



Temporal changes in factors associated with COVID-19 vaccine hesitancy among Chinese adults: Repeated nationally representative survey

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ABSTRACT

Background: COVID-19 vaccine hesitancy has been cited as one of the main obstacles impacting vaccine coverage. However, factors that affect hesitancy may change over time. Understanding these evolving concerns and adapting strategies accordingly are crucial for effectively addressing vaccine hesitancy effectively and promoting public health. We aimed to explore the temporal changes in factors associated with COVID-19 VH during the COVID-19 pandemic and assess the dynamic evolution of VH.

Methods: In August 2022 and February 2023, repeated online surveys were undertaken to collect information from 5378 adults across four regions of China. Multiple linear regression models assessed the influencing factors of COVID-19 VH. The association between protective motive theory (PMT) (perceived severity, susceptibility, benefits, barriers, and self-efficacy) and VH was evaluated by structural equation modeling (SEM).

Results: Repeated measures showed that 573 (10.7%) and 1598 (29.7%) of the 5378 participants reported COVID-19 VH in the baseline and follow-up surveys, respectively. Educational levels, chronic disease, history of allergy, COVID-19 infection, and trust in medical staff and vaccine developers were positively associated with COVID-19 VH ($P < 0.05$). The application of SEM revealed that perceived severity, susceptibility, vaccination barriers, and self-efficacy in the PMT directly impacted on VH ($P < 0.05$). In addition, severity, susceptibility, benefits, and barriers had a significant direct effect on self-efficacy as $\beta = 0.113$, $\beta = 0.070$, $\beta = 0.722$, $\beta = -0.516$ respectively with $P < 0.001$.

Conclusion: The prevalence of COVID-19 VH was relatively low in the baseline survey and much higher in the follow-up survey, with a significant increase in hesitancy rates among mainland Chinese residents. Acknowledging the substantial impact on the shaping of COVID-19 VH, one must consider factors including perceived severity, susceptibility, vaccination barriers, and self-efficacy.

1. Introduction

The World Health Organization (WHO) has declared that COVID-19 is now an established and ongoing health issue, no longer qualifying as a public health emergency of international concern (WHO, 2023). Throughout the global COVID-19 epidemic, the development and vaccination of vaccines have emerged as crucial tools in preventing and controlling the spread of the virus. However, vaccine hesitancy (VH)

related to the COVID-19 vaccine has been a notable and widespread concern. The WHO defines VH as a delay in receiving or refusal of vaccination despite the availability of vaccination services, which has been listed as one of the top ten global health threats (Berdzuli & Datta, 2022).

The detrimental impact of COVID-19 VH, which cannot be overlooked, lies in its tendency to lead individuals to disregard the imperative of vaccination, thereby increasing susceptibility to contracting the

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COVID-19 virus (Bergen et al., 2023). Although the development of the COVID-19 vaccine has been advancing rapidly, with a large body of evidence demonstrating its safety and efficacy, there are still concerns on the side effects and safety of the vaccine, leading to hesitation to vaccination (Adams et al., 2022). However, COVID-19 vaccination remains an effective means of protection during the current low-level COVID-19 epidemic (Lazarus et al., 2023). Unlike the mechanisms underlying conventional vaccine hesitancy, the COVID-19 vaccine is highly accessible and affordable in mainland China (Wu, Ma, Li, et al., 2023), Wu, Xia, et al., 2023, but people still have high levels of VH.

The causes of VH are complex and may involve personal, social, cultural, political, and economic aspects. First, sources of information and cognitive biases may be important factors in VH. Previous studies have shown that there was a wealth of misinformation and conspiracy theories about the COVID-19 vaccine on social media, as well as patients who mistook their personal experiences for vaccine-induced illnesses, which could have a misleading impact on people's judgment (Pertwee, Simas, & Larson, 2022). Secondly, mistrust of technology, medicine, and government is also a significant source of vaccine hesitancy (Kreps & Kriner, 2023). In addition, social, cultural, and economic factors can also contribute to VH. Instances exist where certain regions experience social divisions, poverty, and insufficient education levels, which can be linked to vaccination-related doubts or mistrust (Lazarus et al., 2023). However, factors associated with VH fluctuate dynamically; an in-depth time series and trend characterization of COVID-19 VH is deemed necessary to clarify the changing patterns.

Protection Motivation Theory (PMT) may offer a viable approach when exploring the causes of COVID-19 VH. PMT refers to a cognitive state that is internally driven by an individual's need to protect his or her own interests in the face of certain risk factors in the internal and external environment (Eberhardt & Ling, 2021). The theory includes five main aspects: perceived severity, perceived susceptibility, perceived benefits, environmental barriers, and self-efficacy (Chai et al., 2022). In the case of COVID-19 vaccination, people's protective motivation is mainly derived from the preventive measures against COVID-19 infection, and the vaccine is effective as a means of prevention to reduce the risk of infection and protect individuals from the disease (Griffin, Conner, & Norman, 2022). Integrating the theory of protective motivation with other potential factors to identify factors influencing COVID-19 VH and assessing the relationship and role between these factors will help us acquire a deeper understanding of what VH entails.

Although previous studies have identified a number of factors associated with COVID-19 VH (Wu et al., 2021), the complex relationships that may exist between multiple factors have not been assessed. The SEM approach provides a flexible, complex, and effective framework to analyze multiple variables and is able to take into account the relationships between multiple variables, which could provide a more convincing explanation for COVID-19 VH (Chai et al., 2022). However, there is a dearth of research on the factors associated with vaccination hesitancy in mainland Chinese populations using SEM with PMT. We, therefore conduct baseline and follow-up surveys for repeated measures in the same population sampled from multiple centers in mainland China by using SEM. The aim of this study was to clarify the rate of COVID-19 VH in mainland China and determine the dynamic evolution of VH and its influencing factors, providing valuable evidence for a comprehensive understanding of COVID-19 VH.

2. Methods

2.1. Procedures and participants

We conducted the dynamic evolution of COVID-19 vaccination study, a national, multicenter, observational household tracking survey from China using a stratified random sampling method. 4 cities were selected from the Eastern (Changzhou, Jiangsu), Central (Zhengzhou, Henan), Western (Xi'ning, Qinghai), and Northeast (Mudanjiang,

Heilongjiang) regions.

We calculated the minimum sample size of each region according to the population proportion of China's Seventh National Population Census. In each province, the sample size of urban and rural areas was determined according to the proportion of population, more than two cities and two rural areas were randomly selected for sampling. For all of the cities and families in the sample, coding was carried out followed by random sampling. Finally, all members of the selected family have been involved in this survey (age ≥ 18 years) and completed the online or offline questionnaire with the assistance of investigators. A total of 2556 households from four geographic regions of China were enrolled in the survey. We conducted baseline and follow-up surveys in August 2022 and February 2023 respectively, each lasting about a week. The flow-chart of participants was shown in Fig. 1.

2.2. Questionnaire design and data collection

Online questionnaires were designed to collect data through an online survey conducted through the Wenjuanxing platform. We also conducted a face-to-face interview with participants who cannot use a smartphone. The questionnaire covered five thematic areas: (1) Socio-demographic characteristics: age, gender, nation, religion, marital status, educational status, smoking status, drinking status, and physical activity; (2) Health conditions: chronic disease, the history of allergic, self-report health condition; (3) Perception of COVID-19 and COVID-19 vaccine: public health prevention measures, awareness of COVID-19 vaccines, the risk of COVID-19 infection, the history of COVID-19 infection, the convenience of vaccination, the uptake of COVID-19 vaccine; (4) The protective motivation theory (KMO = 0.796): perceived severity (Cronbach's α = 0.894), perceived susceptibility (Cronbach's α = 0.849), perceived benefits (Cronbach's α = 0.886), perceived barriers (Cronbach's α = 0.932), self-efficacy (Cronbach's α = 0.967) (Table S1); (5) Trust in medical staff and developers.

2.3. Assessments

The primary outcome was COVID-19 VH, assessed by asking participants "In the future, would you like to get a booster vaccination of the COVID-19 vaccine?" Participants could choose 1 response from the options "(1) willing, (2) hesitant or delayed, (3) refused, and (4) not applicable" from the question. According to the definition of VH, option (1) was regarded as "acceptance," and options (2) and (3) were merged into "hesitancy." In addition, participants were excluded if they selected the option "not applicable" in both baseline and follow-up surveys.

2.4. Statistical analysis

Chi-square tests were used to test differences in VH between groups. Binary logistic regression were carried out to examine factors associated with COVID-19 VH in both baseline and follow-up surveys. In stratified multistage sampling, post hoc stratification was used to weight the sample and the corresponding variables so that the sample's estimate of the total was unbiased. Unstandardized path coefficients (B) and standardized path coefficients (β) were presented separately. The goodness of fit was examined by chi-square tests, the comparative fit index (CFI), the Tucker-Lewis index (TLI), and the root mean square error of approximation (RMSEA). A significance test was conducted to examine the mediation hypotheses, using the bootstrap method with 10,000 iterations and a 95% confidence interval. The asymmetric confidence intervals resulting from the bootstrapping procedure did not contain zero, indicating a statistically significant mediation effect. Odds ratios (OR), 95% confidence intervals (95% CI), and *P*-values were calculated for each independent variable. All statistical analyses were carried out using SPSS (version 21.0), STATA (version 16.0) and Mplus (version 8.0). Differences were regarded as statistically significant if *P* values were less than 0.05.

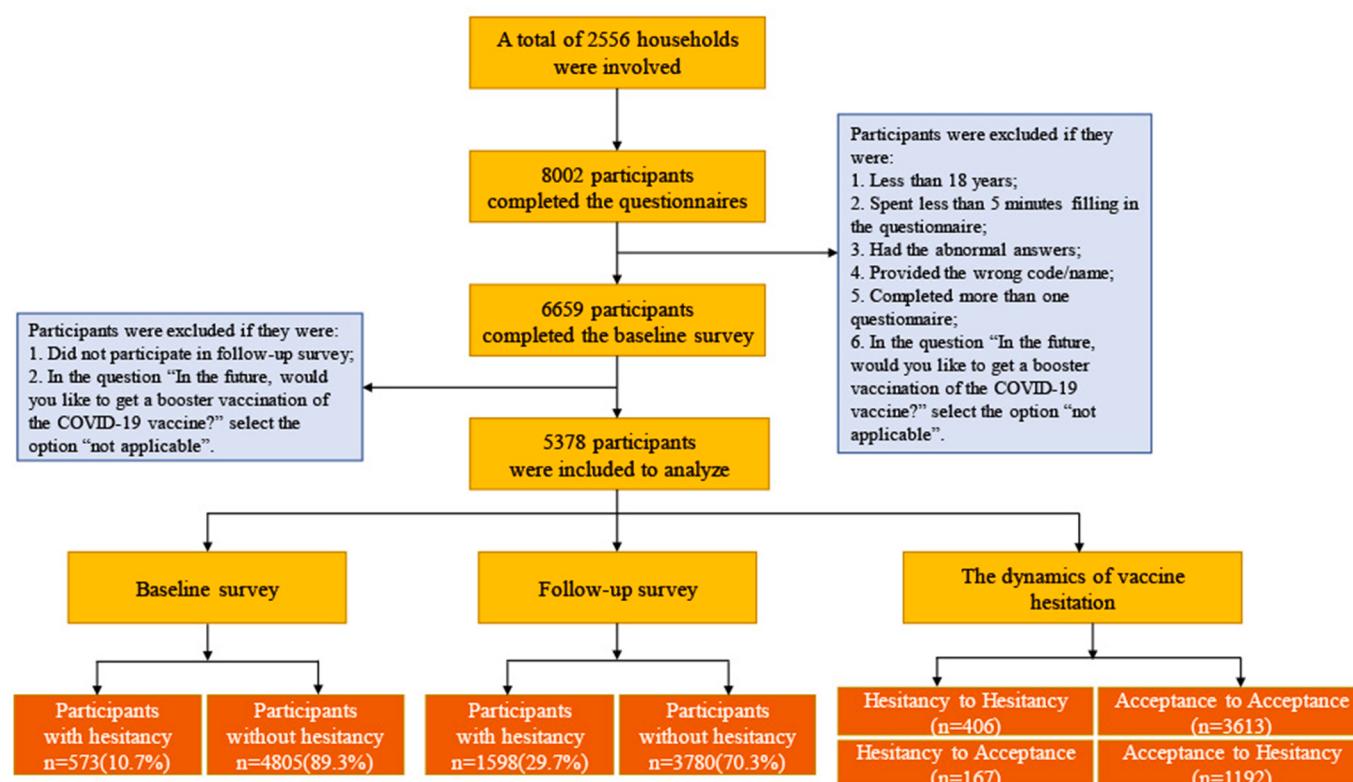


Fig. 1. The flowchart of participant selection, data process and analysis.

3. Results

3.1. Socio-demographic characteristics of the participants

8002 participants from four cities across multiple centers in mainland China completed the online survey. After excluding 2624 non-compliant participants, baseline and follow-up surveys were analyzed for the 5378 finalized participants. The COVID-19 vaccine hesitancy rate was 10.7% and 29.7% in the baseline and follow-up surveys, respectively. The sample population was evenly distributed in age, with a higher proportion of females (2888/5378, 53.7%). The majority of participants were married (4738/5378, 88.1%). In terms of educational attainment, the majority of participants had a high school level or above (3051/5378, 56.8%). In terms of health status, 15.8% and 7.4% of the participants had chronic diseases (850/5378) and a history of allergies (399/5378) respectively. A higher proportion of participants had never smoked (3918/5378, 72.9%) and never consumed alcohol (3723/5378, 69.2%). In addition, only 4 participants (0.1%) had COVID-19 infection in the baseline survey, while 2928 participants (54.4%) had COVID-19 infection in the follow-up survey. Age, education, chronic disease, allergy history, smoking, drinking, and physical activity all differed significantly ($P < 0.05$) between COVID-19 hesitancy and non-hesitancy. Table 1 shows the population characteristics of the two surveys in detail.

3.2. Factors associated with VH in repeated surveys

In both baseline and follow-up surveys, we found age, educational status, smoking status, drinking status, chronic disease, the history of allergic, physical activity, self-report health condition, public health prevention measures, the trust in medical staff, and the trust in developers were all independently associated with COVID-19 VH (all $P < 0.05$).

After adjusting for potential confounders, we found that female,

higher education levels, having a chronic disease, having a history of allergies, lower self-reported health status, taking low levels of public prevention measures, and having lower levels of trust in medical staff and vaccine developers were positively associated with COVID-19 VH in baseline survey ($P < 0.05$). Similarly, age (30–49, ≥ 60), higher educational levels, having a chronic disease, having a history of allergies, lower levels of physical activity, lower levels of COVID-19 vaccine awareness, COVID-19 infection and lower levels of trust in medical staff and vaccine developers were positively associated with COVID-19 vaccine hesitancy in the follow-up survey (all $P < 0.05$). Detailed results are all shown in Fig. 2 & Table S2.

3.3. The dynamics of COVID-19 VH

There has been a notable shift in the COVID-19 VH among mainland Chinese residents, with the rate of hesitancy increasing from 10.7% in the initial survey to 29.7% in the subsequent follow-up survey. In the participant flow screening diagram (Fig. 1), we listed all the participants' attitudinal transitions regarding hesitancy toward the COVID-19 vaccine as follows: hesitancy to hesitancy (406), hesitancy to acceptance (167), acceptance to acceptance (3613), and acceptance to hesitancy (1192). For the purpose of further analysis, we focused on the dynamics of participants transitioning from acceptance to hesitancy.

In the binary logistic regression model, we found that age, educational status, chronic disease, the history of allergic, physical activity, self-report health condition, public health prevention measures, awareness of COVID-19 vaccines, COVID-19 infection, the trust in medical staff, and the trust in developers were all independently associated with acceptance to hesitancy ($P < 0.05$). After adjustment for confounding variables, we found that participants who were older (40–49, ≥ 60), suffered from chronic disease, had lower levels of physical activity, took low levels of public prevention, had low levels of COVID-19 vaccine awareness, had COVID-19 infections, and had lower levels of trust in medical staff and vaccine developers were more likely

Table 1
Participant's socio-demographics in both the baseline and follow-up surveys.

Variables	Baseline survey (August 3 to 14, 2022)			Follow-up survey (February 1 to 18, 2023)		
	Total (%)	Hesitancy (%)	<i>P</i> value	Total (%)	Hesitancy (%)	<i>P</i> value
	5378	573(10.7)		5378	1598(29.7)	
Age, years			< 0.001			< 0.001
18-29	672(12.5)	74(11.0)	0.008	—	156(25.4)	
30-39	1455(27.1)	179(12.3)		—	468(32.8)	
40-49	1039(19.3)	95(9.1)		—	323(30.6)	
50-59	1145(21.3)	98(8.6)		—	280(24.8)	
≥60	1067(19.8)	127(11.9)		—	371(32.2)	
Gender			0.048			0.089
Male	2490(46.3)	243(9.8)		—	718(28.6)	
Female	2888(53.7)	330(11.4)		—	880(30.7)	
Ethnic groups			0.340			0.104
Han	5222(97.1)	560(10.7)		—	1564(29.9)	
Minority	156(2.9)	13(8.3)		—	34(23.6)	
Religion			0.911			0.122
Atheist	5129(95.4)	547(10.7)		—	1536(29.9)	
Others	249(4.6)	26(10.4)		—	62(25.3)	
Marital status			0.603			0.091
Married	4738(88.1)	501(10.6)		—	1433(30.1)	
Others	640(11.9)	72(11.3)		—	165(26.8)	
Educational status			< 0.001			< 0.001
Below high school	2327(43.3)	189(8.1)		—	624(26.8)	
High school graduate	1326(24.7)	155(11.7)		—	415(30.4)	
University graduate	1725(32.1)	229(13.3)		—	559(33.3)	
Chronic disease			< 0.001			< 0.001
Yes	850(15.8)	142(16.7)		914(17.0)	356(38.9)	
No	4528(84.2)	431(9.5)		4464(83.0)	1242(27.8)	
The history of allergic			< 0.001			< 0.001
Yes	399(7.4)	85(21.3)		363(6.7)	165(45.5)	
No	4400(81.8)	390(8.9)		4479(83.3)	1210(27.0)	
Unclear	5791(0.8)	98(16.9)		536(10.0)	223(41.6)	
Smoking status			0.041			0.038
Current smoker	1139(21.2)	105(9.2)		1089(20.2)	323(29.7)	
Former smoker	321(6.0)	45(14.0)		304(5.7)	110(36.2)	
Never smoker	3918(72.9)	423(10.8)		3985(74.1)	1165(29.2)	
Drinking status			0.021			0.018
Current drinker	1350(25.1)	138(10.2)		1357(25.2)	405(29.8)	
Former drinker	305(5.7)	47(15.4)		283(5.3)	105(37.1)	
Never drinker	3723(69.2)	388(10.4)		3738(69.5)	1088(29.1)	
Physical activity			< 0.001			< 0.001
Low level	933(17.3)	124(13.3)		1194(22.2)	448(37.5)	
Middle level	1679(31.2)	202(12.0)		1481(27.5)	485(32.7)	
High level	2766(51.4)	247(8.9)		2703(50.3)	665(24.6)	
COVID-19 infection			0.352			< 0.001
Yes	4(0.1)	1(25.0)		2928(54.4)	986(33.7)	
No	5374(9.9)	572(10.6)		2450(45.6)	612(25.0)	

to transition from acceptance to hesitancy ($P < 0.05$). Detailed results are all presented in [Fig. 3](#) & [Table S3](#).

3.4. Structural equation modeling

We constructed structural equation models to explore whether the PMT could explain the COVID-19 VH of participants in the follow-up population. The results showed acceptable applicability of the SEM with CFI = 0.930, TLI = 0.909, and RMSEA = 0.051 ([Table 2](#)). Matrix analysis showed that the five dimensions of the PMT correlated well with each other ($P < 0.001$) ([Table S4](#)). In addition, severity, susceptibility, barriers, and self-efficacy in the PMT influenced participants' hesitancy to receive the COVID-19 vaccine. Of these, severity ($\beta = 0.163$, $P < 0.001$) and barriers ($\beta = 0.148$, $P < 0.001$) had a facilitative effect on participants' hesitancy to receive the COVID-19 vaccine, and susceptibility ($\beta = -0.050$, $P = 0.024$) and self-efficacy ($\beta = -0.657$, $P < 0.001$) had a negative effect ([Fig. 4](#) and [Table 2](#)). In other words, participants with more severe COVID-19 epidemics, greater barriers to vaccination, weaker susceptibility, and lower self-efficacy were more hesitancy to vaccinate. In addition, severity, susceptibility, benefits, and vaccination barriers had a significant direct effect on self-efficacy ($\beta = 0.113$, $\beta = 0.070$, $\beta = 0.722$, $\beta = -0.516$, respectively; $P < 0.001$). Self-efficacy mediated the relationship between severity and COVID-19 VH ($\beta =$

0.163, $P < 0.001$). Similarly, it mediated the relationship between susceptibility, barriers, and COVID-19 VH, as ($\beta = -0.048$, $P = 0.024$) and ($\beta = 0.148$, $P < 0.001$) respectively. SEM results are visualized in [Fig. 4](#). SEM constructed in the baseline survey demonstrates the similar results ([Tables S5–S6](#), [Fig. S1](#)).

4. Discussion

This study focused on COVID-19 VH in a multi-center setting in mainland China and explored the dynamics of VH and its influencing factors during the COVID-19 pandemic through a continuous survey. The vast majority of participants (89.3%) in the baseline survey indicated a willingness to receive COVID-19 vaccine, with an additional 10.7% experiencing COVID-19 VH. The lower vaccine hesitation rate could be attributed to the Chinese government's enhanced vaccine supply during the COVID-19 pandemic by increasing the number of vaccination sites and continuous free supply, which increased the accessibility of vaccination services. In addition, strengthening vaccine regulation and focusing on the safety and efficacy of vaccines were also important initiatives to increase public confidence in vaccines ([Wang et al., 2023](#)). Finally, timely dissemination of information on vaccination through communication media during the period to reduce people's doubts was also shown to be an effective way to reduce vaccine

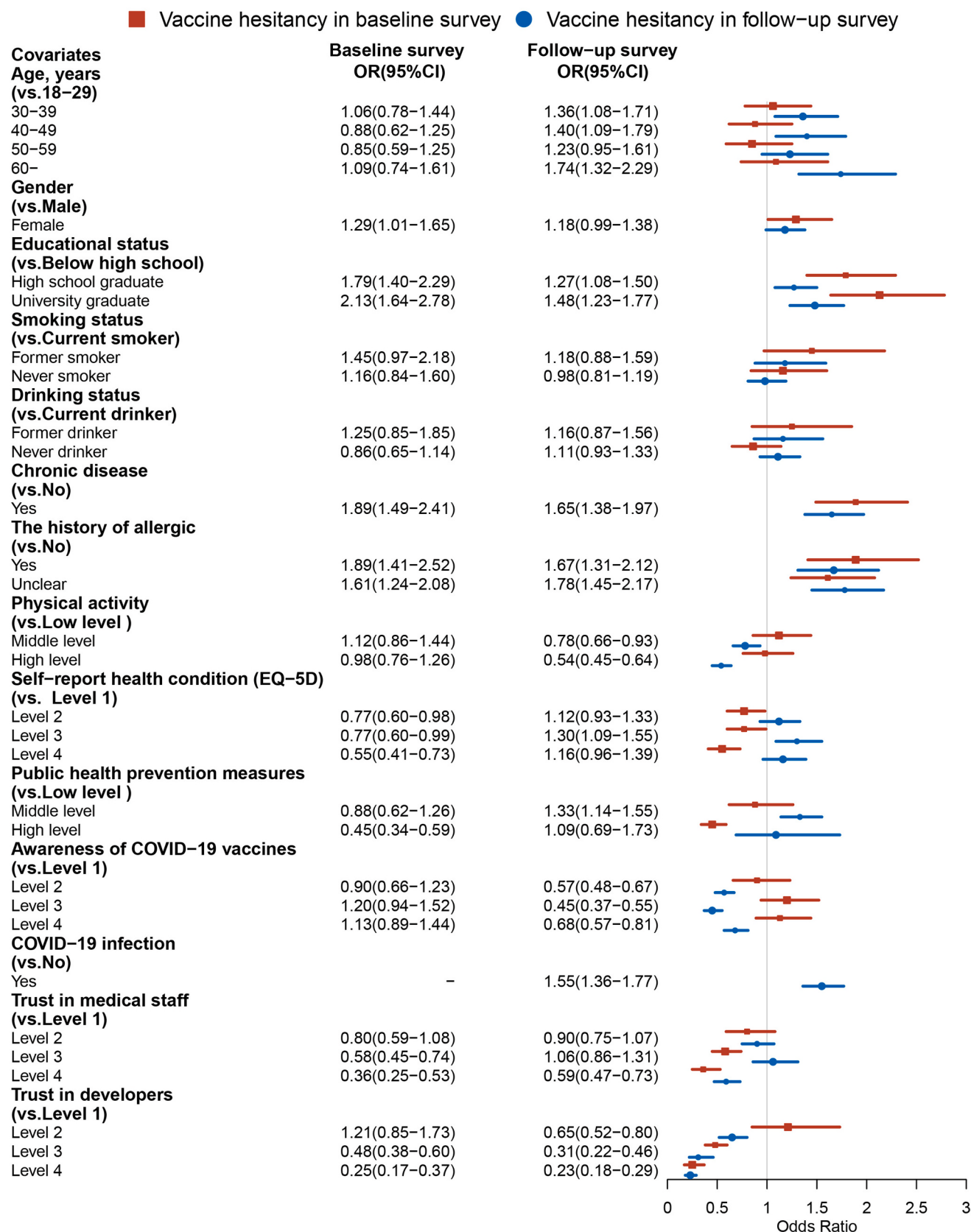


Fig. 2. The effect factors of VH in both the baseline and follow-up surveys.

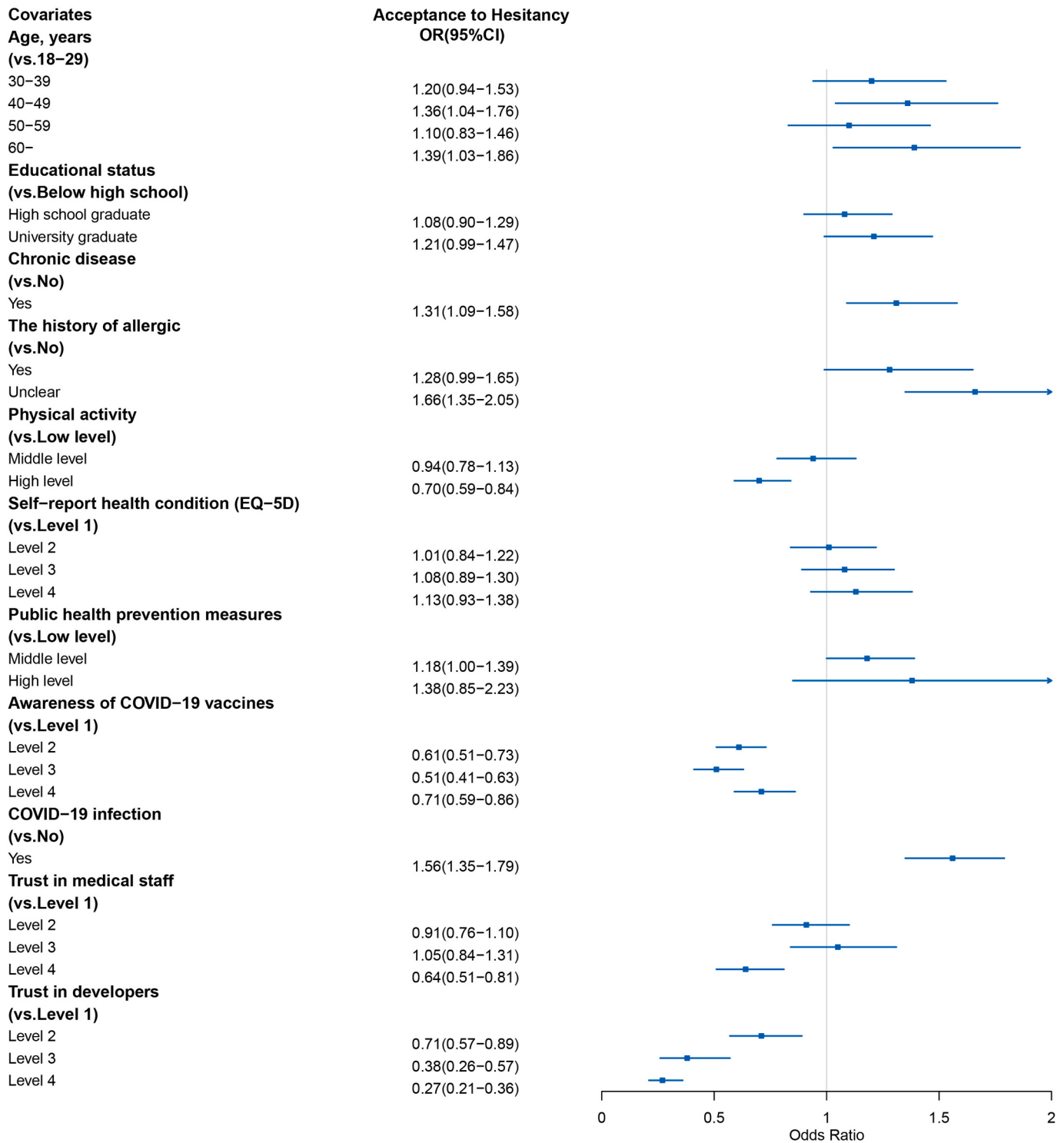


Fig. 3. Associations between COVID-19 vaccination acceptance to hesitancy transitions and characteristics of all participants.

hesitation in previous studies (Wu, Zhao, Wang, et al, 2022).

However, participants' hesitancy about the vaccine is changing dynamically. In the follow-up survey in February 2023, we found a vaccine hesitation rate of 29.7% among the same cohort of participants. This is most likely related to the introduction of the policy in mainland China in December 2022. China has managed COVID-19 with measures against Class B infectious diseases, instead of Class A infectious diseases, in a major shift of its epidemic response policies (Commission, 2022). The introduction of the new policy resulted in increased population mobility and a much higher chance of mutual infection. 2928 (54.4%) of

the 5378 participants developed COVID-19 infection, and of these, 986 (33.7%) were VH. The results suggest that COVID-19 infection was an important reason for the participants' hesitancy about the vaccine. Previous studies have shown that infection with a disease can cause the body to produce antibodies and that vaccination can cause the body to produce similar antibodies(Hsu, Huang, & Nguyen, 2023). Based on this knowledge, it may be tempting to simply assume that the body has acquired sufficient antibodies to fight the virus after infection, and that the COVID-19 vaccine is no longer needed. In addition, vaccine effectiveness has waned over time(Liang, Le, Wu, Sher, & McGuire, 2023), the

Table 2
Estimation results of the COVID-19 VH model (Follow-up survey).

Path	Unstandardized path coefficient(B)	Standardized path coefficients (β)	S.E.	Est./S.E.	P-Value
SE→VH	0.177	0.163	0.023	7.093	< 0.001
SU→VH	−0.050	−0.048	0.021	−2.255	0.024
BE→VH	−0.037	−0.026	0.027	−0.969	0.332
BA→VH	0.178	0.148	0.019	7.681	< 0.001
SFE→VH	−0.657	−0.513	0.021	−24.006	< 0.001
SE→SEF	0.081	0.113	0.012	9.595	< 0.001
SU→SEF	0.052	0.070	0.011	6.161	< 0.001
BE→SEF	0.406	0.722	0.005	137.971	< 0.001
BA→SEF	−0.335	−0.516	0.007	−69.187	< 0.001

occurrence of COVID-19 infection despite having received a booster dose of the COVID-19 vaccine undoubtedly raised concerns about the efficacy and necessity of the vaccine for participants (Xu et al., 2023). This is also likely to be an important reason for the significant rise in VH.

In this study, we also explored this dynamic fluctuation over time and the factors that influence it, using the example of acceptance to hesitancy. As was the case in prior studies of the factors driving reluctance, people with chronic conditions and lower levels of trust in medical staff and vaccine developers were more likely to go from acceptance

to hesitancy. Furthermore, a significant transition could be observed in the 40–49 and 60+ age groups, possibly because individuals in these age groups are more prone to VH due to the prevalence of chronic diseases (Hieber, Sprute, Eichenauer, Hallek, & Jachimowicz, 2022). It is highly noteworthy that COVID-19 infection was a significant factor in the transition from acceptance to hesitancy. Following a major restructuring of the national COVID-19 epidemic control policy, the population experienced a rapid increase in infection rates, which in turn generated COVID-19 VH (Commission, 2022; Wang et al., 2023).

In both the baseline and follow-up surveys, after adjustment for potential confounding variables, we found that participants with higher levels of education, chronic disease, a history of allergies, and lower levels of trust in medical staff and vaccine developers were more likely to be VH. Previous studies have found that people with higher levels of education instead exhibit higher VH (Lazarus et al., 2022; Wu, Ma, et al., 2023). This may be because people with higher levels of education tend to have higher health literacy and healthier lifestyles, so that they do not consider further vaccination. Another possible reason is that the well-educated population has more medical resources to protect themselves against the risk of disease (Wu, Ma, et al., 2023). People with chronic diseases (hypertension, diabetes, etc.) were often concerned about whether people with immunodeficiency and immunosuppression should be vaccinated(Hieber et al., 2022). They remain in a wait-and-see mode because they were confused as to whether having a chronic disease would cause adverse reactions to COVID-19 vaccination and whether vaccination would exacerbate the chronic disease process (Watanabe et al., 2022). This is consistent with the findings of our study as the same trend was seen in participants with a history of vaccination allergy. Previous experiences of vaccination allergy have made people

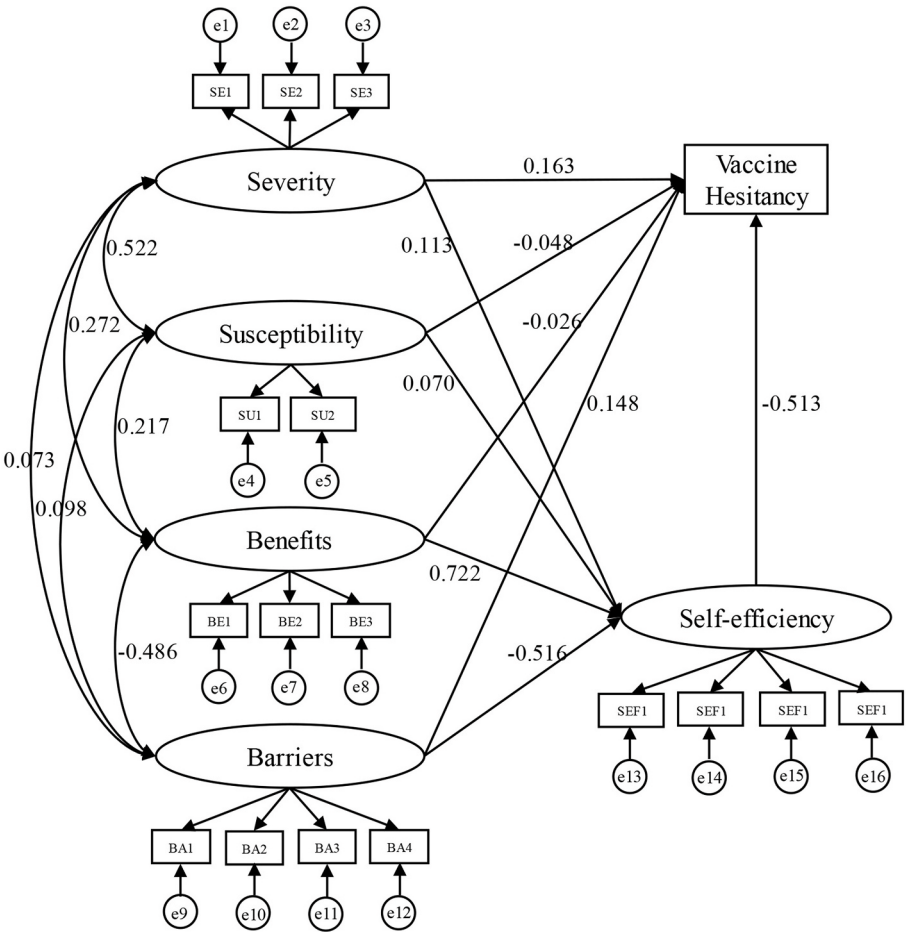


Fig. 4. SEM results on relationships of severity, susceptibility, benefits, barriers, self-efficacy and COVID-19 VH in the follow-up survey.

wary of the COVID-19 vaccine (Caballero & Quirce, 2021). They were unsure whether they would still experience an allergic injury after the COVID-19 vaccination (Li et al., 2021), so hesitancy about the vaccine was inevitable. This suggests that we need to pay extra attention to people with chronic diseases and a history of allergies in our vaccination efforts now and in the future. The most fundamental reason for VH is a lack of trust (Soorapanth, Cheung, Zhang, Mokdad, & Mensah, 2023). Mistrust of medical staff and vaccine developers has been shown to be an important factor in COVID-19 VH that cannot be ignored (Freeman et al., 2020). Medical staff are important promoters of vaccination and need to explain the significance and safety of the vaccine to the public in order to make people more willing to accept it. Therefore, better training of medical staff, enhanced communication between medical staff and the public, as well as increased public satisfaction with medical experience will effectively enhance mutual trust (Wu et al., 2021). Meanwhile, it would be meaningful for vaccine developers to disclose the test results and safety data of vaccines to the public in a timely manner, along as answer public concerns and questions about vaccines.

The findings of SEM suggest that the PMT is appropriately adapted. We found significant direct effects of severity, susceptibility, barriers, and self-efficacy on COVID-19 VH. The relationship between severity, susceptibility, barriers, and VH was mediated by self-efficacy. The results indicated that the less severe the COVID-19 epidemic, the lower the barriers to vaccination, the higher the susceptibility, and the higher the self-efficacy, the lower the VH. This is consistent with the findings of several previous studies on VH (Kharbanda & Vazquez-Benitez, 2022). Therefore, in order to reduce VH, the government and relevant authorities should take measures to reduce barriers to vaccination and improve access to vaccination services (Wu, Ma, Miao, et al., 2022). Providing evidence of vaccine safety and efficacy, improving the vaccination experience, and promoting the latest COVID-19 vaccination guidelines will be effective tools (Zheng et al., 2022). At the same time, appropriate educational activities, such as educating people about the benefits of vaccination from a population and individual perspective respectively, will increase motivation to get vaccinated (Liu et al., 2023). In addition, facilitating the timing of vaccination or policy support would greatly increase self-efficacy. Previous research has also highlighted that higher self-efficacy increases people's willingness to be vaccinated (Wu, Xia, et al., 2023). In summary, the PMT may provide an appropriate framework for developing interventions to reduce VH.

This study provides significant evidence of a causal association between VH and continuous follow-up in the same cohort. It is also the first nationwide multi-center continuous follow-up measurement in a household level. Stringent quality control measures were consistently applied throughout the study, ensuring the integrity of the data, which was found to be comprehensive and of significantly higher evidentiary value. However, this study has certain limitations. Firstly, the absence of standardized measurement tools for VH compelled the use of self-reported data, which introduces the potential for bias and subjectivity. As previously highlighted, the factors contributing to VH are multifaceted. While the utilization of the protection motivation theory (PMT) and structural equation modeling (SEM) provides a logical understanding, it falls short of providing a comprehensive analysis. In the future, a more comprehensive framework analysis encompassing perspectives from both policy and clinical medicine is imperative to address VH effectively.

5. Conclusions

The prevalence of COVID-19 VH was relatively low in the baseline survey and at a higher level in the follow-up survey respectively, with a significant increase in hesitancy rates among mainland Chinese residents. Implementing targeted measures aimed at individuals with higher levels of education, chronic diseases, a history of allergies, and prior COVID-19 infection can play a significant role in reducing VH. It is important to acknowledge that factors such as perceived severity,

susceptibility, vaccination barriers, and self-efficacy also play a substantial role in shaping COVID-19 VH. The theory of protective motivation provides a suitable framework for developing interventions to reduce VH rates. We must act to reduce the rate of VH by reducing barriers to vaccination, increasing trust in medical staff and vaccine developers, as well as the self-efficacy of the population to vaccinate.

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Ethical statement

This study was approved by the Life Science Ethics Review Committee of Zhengzhou University (Approval number: 2021-01-12-05).

CRediT authorship contribution statement

Mingze Ma: Writing – original draft, Software, Methodology, Investigation, Funding acquisition, Data curation. **Xiaoman Wu:** Writing – review & editing, Investigation. **Qiuping Zhao:** Supervision, Funding acquisition. **Rongmei Liu:** Supervision, Funding acquisition. **Quanman Li:** Methodology, Investigation, Data curation. **Xinghong Guo:** Software, Investigation. **Zhanlei Shen:** Investigation. **Clifford Silver Tarimo:** Writing – review & editing. **Yifei Feng:** Investigation. **Lipei Zhao:** Investigation. **Beizhu Ye:** Writing – review & editing, Supervision, Methodology. **Jian Wu:** Supervision, Resources, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Yudong Miao:** Supervision, Resources, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Abbreviations

COVID-19	Corona Virus Disease 2019
VH	Vaccine Hesitancy
WHO	World Health Organization
PMT	Protection Motivation Theory
SEM	Structural Equation Modeling
KMO	Kaiser-Meyer-Olkin
CI	Confidence Interval
OR	Odds Ratio

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ssmph.2023.101574>.

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