social issues, this study explores the influence factors of high-impact online public opinion. Qualitative comparative analysis (QCA) is employed in the study, the essence of this analysis method is to detect the configuration of causal conditions that lead to results of interest, and QCA offers an appropriate way to check which configurations of conditions best explain the generation of high-impact online public opinion, so that follow-up questions can be carried out. Specifically, we collected and adopted data from China internet social hot spot aggregation platform, using 40 typical public health emergencies as samples, we extract the four dimensions of information person, information, information technology and information environment, analyze seven driving factors, including internet users' attention (IA), opinion leader dissemination (OD), government intervention (GI), hazard level (HL), network platform participation (NP), the government public opinion evacuation environment (EE), and the social opinion environment (SE), all of which shape the generation mechanism of online public opinion impact in public health emergency. According to the information ecology theory, the generation public opinion influence is systematic and complex. When the factors are combined with each other, we determine four different combinations to obtain the generation of high-impact public opinion. Our research results can better reflect the generation path of high-impact online public opinion in public health emergency than previous research results, and provide targeted suggestions for preventing and reducing the risk of public opinion.

Our study offers several contributions. First, we provide a targeted analysis of the special event of public health emergencies, which is a special field of emergencies. Public health emergencies and public emergencies, which are different in nature and characteristics, and thus the public opinions generated are also different. Second, we identify multiple influencing factors for the high-impact online public opinion of public health emergencies, expanding the scope of application of online public opinion research. Third, we demonstrate the configuration solutions between the interactions of the influencing factors of online public opinion, which is more suitable for preventing and reducing the risk of public opinion in the complex online public opinion environment, and thus maintaining a rational communication order.

2 Theoretical framework

2.1 Online public opinion

For Online public opinion is the sum of values and emotional tendencies expressed by the public through the Internet, which reflects the focus of public opinion and social situation. The pressure of public opinion is an important part that the government need to consider in order to avoid conflicts and obtain public support (11). Online public opinion dissemination system is a complex system based on causality. To demonstrate the generation mechanism of online public opinion dissemination, it needs to make effective subdivision of the influencing factors of online public opinion dissemination, to parse the complex system causality by analyzing

the internal dynamic connection. Internet users, media, and government are the three main bodies of online public opinion dissemination system (12). Specifically, the participation of internet users and opinion leaders, the number of media audiences, the frequency of media reports, government attention, crisis warning mechanism, and other factors have an important impact on the online public opinion dissemination (13). In addition, response time, responsiveness, and government transparency also have an impact on public sentiment and public opinion dissemination in emergency situations (14).

Emergency online public opinion dissemination system is influenced by multiple and complex factors in social systems. Existing studies have analyzed the internal and external influencing factors of online public opinion, which provide us with profound understanding. However, there is a lack of research in public health opinion of public health emergency, and the interaction and combination of influence factors are relatively insufficient.

2.2 Information ecology theory

Online public opinion dissemination systems are often regarded as complex information ecosystems (15). Information ecology theory lays a good theoretical foundation for the study of multiple influencing factors of online public opinion dissemination from a holistic perspective. The concept of information ecology is the integration of ecology and informatics, it was originally used to investigate the flow of information in the organizations, where information did not operate independently but was affected by the system ecology. Information ecology is the science of studying the law of information, when studying the interaction of many different phenomena, it is necessary to analyze problems with a systematic view (16). A new information ecology theory has been further developed, which defines information ecology as a specific environmental system composed of people, practice, values, and technologies, and states that the focus of information ecosystem is not technology itself, but people (17). Moreover, there are strong interrelationships and dependencies among the different parts of information ecosystems, technologies, actors, environments and value orientations work together to constitute a complex system (18).

It is generally acknowledged by the academic community that information ecology theory is based on information ecosystems as research objects to analyze the interaction relationship of various elements within a system (19). To understand which configuration solutions have greater impact on online public opinion, a unified framework is needed, which incorporates multiple elements and specific environmental conditions. For this, the theoretical framework of information ecology is used to master the internal law of the development of information environment, deconstruct the dynamic changes of human social information environment, and make the information environment, especially the public opinion environment develop in a beneficial direction to human beings. Since information ecology theory is a broad concept, it integrates information person as subjects, while information, information technology and information environment as objects into a systematic visual threshold, each component of it needs to be excavated more deeply, which has its own established literature.

2.2.1 Information person

Based on the perspective of information person factor in the information ecology theory, exploring highly complex human behaviors and analyzing user behavior laws are the core topics of research on emergency online public opinion dissemination (20). The information person factor is the subject of public opinion and the important component of the information ecosystem, which are people or organizations that express cognition, emotions, attitudes, opinions, statements and other remarks in cyberspace, mainly including internet users, network opinion leaders and government. Information person can interact with each other.

In the process of online public opinion dissemination in public health emergencies, internet users receive public opinion information and express their perceptions and attitudes toward the events in the internet, with the dual identities of information receivers and information disseminators. In the new media environment, internet users have become the largest and most active group in the network system. In the process of information exchange of online public opinion, internet users will resonate and converge as a group force due to the existence of cluster mentality, and directly drive the dissemination of online public opinion through comments, likes and retweets. Research shows that the active degree of internet users shows a positive correlation with the impact of online public opinion, and their attention to public opinion events is the main group force driving the spread of online public opinion and forming high-impact online public opinion (21). Therefore, the activity of internet users has an important driving role in the dissemination of online public opinion in public health emergencies.

Network opinion leaders, as active members who often provide information and exert influence on others in interpersonal communication networks, have a relatively stable and large information audience, occupy the accurate push resources of online platforms based on technical algorithms, and have a strong influence on the trend and speed of online public opinion dissemination. The speech and activeness of this group influence the generation of online public opinions and the dissemination of public opinion information, and play an aggravating and guiding role in the generation and dissemination of online public opinion in public health emergencies (22).

The government regulates and controls the development of online public opinion, as well as the information released by official media consisting of government units, central media and other authoritative institutions. Based on the trust of the government and the authority of the governance subject of social risk events, information with extensive credibility is released. Its strong dissemination and influence can squeeze out the space for deviant information, resolve public opinion crises in accordance with the law, reduce negative impacts, correct public opinion information, and orderly guide the promotion of a healthy public opinion ecosystem. It has been pointed out that timely and effective intervention and public voice of relevant departments can calm down negative social emotions and have a positive effect on public opinion mitigation (23).

2.2.2 Information

As the ontology of public opinion, information is the sum of attitudes and emotions expressed by the participants of public opinion on hot topics, which is the root cause of public opinion. Lippmann pointed out that public opinion is developed from

public interest, and whether the information and content of public opinion can arouse users' interest is an important factor influencing their communication behavior. In addition, the degree of disclosure and credibility of information about an event also has an important influence on the development of public opinion (24).

Public health emergency has a real impact on public life safety and health, and the relevant information is very likely to mobilize public attention and generate online buzz. The outbreak of emotions, attitudes and intentions generated by high attention and online discussions constitutes a necessary condition for the generation of online public opinion events (25). With the advantages of high timeliness, interactivity and flatness, internet information has become the important way for the public to obtain information about public health emergency, while its instantaneous, individualized, and fragmented characteristics easily lead to distortion of the information carried, and in order to increase the heat and traffic, the importance and harm of public health events are expanded or one-sidedly disseminated, thus further causing amplification of risk communication and biased public perception (26). The information factors such as the hazard level contained in the information of public health emergency will become the focus of attention of online public opinion dissemination and the key elements of information text interpretation, coding and construction in the process of generation.

2.2.3 Information technology

Information technology mainly refers to online media. Over the past decade, online media such as Twitter, Facebook, Microblog, TikTok, and WeChat have gradually become integrated into people's lives and gradually blurred the boundaries of human society, and emergencies have accelerated this phenomenon. Not only internet users, but also more and more news media and government organizations are using social media for their work.

The participation of online media catalyzes the development of online public opinion. Online media reports on hot social events, realizing the dissemination of public opinion information in multiple directions, at multiple levels, and in many aspects, builds an information cultivation soil and amplification station for the dissemination of public health emergencies. Online public opinion information has become a sensitive tentacle for perceiving social and public opinion, and online media has become a platform for two-way communication and timely feedback in public health emergency (27).

In public health emergency, due to the lag of government response to disposal and information disclosure, the public generates various doubts and speculations, which will express tendentious emotions, opinions and remarks on online media platforms for concerns and exert certain influences. Driven by the interest chain of heat, traffic, fan increase and cash, online media platforms pursue the "signal value" brought by the high-impact public opinion and the event itself, and use platform resources to fatten up and add material to further promote the influence of public opinion on the event. Online media platforms are not only the petri dish for the influence of online public opinion in public health emergency, but also the weathervane for the influence of public opinion based on the feedback of public opinion information, and the number of network platforms reporting on the event can be used as a barometer for the influence of public opinion (28).

2.2.4 Information environment

Information environment, it mainly refers to the public opinion environment, which is the external environment and space for the dissemination of online public opinion. In public health emergency, it mainly includes the public opinion evacuation environment constructed by information environment control subjects and the social opinion environment naturally formed by public opinion. Government authorities, online media platforms, health and medical research institutions and public health professionals constitute the control subjects of information environment, among which government authorities occupy the core position of control subjects (29).

External intervention in the dissemination and development of public opinion is mainly carried out by the government through organizing official central media to release information, online media platforms to restrict negative and false statements, health and medical research institutions, together with public health professionals to popularize public health and safety knowledge (30, 31), which are the exogenous driving force for the evolution, development and resolution of public opinion. The specific countermeasures and strength of the government's public opinion evacuation have significant influence on the formation of the public opinion evacuation environment. The public opinion environment can reflect the development trend of public opinion, the attention degree of information subjects to public opinion information, the duration of public opinion and the influence of public opinion events, and it is the endogenous driving force for the evolution and development of public opinion. During the duration of public opinion, the amount of information related to public opinion can reflect the influence of public opinion environment on the information subject.

2.3 Analytical framework

Accordingly, on the basis of the previous theoretical discussion, this paper firstly identifies the preconditions for the generation of online public opinion from the perspective of system and based on the theoretical framework of information ecosystem, with information person (public opinion subject), information (public opinion ontology), information technology (public opinion platform), and information environment (public opinion environment) as the four analytical dimensions, and extracts seven preconditions affecting online public opinion in public health emergencies: internet users' attention (IA), opinion leader dissemination (OD), and government intervention (GI) correspond to the degree of information person's attention, the hazard level (HL) of public health emergencies corresponds to the content elements embedded in the information, network platform participation (NP) corresponds to information technology, and the government public opinion evacuation environment (EE) and the social opinion environment (SE) correspond to the information environment. Meanwhile, the outcome variable is online public opinion impact generation.

This paper focuses on the cognition of the causality of the generation of high-impact public opinion and not high-impact public opinion, emphasizes the interaction and combination of factors in the system, and studies how the factors can jointly drive the generation of high-impact online public opinion of public health emergencies through configuration solutions. In summary, the analytical framework of this paper is constructed, as shown in Figure 1.

3 Materials and methods

3.1 Sample

Due to the large number of users of Twitter, Facebook, Microblog, TikTok, WeChat, and other online media, these online media are often used by the public to spread public opinion on emergencies. Current research is increasingly focused on obtaining information on public opinion, attitudes, and key factors related to various research subjects through various online media. Several studies have shown that to analysis of tweets and images about Zika virus in Twitter and Instagram to study the dissemination of public opinion information, it can be found that news media, public health agencies and internet users are the most obvious and frequent sources and disseminators (32). Some studies have also examined the public opinion information dissemination behavior through Microblog message posting, commenting and retweeting data (33).

Microblog and WeChat are the widely used online media platforms in China (34–36), its data has become a popular source of academic research, providing researchers with rich materials and in-depth insights. According to the financial report released by Tencent Holdings and Sina Microblog, by the end of December 2023, the combined monthly active accounts of WeChat and WeChat international numbered 1.343 billion, while Microblog had 598 million monthly active users. Therefore, researchers can obtain high-quality raw data, and aggregated user opinions can reflect the online public opinion of an event. Due to the wide impact of public health emergencies, individuals do not have the ability to collect all the data from the Internet and data analysis platforms, so the Zhiwei data analysis platform is used as an event impact index analysis tool (37). Zhiwei Data are one of the most commonly used Internet hotspot aggregation platforms in China. Compared with data analysis platforms such as China Percent Technology and Qingbo Big Data, Zhiwei Data is a specialized analysis tool for popular events on the Internet, especially good at building a complete ecology of discovery, tracking, mining and prediction of social hotspot events based on massive Internet data, which is applicable to individuals, enterprises and governments. The main data sources of Zhiwei Data Analytics Platform are microblogs, WeChat and online media. The event influence index is calculated by adding up the event impacts in the self-media (mainly Weibo and WeChat) and online media, and then normalizing the event impacts to get an event impact index ranging from 0 to 100. Individuals can filter public health emergencies according to the keywords of the event, and can query the main media that released the information, the trend of the proportion of the public opinion field, the speed of dissemination of the event, the duration of the event, and other public opinion field data, which can form an effective evaluation criterion of the influence of the event and conduct comparative analysis of similar events. The 79th executive meeting of the State Council of China adopted the Overall Emergency Plan for National Public Emergencies, which was promulgated and implemented on January 8, 2006. It is clearly pointed out that public health incidents mainly include the epidemic situation of infectious diseases epidemic, mass diseases of unknown causes, food safety and occupational poisonings, animal epidemics, and other incidents that seriously affect public health and life safety. In this study, the high-impact public health emergencies in the database of Zhiwei data platform from 2016 to 2023 as the basic case base, and the cases were cross-validated and supplemented by CNKI, Baidu index, and Microblog, Ant Square software, etc. In order to reflect the principle of influence, typicality and diversity of cases, four cases of the same subspecies of avian influenza outbreak were deleted, one case of

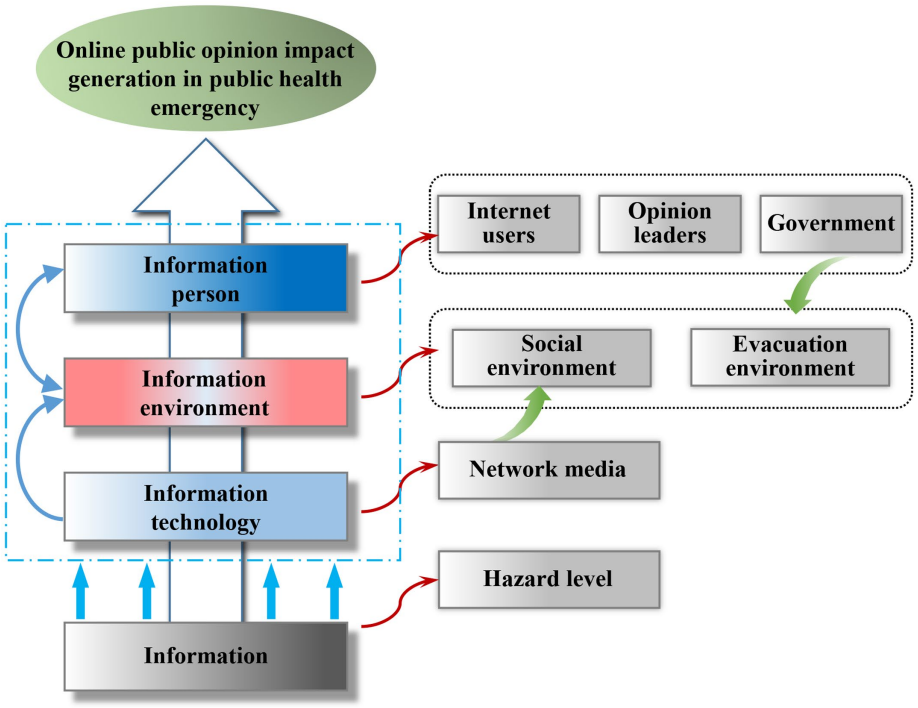


FIGURE 1
Analytical framework of the configuration online public opinion impact in public health emergency.

norovirus related cases with similar time but different regions was deleted, and three cases of food poisoning in the basic case database were added (food poisoning of 100 employees of a furniture factory in Shanghai, vomiting and diarrhea in a community in Shenyang, and Suspected food poisoning occurred in a snack bar in Guangdong), as well as one environmental pollution incident (40,000 mu of fish and crabs died in Hongze Lake), one case of occupational and chemical poisoning incident (brucella infections at two veterinary research institutes under the CAAS). Finally, 40 typical events were finally selected as the research objects, including six cases of infectious disease epidemic, two cases of unknown-cause disease, nine cases of animal epidemics, 10 cases of food safety, four cases of occupational and chemical poisoning, and nine cases of drag safety and pollution, as shown in Table 1.

3.2 Methods

Qualitative comparative analysis (QCA) is a configuration method based on set theory and fuzzy theory (38), which is particularly suitable for studying complex causality and multiple interactions (39). The generation of online public opinion impact in public health emergencies is influenced by the coupling effect of multiple complex factors, which is suitable for the QCA method. First, QCA can identify whether a single condition is necessary to achieve an outcome. Second, it can explore multiple sufficiency configurations associated with the same outcome, a situation called equilibrium, where a system can reach the same final state through different initial conditions and a variety of different paths. Third, QCA can check for causal asymmetry for high and not-high performance.

Qualitative comparative analysis is based on Boolean logic, mainly studying necessary conditions and sufficient conditions. In detail, necessary conditions are those that are present in all cases of outcome, and sufficient conditions are those that always produce a certain outcome when present (40). QCA results are interpreted according to consistency and coverage. Consistency refers to the extent to which similar causal configurations lead to outcomes, while coverage refers to the number of cases valid for a given combination. We show our results by the conventional notations: core conditions are present ● or absent ⊗, peripheral conditions are present ● or absent ⊗, and a blank space indicates that the condition is irrelevant whether it is presence or absence (41). Core conditions are those present in both parsimonious solutions and corresponding intermediate solutions. Peripheral conditions are those present intermediate solutions, but not in parsimonious solutions (42). Fuzzy-set QCA (fsQCA), unlike the crispy-set QCA (csQCA), and the multi-valued QCA (mvQCA), uses membership degree assignment, which improves the research quality. CSQCA can only handle two-point variables. Although mvQCA expands the scope of dichotomy to a certain extent, it is still based on deterministic multivalued sets rather than continuous fuzzy sets. FSQCA is more case-oriented and able to explain the causal factors in more detail. Therefore, we apply the fsQCA in study.

3.3 Measures for set membership

Too many variables will lead to individualization of cases, and the number of cases identified needs to form a well-balanced relationship with the condition variables. QCA technology could be suitable not limited to handle data from small and medium samples, and it has also been widely applied in research designs with large sample sizes (41). The sample size of our study belongs to the medium-sized sample, which is suitable for analysis by QCA method. A medium-sized sample means that the external validity of the case can be guaranteed, and the depth of the case and its uniqueness can also be retained. For a medium-sized sample, the usual selection of condition variables is 4–6 or 4–7 (43). Therefore, we determine that the seven condition variables met the requirements. The settings and measurement descriptions of the condition variables and outcome variables are shown in Table 2.

3.4 Calibrations for set membership

Calibration is the process of transforming into set membership, the variables must be calibrated to generate values from 0 to 1 before using fsQCA for analysis. There are three methods to determine which qualitative anchors to use for scale measures, the first calibration method is to obtain substantial knowledge from pre-validated scale anchor points as the threshold values, the second relies on sample maximum, mean or midpoint, and minimum values when partial knowledge is available, and the third is to use the percentile of the sample without explicit theory and external knowledge as a guide (44).

Since there is a recognized basis and standard for classifying the hazard level of public health emergencies, the first calibration method can be used. Specifically, we use the four-value fuzzy set calibration method, which uses four calibration values of 1, 0.67, 0.33, and 0 to refer to "full in," "more in than out," "more out than in," and "full out," respectively. In the event hazard level, extremely significant (level I) is assigned a value of 1, significant (level II) is assigned a value of 0.67, large (level III) is assigned a value of 0.33, and general (level IV) is assigned a value of 0. For other variables, there is no explicit theory or external knowledge available, so the third method mentioned above can be used. Based on the data of the cases themselves, qualitative anchors representing three important threshold ranges of full in, crossover point, and full out are selected for calibration. The three qualitative anchors are taken from the upper and lower quartiles of the case data, which are the upper quartile, the median, and the lower quartile. Specifically, the three anchors of the variables, except for the calibrated hazard level, are set as fully in (75%), crossover point (50%), and fully out (25%). In addition, when a case has a membership score of exactly 0.5, it is usually recalibrated each set by adding a small constant (0.001) (41). When cases arise where the affiliation score is exactly 0.5 and cannot be categorized, the categorization is usually adjusted by adding 0.001 to the affiliation score. The calibration anchors for each fuzzy set, and descriptive statistics are shown in Table 3.

4 Results

4.1 Necessity conditions analysis

When a factor is always present when an outcome occurs, this factor is called a necessary condition for this outcome, from which the core conditions leading to the outcome can be initially determined. The impact factors of online public opinion generation in public health emergencies are mainly to analyze the necessity of condition variables and to examine consistency and coverage, consistency greater than 0.9 can be regarded as a necessary condition for an event

10.3389/fpubh.2024.1404587

TABLE 1 Typical cases of public health emergencies.

No.	Year	Case	Type	Influence Index(II)	No.	Year	Case	Type	Influence Index (II)
1	2019	COVID-19 in Wuhan and other places	UD	100	21	2016	Formaldehyde poisoning of all junior students in a school in Jilin	OC	68.5
2	2018	Changsheng Biological Vaccine Fraud Incident	DP	94.1	22	2018	Multiple children vaccinated with expired vaccines in Shanxi	DP	68.3
3	2016	Unfrozen vaccines flow into 18 provinces	DP	86	23	2020	Bayan Nur confirmed a case of glandular plague	AE	68.1
4	2023	The rat head and duck neck incident in Jiangxi Industry Polytechnic College	FS	85.9	24	2021	Seven deaths due to harmful gas leakage from a food factory in Sichuan	OC	66.9
5	2020	Fake milk powder caused the reappearance of large-headed children	FS	82.2	25	2020	H5N1 avian influenza outbreak in Hunan	AE	66.6
6	2018	Pig, cattle and sheep epidemic outbreak in many places	AE	81.2	26	2019	Norovirus infection in Chaoyang District, Beijing	ID	65.6
7	2022	Pickled Chinese sauerkraut in dirt pits incidents	FS	80.2	27	2019	A patient diagnosed with glandular plague in Xilingole Meng	AE	65.5
8	2019	A school in Chengdu gave students moldy food caused discomfort	FS	78.6	28	2021	Anthrax deaths occurred in Shandong Province	ID	63.8
9	2016	Students' abnormal health caused by the relocation of a middle school in Jiangsu	OC	76.2	29	2019	Sichuan children suspected of receiving expired vaccines	DP	63.2
10	2020	Heilongjiang "sour soup" poisoning incident	FS	75.1	30	2018	Food poisoning in a hotel in Guilin	FS	62.3
11	2019	11 enterprises suspected of detecting African swine fever	AE	73.9	31	2022	Henan confirmed 1 person infected with H3N8 avian influenza	AE	61.8

(Continued)

TABLE 1 (Continued)

No.	Year	Case	Type	Influence Index(II)	No.	Year	Case	Type	Influence Index (II)
12	2019	A hospital in Hainan has been reported to sell fake HPV vaccines	DP	73.7	32	2018	Nearly 40,000 mu of fish and crabs died in Hongze Lake	DP	61.7
13	2019	145 children in Jiangsu province received oral expired vaccine	DP	72.9	33	2019	Brucella infections at two veterinary research institutes under the CAAS	OC	61.4
14	2021	Clenbuterol mutton appeared in Hebei province	FS	72.1	34	2019	Beijing confirmed 1 person infected with H5N6 avian influenza	AE	61.2
15	2023	Rice with essence event	FS	71.6	35	2020	H5N6 avian influenza outbreak in Xichong, Sichuan	AE	57.4
16	2019	The vaccine of a community health center was replaced by low-cost vaccine	DP	69.9	36	2019	Tianjin University of Technology students infected with norovirus	ID	57.3
17	2022	BYD factory is accused of pollution causing nosebleed of many children	DP	69.5	37	2018	African swine fever has been confirmed in Jizhou, Tianjin,	AE	57
18	2019	Tuberculosis epidemic in Taojiang, Hunan	ID	69.4	38	2020	Suspected food poisoning occurred in a snack bar in Guangdong	FS	48.6
19	2017	H3 influenza outbreak in Hong Kong	ID	69.3	39	2019	300 people vomiting and diarrhea in a community in Shenyang	UD	39.2
20	2016	The second case of Zhaika virus infection confirmed in China	ID	68.5	40	2016	Food poisoning of 100 employees of a furniture factory in Shanghai	FS	28.1

ID, Infectious diseases epidemic; UD, Unknown-cause disease; AE, Animal epidemic; FS, Food safety; OC, Occupational and chemical poisoning; DP, Drug safety and pollution.

to occur. Coverage is mainly used to determine the degree to which a conditional variable can interpret the outcome variable, and a larger value means a stronger explanation of the conditional variables. Table 4 presents the results of this analysis.

We can see from the Table 4 that when the outcome variable is set to "public opinion impact generation," the consistency of OD reaches 0.971, indicating higher opinion leader dissemination is a necessary condition for the generation of public opinion influence in public health emergencies. At the same time, the coverage of OD reached 0.961, indicating that 96.1% of public health emergencies had the intervention and impact of dissemination of opinion leaders. In addition, the consistency of IA, GI and NP is 0.845, 0.821, and 0.895, respectively, which exceeds 0.8. All of them can be regarded as sufficient conditions for the generation of high-impact online public opinion in public health emergencies. From the necessity test of a single variable, we can find that IA, OD, GI, and NP can independently trigger the

10.3389/fpubh.2024.1404587

TABLE 2 Measurement descriptions for sets.

Type	Sets		Measurement descriptions
Condition variables	Information person	Internet users' attention (IA)	Average speed of information dissemination during events
		Opinion leader dissemination (OD)	The total number of fans of the top five Microblog bloggers involved in the event discussion
	Information	Government intervention (GI)	The proportion of participating central media in all media
		Hazard level (HL)	Classified according to the "Emergency Plan for Public Health Emergencies" and the Law of "China on Prevention and Control of Infectious Diseases"
	Information technology	Network platform participation (NP)	The number of online media platforms for reporting
	Information environment	Evacuation environment (EE)	Refers to the government's efforts to alleviate public opinion, represent sum of products of government feedback department level, feedback channels and times $Q = \sum L_i C_j N_K$ ($i = 1,2...5$; $j = 1,2...5$; $k = 1,2...n$)
		Social opinion environment (SE)	Number of Baidu related web pages during the duration of public opinion (Baidu Index)
Outcome variable	Online public opinion impact generation (II)		The total cumulative dissemination effect of the case in the media, which can be reflected by the influence index

Q refers to the government's efforts to alleviate public opinion; L_i means government feedback department level, L_1 (the central leadership or State Council) = 4, L_2 (the national level) = 3, L_3 (the provincial level) = 2, L_4 (the city level) = 1, L_5 (the county level) = 0.5; C_j means feedback channel, C_1 (special meetings) = 4, C_2 (press conferences) = 3, C_3 (official media) = 2, C_4 (competent leaders or department core experts) = 1, and C_5 (relevant experts' report) = 0.5; N_K means times.

generation of high-impact online public opinion, which shows that information person and information technology have a significant impact on the generation of high influence of online public opinion.

When the outcome variable is set to "~public opinion impact generation," the consistency of ~IA, ~ OD and ~ NP is higher than 0.9, which are all necessary conditions for the generation of not high-impact online public opinion in public health emergencies and have stronger explanatory power. Besides, the consistency of ~GI and ~ HL is greater than 0.8, which is a sufficient condition for the generation of not high-impact online public opinion. According to the information ecology theory, the generation of online public opinion impact is systematic and complex, and the synergistic influence of various factors such as information person, information, information technology and information environment needs to be further analyzed.

4.2 Sufficiency analysis for online public opinion

We use fsQCA3.0 software to deal with the standardized data, construct the truth table and conduct a sufficiency analysis. QCA analysis usually provides three solutions: complex solution, parsimonious solution and intermediate solution. The intermediate solution is often considered to be the preferred solution because its complexity is moderate and reasonable, and the necessity conditions of the intermediate solution cannot be eliminated, so it is often considered as the preferred solution. Referring to the existing research, this paper selects the intermediate solution for analysis (45). Referring to existing studies, we use a frequency benchmark ≥ 1, raw consistency benchmark ≥ 0.8, and a proportional reduction in inconsistency (PRI) ≥ 0.70 (46). Using these standards, we obtain the truth table and identified four configuration solutions that can lead to high-impact online public opinion. The overall solution coverage is 0.725, indicating that these configurations can explain about 72.5% of the high-impact generation outcomes of online public opinion, and overall solution consistency is 0.994, which can cover and explains the high-impact generation of online public opinion. We further identified six configuration solutions that can lead to low-impact generation of online public opinion. The overall solution consistency is 0.977, with a coverage of 0.784.

We analyze four configuration solutions of high-impact online public opinion horizontally and found that they all have the same core conditions. Based on the difference of the four configuration solutions, three types of online public opinion generation with high impact in public health emergencies can be divided: information environment driven in a crisis-free situation, dual EE-SE driven in a non-sensitive crisis situation, and a single-driven type of crisis situation.

4.2.1 Configurations for high-impact online public opinion

In Table 5, we display results for four configuration solutions where the solutions are sufficient for high-impact online public opinion with high solution consistency and solution coverage (0.994 and 0.725, respectively) and that satisfied consistency and coverage of each solution.

Solution 1 (S1) is information environment driven in a crisis-free situation. This type is the main type and consists of combination S1a and S1b in which the internet users' attention, opinion leader

10.3389/fpubh.2024.1404587

TABLE 3 Sets, calibrations and descriptive statistics.

Sets	Fuzzy set calibrations			Descriptive statistics			
	Fully in	Crossover	Fully out	Mean	SD	Min	Max
IA	22.50	7	2.25	30.70	67.01	1	298
OD	5,318	2,896	1136.75	6174.50	10630.39	0	52,987
GI	54.33	39.40	5.50	35.74	27.69	0	93.1
HL	1 0.67 0.33 0			0.26	0.30	0	1
NP	81	44	18.25	54.43	51.58	1	240
EE	17.75	12	5	37.59	149.19	1	965
SE	117,352	29,735	10123.50	141,105	316240.80	1,142	1,866,780
II	74.80	68.50	61.93	68.57	12.87	28.10	100

TABLE 4 Analysis of necessary conditions.

Sets	Outcome = public opinion impact generation		Outcome = ~public opinion impact generation	
	Consistency	Coverage	Consistency	Coverage
IA	0.845	0.914	0.210	0.223
~IA	0.282	0.267	0.919	0.853
OD	0.971	0.961	0.261	0.253
~OD	0.245	0.253	0.960	0.970
GI	0.822	0.816	0.319	0.310
~GI	0.305	0.314	0.811	0.817
HL	0.340	0.667	0.317	0.609
~HL	0.800	0.544	0.827	0.551
NP	0.895	0.924	0.247	0.250
~NP	0.274	0.271	0.925	0.896
EE	0.782	0.773	0.401	0.388
~EE	0.382	0.394	0.766	0.775
SE	0.713	0.730	0.374	0.375
~SE	0.389	0.388	0.730	0.714

~ means the absence of. For example: ~… = absence of high.

dissemination, and network platform participation are core conditions, and the lack of hazard level plays a supplementary role, government intervention is irrelevant. Only the information environment is different. It shows that even if the public health emergencies with low hazard level can attract the high attention of informants represented by internet users and online opinion leaders, and more information technology platforms participate in the reporting, although they lack the attention of the central media, they can form a high-impact online public opinion in both a good evacuation environment and an active social opinion environment. The consistency of S1a and S1b reached 0.983 and 0.992 respectively, and the coverage rates were 0.265 and 0.196, respectively. This type of events mainly focused on public health emergencies closely related to public life, such as the rat head and duck neck incident in Jiangxi Industry Polytechnic College, a school in Chengdu gave students moldy food caused discomfort, 11 enterprises suspected of detecting African swine fever, and Clenbuterol mutton appeared in Hebei province.

Solution 2 (S2) is dual EE-SE driven in a non-sensitive crisis situation. In addition to the core roles played by internet users' attention, opinion leader's dissemination, and network platform participation, evacuation environment and social opinion environment are marginal conditions that play supplementary roles, and event hazard level is an irrelevant condition. Specifically, regardless of the hazard level of public health emergencies, as long as the high attention of information person and the participation of more network platforms are aroused, most public health emergencies can attract widespread attention in the society, and the high influence of online public opinion can be formed through the drive of public opinion evacuation environment constructed by governments at all levels, public health departments and experts, as well as the social public opinion environment formed naturally by public opinion. The consistency of S2 reaches 0.997, and the coverage rates is 0.450. Dual EE-SE driven in a non-sensitive crisis situations are mainly focused on medical safety and epidemic infectious diseases, because public health emergencies have an important impact on life safety and

physical health, which is easy to trigger public panic and form a public opinion environment. Typical examples include the COVID-19 outbreak in Wuhan and other places in 2019, Changsheng Biological Vaccine Fraud Incident in 2018, and Unfrozen vaccines flow into 18 provinces in 2016.

Solution 3 (S3) is a single-driven type of crisis situation. In S3, the internet users' attention and opinion leader dissemination play core roles, and the lack of government intervention and the lack of participation of network platforms also play a core role. The hazard level of the event plays a supplementary role, and the lack of evacuation environment and the lack of social opinion environment also play a supplementary role. For public health emergencies with high hazard level, based on the joint effect of the two core conditions of high online public opinion influence, high internet users' attention and high opinion leader dissemination, even if the participation of central media and network platform is low, the evacuation environment for public opinion is lack and the social opinion environment is not active, it can still form high-impact online public opinion. The single-driven type of crisis situation mainly focuses on small-scale public health emergencies of infectious diseases with high hazard level, such as Beijing confirmed one person infected with H5N6 avian influenza in 2019, Bayan Nur confirmed a case of glandular plague in 2020, Brucella infections at two veterinary research institutes under the CAAS in 2019.

From Table 5, we can find that in public health emergencies, the core pathways of high-impact generation of online public opinion are S1 and S2, with the raw coverage rate higher than 45%. By integrating the two core pathways, we can get the formula of the generation type of high-impact of online public opinion of public health emergencies: public opinion influence = A*B*E (C + ~D) (F + G). From the simplified formula, it can be seen that in public health emergencies, information person and information technology are still proved to be the necessary conditions for the high-impact pathway, and both the information environment of public opinion evacuation environment and social opinion environment also play the important role of supplement conditions in the combination of conditions, while the impact of the hazard level factors contained in the information is contrary to traditional cognition.

4.2.2 Configurations for not high-impact online public opinion

Besides investigating the configurations for high-impact online public opinion, we also display results for six configurational solutions for not high-impact online public opinion in Table 5, with high solution consistency and solution coverage (0.977 and 0.784, respectively) and that satisfied consistency and coverage of each solution. At the same time, Solution 4 and 5 are the core pathways for the generation of not high-impact public opinion in public health emergencies. They both have a raw coverage rate higher than 45%. By integrating the core pathways, the formula for generating not high public opinion can be simplified as follows: ~A* ~B* ~C* ~D* ~E*(~F + ~G). It can be seen that in public health emergencies, information person and information technology are still proved to be the necessary conditions for the not high-impact pathway, public opinion evacuation environment and social opinion environment included in the information environment, as well as hazard level also play the role of necessary conditions in the combination of conditions.

4.3 Robustness checks

In order to avoid the randomness and sensitivity of the results, robustness test is necessary in QCA analysis. The specific robustness test of set theory mainly includes adjusting the calibration threshold, modifying the frequency of cases, resetting the consistency threshold, adding other conditions, supplementing or eliminating cases, etc. Based on the existing research experience, we carried out the robustness test by eliminating some cases. According to the indicator of generating public opinion impact in the outcome variable, cases were excluded. Three qualitative anchor points (74.80, 68.50, and

TABLE 5 Configuration for public opinion generation (fsQCA).

Sets	Configuration for high-impact public opinion generation				Configuration for not high-impact public opinion generation						
	S1a	S1b	S2	S3	S4	S5	S6	S7	S8	S9	S10
IA	●	●	●	●	⊗	⊗	⊗	⊗	⊗	⊗	●
OD	●	●	●	●	⊗	⊗	⊗	⊗	⊗	⊗	●
GI			●	⊗	⊗	⊗		⊗	⊗	●	⊗
HL	⊗	⊗		•	⊗	⊗	⊗			⊗	●
NP	●	●	●	⊗	⊗	⊗	⊗	⊗	⊗	●	⊗
EE	•	⊗	•	⊗	⊗		⊗	⊗	•		•
SE	⊗	•	•	⊗		⊗	•	•	⊗	⊗	⊗
Consistency	0.983	0.992	0.997	0.982	0.987	1	0.953	0.971	1	0.982	0.998
Raw coverage	0.265	0.196	0.450	0.080	0.542	0.497	0.297	0.273	0.241	0.139	0.056
Unique coverage	0.128	0.087	0.279	0.040	0.009	0.015	0.031	0.022	0.017	0.045	0.011
Overall solution consistency	0.994				0.977						
Overall solution coverage	0.725				0.784						

61.93) were used to divide 40 cases into four groups. Cases 1–10 are grouped together, and cases 5, 6, and 7 were excluded; cases 11–21 are a group, excluding cases 15–17; cases 22–30 are grouped together, excluding cases 25, 26, and 27; cases 31–40 are grouped together, excluding cases 35, 36, and 37. A total of 12 cases are eliminated, and then we analyzed the remaining case sets again. After the robustness test and analysis, the conclusion is basically consistent with the original conclusion, and can confirm each other, indicating that the research results remained robust.

5 Discussion

5.1 Research conclusions

Through qualitative comparative analysis of fuzzy sets of research cases, we extract and identify the core conditions and configurational solutions for the generation of high-impact online public opinion in public health emergencies, we found that the generation and evolution of the impact of online public opinion basically follow the action mechanism and common evolutionary characteristics of information ecology theory and online public opinion dissemination theory, but also have their unique evolutionary characteristics.

Information person and information technology are the key conditions for the generation of high-impact online public opinion in public health emergencies. From the necessity measure of a single variable, we can observe that higher internet users' attention, opinion leaders' communication power and online platforms' participation are necessary conditions for the generation of high-impact online public opinion in public health emergencies. Meanwhile, from the configurational solutions we can also find that the three are the core conditions for the generation of high-impact public opinion, which can prove that the information person and information technology are the key forces for the generation of online public opinion impact of public health emergencies. With the development of information technology, online media characterized by mobile, extensive, civilian, social, and interactive has emerged, and the survey found that online media gradually dominated the competition with central media, which can indicate that opinion leaders and network media platforms also have strong enough driving force in online public opinion impact generation. Comparing the two core combination pathways, both the information environment of public opinion evacuation environment and social opinion environment can generate high public opinion impact. If the government involvement is higher and the evacuation degree is greater, then the information environment that plays a key role in high-impact online public opinion will be constructed by the government. Although government public opinion evacuation environment is not a necessary condition for public opinion impact generation, public health emergencies with longer duration of public opinion and greater difficulty of government public opinion evacuation are often found in the pathway with higher degree of government intervention.

However, from the perspective of public opinion risk preventing and reducing, configuration S2 is the best, S3 is the worst, S1a is better than S1b. Traditionally, the higher hazard level of event, the greater the casualties and economic losses, the longer the time of government public opinion risk relief, the more the online media will continue to question the progress of events, and the number of network platform participation and the duration of reporting will greatly increase, thus promoting the generation of high-impact online public opinion. However, the study found that the generation of high-impact online public opinion is not sensitive to the hazard level of the event itself, indicating that the information elements of high-impact public opinion on the network causing public health emergencies are multivariate. Therefore, the contrary should not simply be based on the hazard level of public health emergencies as a predictive measure of public opinion risk.

5.2 Theoretical implications

First, based on the information ecology theory and the online public opinion dissemination theory, we constructed an analytical framework of online public opinion impact in public health emergencies and conducted a configurational analysis, to reveal the generation mechanism of online public opinion impact. Up to now most studies have focused on the impact factors of online public opinion on public emergencies while there are few studies on the influence of online public opinion in public health emergencies (47). Public health emergencies as a special area of emergencies, because they have a real impact on the safety of public life and health, are easy to attract public attention and trigger high impact online discussion. Therefore, our targeted analysis of such events has important theoretical implications for preventing and resolving major public opinion risks and reducing their impact.

Second, we contribute to information ecology theory. The generation of online public opinion impact is systematic and complex, and it is necessary to further analyze the synergistic impact of various factors such as information person, information, information technology, and information environment (48). On the basis of the four dimensions of the information ecology theory, we refine it and extract seven preconditions conditions affecting online public opinion in public health emergencies: internet user's attention, opinion leader dissemination, government intervention, hazard level, network platform participation, government public opinion evacuation environment, and social opinion environment, revealing the interaction mechanism among them.

Third, we apply QCA method to online public opinion research, which broadens the choice of online public opinion research methods. The generation of public opinion impact conforms to the characteristics of multi-causal induction. This study not only reveals the multifactorial configuration of high-impact online public opinion, but also reveals the configuration leading to not high-impact online public opinion.

5.3 Practical implications

Public health emergencies are closely related to the interests of the public and can create a public opinion field where the discourse related to the event is gathered, released, contested and divided. The factors triggering the impact of online public opinion in public

health emergencies are multiple and varied, and the paths are complicated, so preventing or reducing the public opinion risks implied by public opinion becomes a complex systematic project. Based on the generation mechanism and evolution characteristics of the impact of online public opinion in public health emergencies, the following risk avoidance measures are proposed: first, define the discourse space of online opinion leaders and maintaining rational communication order; second, improve the management system of network platforms and build new central media platforms; third, establish a collaborative information sharing mechanism and build a strong interactive public opinion ecology; fourth, build an institution for public opinion risk research and evaluation, improve the ability of government intervention and evacuation. This study analyzed the generation of online public opinion impact of public health emergencies, in order to provide new ideas and management pathways for future public health emergencies.

5.4 Limitations and future research

Despite our best efforts, our research still has limitations. First, we selected these cases for public health emergencies that all occurred in China. Affected by the time span of typical cases of public health emergencies and the development cycle of the Internet platform, many details of typical cases of different events, such as the number of materials, information quality, and development map, are inevitably lost and missed. Moreover, 40 typical cases may not be enough to cover all the factors of public health emergencies, which will lead to certain errors in the results. Additionally, if cases from other countries can be included in the study, we can further enrich our research results and enhance its universality. Second, although the cases selected were all public health emergencies, these events have different types and ripple effects. In the future, our study can be further refined by analyzing and comparing the differences in the influencing factors among them according to the types of events, which can be more focused. Third, this study only focused on the role of four dimensions of information person, information, information technology and information environment on the impact of online public opinion, a more comprehensive research model can be constructed based on this study by further subdividing the four dimensions in the future.

Data availability statement

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

Author contributions

TL: Data curation, Formal analysis, Investigation, Methodology, Software, Writing – original draft, Writing – review & editing. XH: Funding acquisition, Supervision, Validation, Writing – review & editing. QD: Supervision, Validation, Software, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This study was supported by the Scientific Research Project of Ministry of Emergency Management of China in 2021, Beijing, China (KH54443501).

Acknowledgments

The authors would like to thank all the participants in this study, and those all who provide help to this study.

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.

Publisher's note

References

1. Cleaton JM, Viboud C, Simonsen L, Hurtado AM, Chowell G. Characterizing Ebola transmission patterns based on internet news reports. *Clin Infect Dis*. (2016) 62:24–31. doi: 10.1093/cid/civ748

2. Habermas J. Communication and the Evolution of Society. Cambridge: Polity Press (1991).

3. Huang Y, Yu Z, Guo J, Yu Z, Xian Y. Legal public opinion news abstractive summarization by incorporating topic information. *Int J Mach Learn Cybern*. (2020) 11:2039–50. doi: 10.1007/s13042-020-01093-8

4. Ayers JW, Althouse BM, Dredze M, Leas EC, Noar SM. News and internet searches about human immunodeficiency virus after Charlie Sheen's disclosure. *JAMA Intern Med*. (2016) 176:552–4. doi: 10.1001/jamainternmed.2016.0003

5. Panagiotopoulos P, Barnett J, Bigdeli AZ, Sams S. Social media in emergency management: twitter as a tool for communicating risks to the public. *Technol Forecast Soc*. (2016) 111:86–96. doi: 10.1016/j.techfore.2016.06.010

6. Lash S. Reflexive modernization: the aesthetic dimension. *Theor Cult Soc*. (1993) 10:1–23. doi: 10.1177/026327693010001001

7. Cao Y, Shan J, Gong Z, Kuang J, Gao Y. Status and challenges of public health emergency management in China related to COVID-19. *Front Public Health*. (2020) 8:250. doi: 10.3389/fpubh.2020.00250

8. Posid JM, Bruce SM, Guarnizo JT, O'Connor RC, Papagiotas SS, Taylor ML. Public health emergencies and responses: what are they, how long do they last, and how many staff does your agency need? *Biosecur Bioterror*. (2013) 11:271–9. doi: 10.1089/bsp.2013.0044

9. Fleming N. Fighting coronavirus misinformation. *Nature*. (2020) 583:155–6. doi: 10.1038/d41586-020-01834-3

10. Cochran JK, Chamlin MB. Can information change public opinion? Another test of the Marshall hypotheses. *J Crim Just*. (2005) 33:573–84. doi: 10.1016/j.jcrimjus.2005.08.006

11. Noelle-Neumann E. The spiral of silence a theory of public opinion. *J Commun*. (1974) 24:43–51. doi: 10.1111/j.1460-2466.1974.tb00367.x

12. Zhang X, Zhou Y, Zhou F, Pratap S. Internet public opinion dissemination mechanism of COVID-19: evidence from the Shuanghuanglian event. *Data Technol Appl*. (2022) 56:283–302. doi: 10.1108/DTA-11-2020-0275

13. Gao G, Wang T, Zheng X, Chen Y, Xu X. A systems dynamics simulation study of online public opinion evolution mechanism. *J Glob Inf Manag*. (2019) 27:189–207. doi: 10.4018/JGIM.2019100110

14. Xie T, Wei Y, Chen W, Huang H. Parallel evolution and response decision method for public sentiment based on system dynamics. *Eur J Oper Res*. (2020) 287:1131–48. doi: 10.1016/j.ejor.2020.05.025

15. Qu Y, Tian H, Chen H. Research on the emotional evolution mechanism of network public opinion based on an information ecosystem. *Discret Dyn Nat Soc*. (2022) 2022:4875099. doi: 10.1155/2022/4875099

16. Davenport TH, Prusak L. Information Ecology: Mastering the Information and Knowledge Environment. New York: Oxford University Press (1997).

17. Nardi BA, O'Day V. Information Ecologies: Using Technology With Heart. Massachusetts: MIT Press (1999).

18. Finin T, Joshi A, Kolari P, Java A, Kale A, Karandikar A. The information ecology of social media and online communities. *AI Mag*. (2008) 29:77–92. doi: 10.1609/aimag.v29i3.2158

19. Kish K. Paying attention: big data and social advertising as barriers to ecological change. *Sustainability*. (2020) 12:1–27. doi: 10.3390/su122410589

20. Gernat T, Rao VD, Middendorf M, Dankowicz H, Goldenfeld N, Robinson GE. Automated monitoring of behavior reveals bursty interaction patterns and rapid spreading dynamics in honeybee social networks. *Proc Natl Acad Sci USA*. (2018) 115:1433–8. doi: 10.1073/pnas.1713568115

21. Kim D, Eom K, Chung CJ. Measuring online public opinion for decision making: application of deep learning on political context. *Sustainability*. (2022) 14:1–16. doi: 10.3390/su14074113

22. Enke N, Borchers NS. Social media influencers in strategic communication: a conceptual framework for strategic social media influencer communication. *Int J Strateg Commun*. (2019) 13:261–77. doi: 10.1080/1553118X.2019.1620234

23. Chen T, Wang Y, Yang J, Cong G. Modeling public opinion reversal process with the considerations of external intervention information and individual internal characteristics. *Healthcare*. (2020) 8:160. doi: 10.3390/healthcare8020160

24. Boehmer J, Tandoc EC. Why we retweet: factors influencing intentions to share sport news on twitter. *Int J Sport Commun*. (2015) 8:212–32. doi: 10.1123/IJSC.2015-0011

25. Liu J, Liu L, Tu Y, Li S, Li Z. Multi-stage internet public opinion risk grading analysis of public health emergencies: an empirical study on microblog in COVID-19. *Inf Process Manag*. (2022) 59:102796. doi: 10.1016/j.ipm.2021.102796

26. Xing Y, Li Y, Wang FK. How privacy concerns and cultural differences affect public opinion during the COVID-19 pandemic: a case study. *Aslib J Inf Manag*. (2021) 73:517–42. doi: 10.1108/AJIM-07-2020-0216

27. Zhang M, Su H, Wen J. Analysis and mining of internet public opinion based on LDA subject classification. *J Web Eng*. (2021) 20:2457–72. doi: 10.13052/jwe1540-9589.20811

28. Gerbaudo P, Trere E. In search of the "we" of social media activism: introduction to the special issue on social media and protest identities. *Inf Commun Soc*. (2015) 18:865–71. doi: 10.1080/1369118X.2015.1043319

29. Cervi L, García F, Lladó CM. Populism, twitter, and covid-19: narrative, fantasies, and desires. *Sociol Sci*. (2021) 10:294. doi: 10.3390/socsci10080294

30. Jarynowski A, Belik V, Wójta-Kempa M. Trends in interest of COVID-19 on polish internet. *Przegl Epidemiol*. (2020) 74:258–75. doi: 10.32394/pe.74.20

31. Beckers K. Power of the people or the expert? The influence of vox pop and expert statements on news-item evaluation, perceived public opinion, and personal opinion. *Commun Ger*. (2022) 47:114–35. doi: 10.1515/commun-2019-0186

32. Leong AD, Ho SS. Perceiving online public opinion: the impact of Facebook opinion cues, opinion climate congruency, and source credibility on speaking out. *New Media Soc*. (2021) 23:2495–515. doi: 10.1177/1461444820931054

33. Yin F, Shao X, Wu J. Nearcasting forwarding behaviors and information propagation in Chinese Sina-microblog. *Math Biosci Eng*. (2019) 16:5380–94. doi: 10.3934/mbe.2019268

34. Wang G, Zhang W, Zeng R. WeChat use intensity and social support: the moderating effect of motivators for WeChat use. *Comput Hum Behav*. (2019) 91:244–51. doi: 10.1016/j.chb.2018.10.010

35. Wen Z, Geng X, Ye Y. Does the use of WeChat Lead to subjective well-being? The effect of use intensity and motivations. *Cyberpsychol Behav Soc Netw*. (2016) 19:587–92. doi: 10.1089/cyber.2016.0154

36. Liu Y, Wu Y, Li C, Song C, Hsu W. Does displaying one's IP location influence users' privacy behavior on social media? *Evid Chin Weibo Telecommun Policy*. (2024) 48:102759. doi: 10.1016/j.telpol.2024.102759

37. Gao S, Zhang Y, Liu W. How does risk-information communication affect the rebound of online public opinion of public emergencies in China? *Int J Environ Res Public Health*. (2021) 18:7760. doi: 10.3390/ijerph18157760

38. Ragin CC, Fiss PC. Net Effects Analysis versus Configurational Analysis: An Empirical Demonstration. Redesigning Social Inquiry: Fuzzy Sets and Beyond. Chicago: University of Chicago Press (2008).

39. Fiss PC. Building better causal theories: a fuzzy set approach to typologies in organization research. *Acad Manag J*. (2011) 54:393–420. doi: 10.5465/AMJ.2011.60263120

40. Schneider CQ, Wagemann C. Standards of good practice in qualitative comparative analysis (QCA) and fuzzy-sets. *Comp Sociol*. (2010) 9:397–418. doi: 10.1163/156913210X12493538729793

41. Du Y, Kim PH. One size does not fit all: strategy configurations, complex environments, and new venture performance in emerging economies. *J Bus Res*. (2021) 124:272–85. doi: 10.1016/j.jbusres.2020.11.059

42. Du Y, Kim PH, Aldrich HE. Hybrid strategies, dysfunctional competition, and new venture performance in transition economies. *Manag Organ Rev*. (2016) 12:469–501. doi: 10.1017/mor.2016.30

43. Hudson J, Kühner S. Qualitative comparative analysis and applied public policy analysis: new applications of innovative methods. *Polic Soc*. (2013) 32:279–87. doi: 10.1016/j.polsoc.2013.10.001

44. De Crescenzo V, Ribeiro-Soriano DE, Covin JG. Exploring the viability of equity crowdfunding as a fundraising instrument: a configurational analysis of contingency factors that lead to crowdfunding success and failure. *J Bus Res*. (2020) 115:348–56. doi: 10.1016/j.jbusres.2019.09.051

45. Rihoux B, Ragin CC. Configurational Comparative Methods: Qualitative Comparative Analysis (QCA) and Related Techniques. London: SAGE Publications (2008).

46. Greckhamer T, Furnari S, Fiss PC, Aguilera RV. Studying configurations with qualitative comparative analysis: best practices in strategy and organization research. *Strateg Organ*. (2018) 16:482–95. doi: 10.1177/1476127018786487

47. Hui F. Research on the construction of emergency online public opinion emotional dictionary based on emotional feature extraction algorithm. *Front Psychol*. (2022) 13:857769. doi: 10.3389/fpsyg.2022.857769

48. Depoux A, Martin S, Karafillakis E, Preet R, Larson HJ. The pandemic of social media panic travels faster than the COVID-19 outbreak. *J Travel Med*. (2020) 27:1195–982. doi: 10.1093/jtm/taaa031

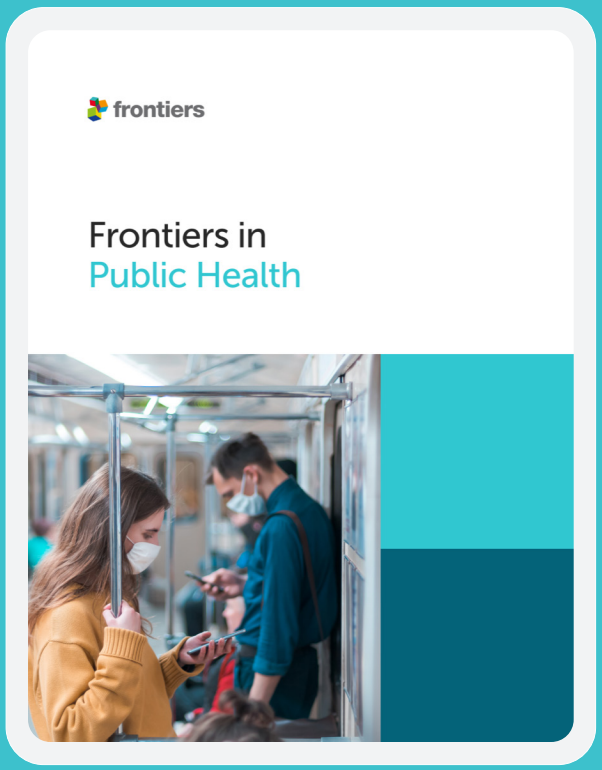
Frontiers in Public Health

Explores and addresses today's fast-moving healthcare challenges

One of the most cited journals in its field, which promotes discussion around inter-sectoral public health challenges spanning health promotion to climate change, transportation, environmental change and even species diversity.

Discover the latest Research Topics

See more →



Frontiers

Avenue du Tribunal-Fédéral 34
1005 Lausanne, Switzerland
frontiersin.org

Contact us

+41 (0)21 510 17 00
frontiersin.org/about/contact