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RESEARCH ARTICLE

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COVID-19 vaccine hesitancy in Chinese residents: A national cross-sectional survey in the community setting

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ABSTRACT
Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) vaccine hesitancy is associated with community aggregation, inducing low vaccine coverage and potentially more frequent community-level outbreak. Addressing vaccine hesitancy in community settings should be a priority for healthcare providers. A cross-sectional online questionnaire survey was conducted during June and July 2022. Ten sites were set up in eastern, central, and western China, from where residents were recruited in a community setting. In total, 7,241 residents from 71 communities were included. Of the residents, 7.0% had refusal administration, 30.4% had delayed administration, and community clustering accounted for 2.4–3.7% and 8.5–9.6% of the variation, respectively. The reasons for primary-dose refusal were diseases, pregnancy, or lactation, whereas the main reasons for booster-dose refusal were diseases during the vaccination period, no time to vaccinate, and felt unnecessary to vaccinate. Younger age (under 40), female, residing in urban settings and having self-reported diseases were sociodemographic indicators of risk for refusal. In the health belief model of refusing to vaccinate, perceived barriers had a positive impact on refusal ($\beta = 0.08$), while perceived benefits had a negative impact ($\beta = -0.09$). In conclusion, this study underscores the population heterogeneity and community clustering of SARS-CoV-2 vaccine hesitancy. Targeted interventions for these high-risk groups are crucial to enhance vaccination coverage and prevent outbreaks. Public health strategies should address vaccine hesitancy at different stages and doses, while considering both individual beliefs and community dynamics.

HIGHLIGHTS

- Sociodemographic influences: Younger women in urban areas with health conditions were more likely to refuse or delay vaccination.
- Vaccine hesitancy behaviors in community: We focused on vaccine hesitancy behaviors rather than willingness or confidence, in a large community setting.
- Clustering of hesitancy: Vaccine hesitancy clustered within communities, with community variation accounting for 2.4%–3.7% for refusal and 8.5%–9.6% for delayed vaccination.
- Concerns in high-risk groups: We identified a gap between low vaccine acceptance in patients with severe diseases or comorbidities and the prioritization of these groups for vaccination.

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Vaccine hesitancy; COVID-19 vaccine; community; cross-sectional study

Background

Since 2019, the novel coronavirus disease 2019 (COVID-19) has had a devastating impact on global public health.[1] With the added benefit of lessening the severity of COVID-19, the vaccine against severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is an effective approach to preventing death.[2] Understanding the factors influencing COVID-19 vaccine uptake is crucial, as delays in vaccination can lead to the emergence and spread of new variants.[3]

Globally, COVID-19 vaccine acceptance has been a significant challenge, with varied rates of uptake across different countries and regions. A global review showed that 72 out of 114 countries/territories had acceptance rates ≥60%, while others, particularly low-income countries, had lower vaccination rates, exacerbating the spread of the virus. Efforts to increase vaccine coverage have been hampered by hesitancy, misinformation, and logistical challenges in many areas.[4] In contrast, China has achieved

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a high first-dose vaccination rate, with over 85% of the population receiving at least one dose by 2022. However, despite this progress, delayed vaccination, refusal of booster shots, and ongoing vaccine hesitancy remain significant challenges. These behaviors are particularly prevalent among certain demographic groups. Understanding these hesitancy drivers in China is crucial for developing targeted strategies to improve vaccine uptake, especially in vulnerable groups.

Vaccine acceptance, hesitancy, and refusal are influenced by complex factors, including sociodemographic characteristics (e.g., age, gender, socioeconomic status, geography) and concerns over vaccine safety or effectiveness.[5,6] Older adults tend to show lower vaccine acceptance compared to younger individuals.[7] For people with chronic conditions, barriers include perceived contraindications and a lack of awareness among healthcare providers.[8–10] World Health Organization (WHO) identified that the greatest benefits within the vaccination deployment will come from prioritizing full vaccination and boosters for high-risk populations – older adults, healthcare workers, persons with co-morbidities including immunocompromised persons.[11] Targeted campaigns tailored to these groups are essential, as they are often underserved by general public health campaigns.[12] In addition, vaccine hesitancy often clusters within communities, resulting in frequent outbreaks, thus improve the vaccination coverage and overcome vaccine hesitancy should be a precedence in communities, especially in priority groups.

The health belief model (HBM) posits that individuals are more likely to engage in health-promoting behavior when they perceive significant personal benefits and when barriers to that behavior are minimized. In the context of COVID-19 vaccination, perceived barriers refer to the obstacles individuals perceive in engaging in health-promoting behaviors, such as concerns over vaccine safety, fear of side effects, or logistical difficulties. These barriers can lead to hesitation or delay in vaccination, as observed in our study where a significant proportion of participants delayed their COVID-19 vaccination despite overall acceptance. On the other hand, perceived benefits involve the positive outcomes individuals expect from engaging in the behavior, such as protection from severe illness and contributing to herd immunity. The more individuals perceive these benefits – both personal and societal – the more likely they are to overcome barriers and proceed with vaccination. Thus, addressing these barriers through education while clearly emphasizing the benefits of vaccination can help reduce hesitancy and delay.

The objective of this study is to explore the factors influencing vaccine hesitancy in high-risk groups in China, with a particular focus on delayed vaccination and booster shots. This study aims to identify the key sociodemographic, health belief, and other barriers that contribute to vaccine hesitancy and to develop recommendations for improving vaccination uptake among these groups. Therefore, this study would conduct an in-depth study of vaccine hesitancy in the community of priority groups. Understanding the causes and influences of vaccine hesitancy through robust survey tools is critical for enhancing vaccine uptake.[13,14]

Methods

Sample and data

This study set up ten survey sites in eastern (Dezhou and Jining City), central (Harbin and Suzhou City), and western (Ngawa, Lanzhou, and Dingxi City) China and recruited participants from the community at each site during June and July 2022. In each city, six to eight communities or townships with a willingness to participate were randomly selected. Within each selected community or township, participants were recruited using convenience sampling.

The community service center was used to publicize the study and recruit study participants. Residents were invited to complete an electronic questionnaire via a link distributed through WeChat, a widely used instant messaging program with widespread use in China (WeChat, Copyright 1998–2023 Tencent, Shenzhen, China). By scanning the QR codes on promotional materials or clicking the link in the community's WeChat group, community members could complete the electronic questionnaire. For individuals without smartphones, an alternative was provided: staff members at the community service center assisted participants in completing the survey on their devices, which aimed to minimize selection bias by including residents who might not have access to WeChat or smartphones.

The inclusion criteria were adults aged ≥18 y, permanent residents of selected communities, and volunteering to participate in this study. Residents with impaired hearing, reading, comprehension, or expressions were excluded.

Ethical considerations

This study was approved by the Ethics Committee of Peking University Health Science Center (IRB00001052–22037), with an exemption from signed informed consent. The sign-free informed consent was obtained electronically via the online survey. Participants were provided with a study introduction on the first page. By selecting "Agree to participate," they indicated their consent before proceeding with the questionnaire. Participants were informed of their right to withdraw at any time without consequence. And the study data were anonymous to protect the privacy and confidentiality.

Measures of variables

- Vaccination behavior

The questionnaire collected whether the primary and booster doses of COVID-19 vaccines were administered and when they were administered to participants. Vaccination behavior was categorized as delayed or refusal behavior based on the definition of vaccine hesitancy, as defined below. Vaccine hesitancy is defined by the WHO Strategic Advisory Group of Experts (SAGE) as refusal or delayed vaccination despite the availability of vaccination services.[5,15]

Residents were defined as refusal vaccination if one of the following conditions was met: (1) have received vaccination notification of the primary dose but are not administered; (2) have received vaccination notification of the booster dose but are unadministered. Residents were defined as having delayed vaccination if one of the following conditions were met: (1) have received vaccination notification of primary dose but unadministered until 2 months or later; (2) have received vaccination notification of booster dose but unadministered until 2 months or later.

- Health belief scale

Eight items derived from the HBM were adopted to measure health beliefs about COVID-19 vaccination. The scale is composed of perceived threats, perceived benefits, and perceived barriers. All items are scored on a Likert scale (strongly disagree, disagree, neutral, agree, and strongly agree), as presented in Supplement 1. The reliability and validity could be accessed in Supplement 1. And according to test findings that are up to standard, the scale in residents has a stable structure and good internal-external consistency, which guarantees the scale applicability.

- Sociodemographic characteristics:

Seven questions on sociodemographic characteristics about age, sex, region, education, monthly income, and self-reported disease were collected. To make the dummy variables of sociodemographic characteristics more reasonable, age, educational attainment, and monthly income were reclassified. The heterogeneity tests for model fitting and model efficiency were constructed in Supplement 2–7 to evaluation of the effects of different sociodemographic classifications on the multifactor model. The final classifications of sociodemographic factors were illustrated below. Social demographic information included age (≤40 y old, 40–60 y old, and >60 y), region (urban or rural), sex (male or female), monthly income (≤2000 RMB, 2000–5000 RMB, or >5000 RMB per month), educational attainment (junior high school and below or senior high school and above), and self-reported diseases (No or Yes).

In accordance with Chinese regulations, people over 60 y of age were identified as elderly. Self-reported diseases were measured by a multiple-choice list including obesity, high blood pressure, hyperlipidemia, diabetes, cardiovascular disease, chronic lung disease, chronic liver disease, chronic kidney disease, cancer, immunological diseases, and others. Residents reporting one or more of these conditions were defined as having a self-reported disease.

Statistical analysis

To minimize missing and invalid data, the online questionnaire incorporated mandatory item checks and logical consistency validations. These measures ensured complete and valid responses, with no missing data in the final analysis.

A multi-stage sampling method was used in the survey. The sample size was calculated in Supplement 8. Binary logistic regression models were constructed to explain the effects of sociodemographic characteristics on vaccine hesitancy. Multilevel linear regression models were fitted to investigate differences in refusal and delayed administration among communities. The proportion of variation attributable to the community at the individual level was calculated using the variance partition coefficient (VPC) to measure community clustering. The variables of regression model were screened by stepwise regression method, and the inclusion threshold of P-values for variables was 0.05, the exclusion threshold was 0.1.

The reliability of the survey instrument was assessed using Cronbach's α coefficient and Composite Reliability (CR), with values ≥0.7 indicating acceptable internal consistency. Average Variance Extracted (AVE) was also calculated to measure the proportion of variance explained by latent variables to assess the convergent validity. Construct validity was evaluated through confirmatory factor analysis (CFA) within the structural equation modeling framework. Items with factor loadings ≥0.4 were considered to have sufficient validity, and model fit indices were checked to confirm the adequacy of the measurement model. Structural equation modeling (SEM) with maximum likelihood estimation was used to measure the relationship between health beliefs and vaccine hesitancy. The model fitting index should meet the following criteria if the proposed model is supported: goodness of fit index (GFI) > 0.90, comparative fit index (CFI) > 0.90, Tucker–Lewis index (TLI) > 0.90, root mean square error of approximation (RMSEA) < 0.08, and standardized root mean squared residual (SRMR) < 0.08. Under normality conditions, the skewness and kurtosis of the SEM normality test should ideally approximate zero. A sample is deemed non-normal if the skewness coefficient exceeds 3 or the kurtosis coefficient exceeds 8. When the kurtosis coefficient surpasses 20, it indicates a severe deviation from normality. Multigroup modeling based on SEM was employed to examine potential differences in the relationships between variables across distinct groups (e.g., gender, age). This approach allows for the comparison of model parameters across groups, testing for invariance in model structure.

Statistical analyses were performed using Stata 17.0 (Stata Corporation, College Station, TX, USA) and IBM SPSS Amos 26.0.0 (IBM Corporation, Armonk, NY, USA).

Results

Characteristics of delays and refusals of COVID-19 vaccination

A total of 7,241 residents from 71 communities in ten survey sites across eastern, western, and central China participated in this study. The analysis focused on the uptake of the inactivated COVID-19 vaccine, including two primary doses and one booster dose.

Overall, 7.0% of residents refused COVID-19 vaccination, and 30.4% experienced delays. After an initial delay, 2.0% remained unvaccinated. The refusal rate for the primary dose was 2.8%, with a 24.9% delay rate, whereas for the booster dose, the refusal and delay rates were 4.4% and 15.1%, respectively. Vaccine hesitancy varied by age and residential setting: residents under 60 had higher refusal (7.9%) and delay rates (33.6%) compared to those over 60 (refusal: 5.6%, delay: 25.7%). Urban residents had significantly higher refusal (9.7%) and delay rates (41.0%) than rural residents (5.7%

Table 1. Rate of refused and delayed COVID-19 vaccination.

	Refused vaccination		Delayed vaccination	
Category	n	Proportion (%)	n	Proportion (%)
All residents				
All dose	505	7.0	2201	30.4
Primary dose	202	2.8	1804	24.9
Booster dose	303	4.4	986	15.1
Residents under 60 y old				
All dose	337	7.9	1439	33.6
Primary dose	115	2.7	1189	27.8
Booster dose	222	5.5	598	15.6
Residents above 60 y old				
All dose	168	5.7	762	25.7
Primary dose	87	2.9	615	20.8
Booster dose	81	2.9	388	14.4
Urban residents				
All dose	226	9.7	954	41.0
Primary dose	77	3.3	789	33.9
Booster dose	149	6.9	474	23.5
Rural residents				
All dose	279	5.7	1247	25.4
Primary dose	125	2.6	1015	20.7
Booster dose	154	3.3	512	11.4

refusal, 25.4% delay) (Table 1). Multilevel model results showed that, the VPC attributable to the community for refused administration was 3.1%, of which 3.7% for the primary dose and 2.4% for the booster dose. VPC attributable to the community for delayed administration was 9.6%, with 8.6% for the primary dose and 8.5% for the booster dose.

Among the 202 residents who refused the primary dose, the main reasons were self-reported diseases, pregnancy, or lactation, while for the 303 residents who refused the booster dose, the primary concerns were self-reported diseases, lack of time, and perceived lack of necessity (Figure 1). Regional differences were observed in rural areas, primary-dose refusal was mostly due to self-reported diseases, while in urban areas, self-reported diseases, lack of time, and perceived lack of necessity were key reasons for refusal (Figure 1(a)). Age-stratified analysis revealed that among individuals under 60 y old, primary refusal was driven by self-reported diseases (9.3‰) and pregnancy (7.9‰), while booster hesitancy was mainly due to lack of time (11.9‰), perceived lack of necessity (7.9‰), and pregnancy (7.0‰). Among those over 60 y old, self-reported diseases were the leading cause of refusal for both doses (Figure 1(b)). Common health conditions preventing vaccination included hypertension, cancer, and cardiovascular disease, with specific patterns varying between the primary and booster doses (Figure 1(c,d)).

Influencing factors of COVID-19 vaccine hesitancy

The sociodemographic characteristics of the residents are shown in Table 2. The univariate analysis indicated that refusal behavior was associated with younger age (≤40), female gender, urban residence, higher educational attainment, higher income, and self-reported diseases. While delayed behavior was only associated with age, regions, educational attainment, and monthly income.

Stepwise logistic regression suggested that for the primary dose, refusal was more likely among individuals with no self-reported diseases (OR = 0.20) and older age (OR = 0.32–0.38), followed by middle-income (OR = 0.70) and male gender (OR = 0.40). For booster refusal, the most influential factors were older age (OR = 0.17–0.23), self-reported diseases (OR = 0.31), urban residence (OR = 0.42), middle-income (OR = 0.69), and higher education (OR = 0.73). (Figure 2(a))

For delayed primary doses, factors included younger age (OR = 0.59–0.66), rural residence (OR = 0.53), senior high-school education (OR = 1.22), and absence of comorbidities (OR = 0.59); Delay of booster doses was influenced by younger age (OR = 0.78–0.79), male sex (OR = 0.82), urban residence (OR = 0.45), higher income (OR = 1.22–1.36), and no self-reported diseases (OR = 0.82). (Figure 2(b))

The results of the second-order additive interaction test showed that age and sex (RERI = −0.44; 95%CI = −0.75, 0.22), income and living areas (RERI = −0.70; 95%CI = −1.21, −0.18) had antagonistic additive effects and reduced the total delay behavior. (Supplement 9) The notable additive interactions with significant effects would be visualized by the fitted regression plots. (Supplement 10)

Construction of health belief models for COVID-19 vaccine hesitancy

Cronbach's α coefficients of perceived threat, perceived benefit, and perceived barrier were 0.844, 0.839, and 0.793, respectively. The factor loads of each item in the refused-vaccination model ranged from 0.442 to 0.933, and those in the delayed vaccination model ranged from 0.437 to 0.933, indicating the acceptable structural validity of the model (Supplement 1). The fitting indices of the two models were RMSEA = 0.06, GFI = 0.98, CFI = 0.98, and RFI = 0.96. The results of the normality test for the SEM model in this study revealed that the skewness ranged from 0.07 to 2.43, and the kurtosis ranged from 1.27 to 5.70. These values fall within acceptable limits, suggesting that the sample distribution approximates normality. In the model constructed based on health beliefs of refusing vaccination, there was a positive impact on vaccine hesitancy from perceived barriers (β = 0.08) and a negative impact from perceived

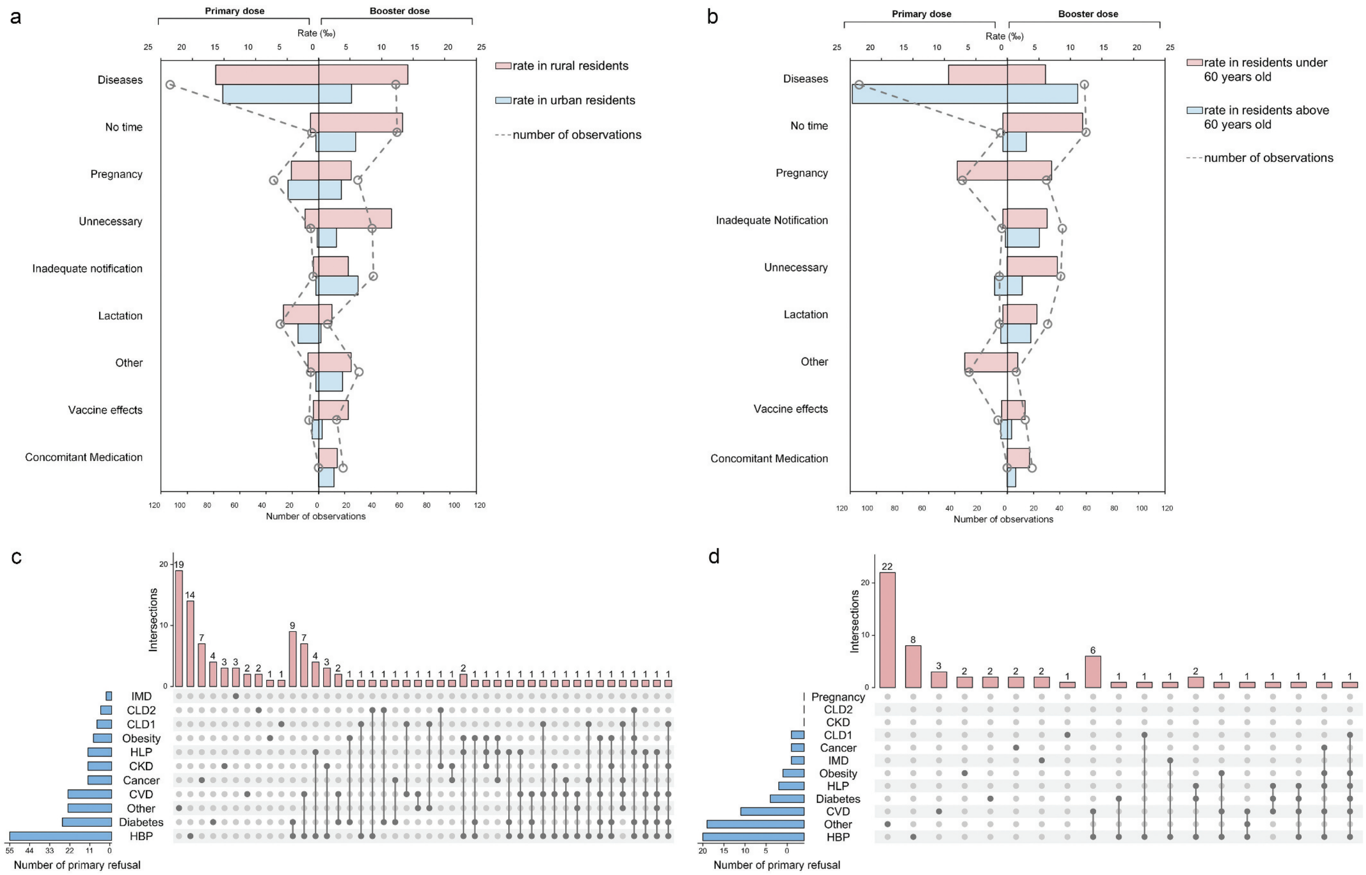

Figure 1. The reasons for the refusals of SARS-CoV-2 vaccination. (a) The reasons for the refused vaccination stratified by region. The bars represented the incidence of each cause, and the dashed lines represent the number of each cause. (b) The reasons for the refused vaccination stratified by age. The bars represented the incidence of each cause, and the dashed lines represent the number of each cause. (c) The existence and co-existence of self-reported diseases among residents who refused the primary administration due to disease. (d) The existence and co-existence of self-reported diseases among residents who refused the booster administration due to disease. Abbreviation: HBP, high blood pressure; CVD, cardiovascular disease; CKD, chronic kidney disease; HLP, hyperlipidemia; CLD1, chronic lung disease; CLD2, chronic liver disease; IMD, immunological diseases.

Table 2. Basic characteristics of participants.

		Refused vaccination		Delayed vaccination	
Variables	n	Frequency (%)	P (Wald. Test)	Frequency (%)	P (Wald. Test)
Age			<0.001		<0.001
<60	4280	337 (7.87)		1439 (33.62)	
≥60	2961	168 (5.67)		762 (25.73)	
Sex			<0.001		0.165
Male	3178	168 (5.29)		939 (29.55)	
Female	4063	337 (8.29)		1262 (31.06)	
Region			<0.001		<0.001
Urban	2330	226 (9.70)		954 (40.94)	
Rural	4911	279 (5.68)		1247 (25.39)	
Education			0.004		<0.001
Junior and below	5016	321 (6.40)		1338 (26.67)	
Senior and above	2225	184 (8.27)		863 (38.79)	
Income			0.006		<0.001
<5000 RMB	6345	423 (6.67)		1866 (29.41)	
≥5000 RMB	896	82 (9.15)		335 (37.39)	
Diseases (self-reported)			<0.001		0.452
No	4526	217 (4.79)		1390 (30.71)	
Yes	2715	288 (10.61)		811 (29.87)	

benefits (β=-0.09). In the model constructed based on health beliefs about delayed vaccination, there was a positive impact on vaccine hesitancy from perceived barriers (β = 0.10) and a negative impact from perceived benefits (β=-0.10) (Figure 3).

To estimate the moderating effect of demographic statistical variables in the SEM, we conducted multigroup models of age, sex, region, and self-reported disease, as shown in Supplement 11. The fitting indices of the multigroup models were RMSEA = 0.04–0.05, GFI = 0.97–0.98, CFI = 0.97–0.98, and RFI = 0.95–0.96, which indicated a good model fitting. The group estimates showed the same significance and direction of paths as the main model, but the differences in subgroups had

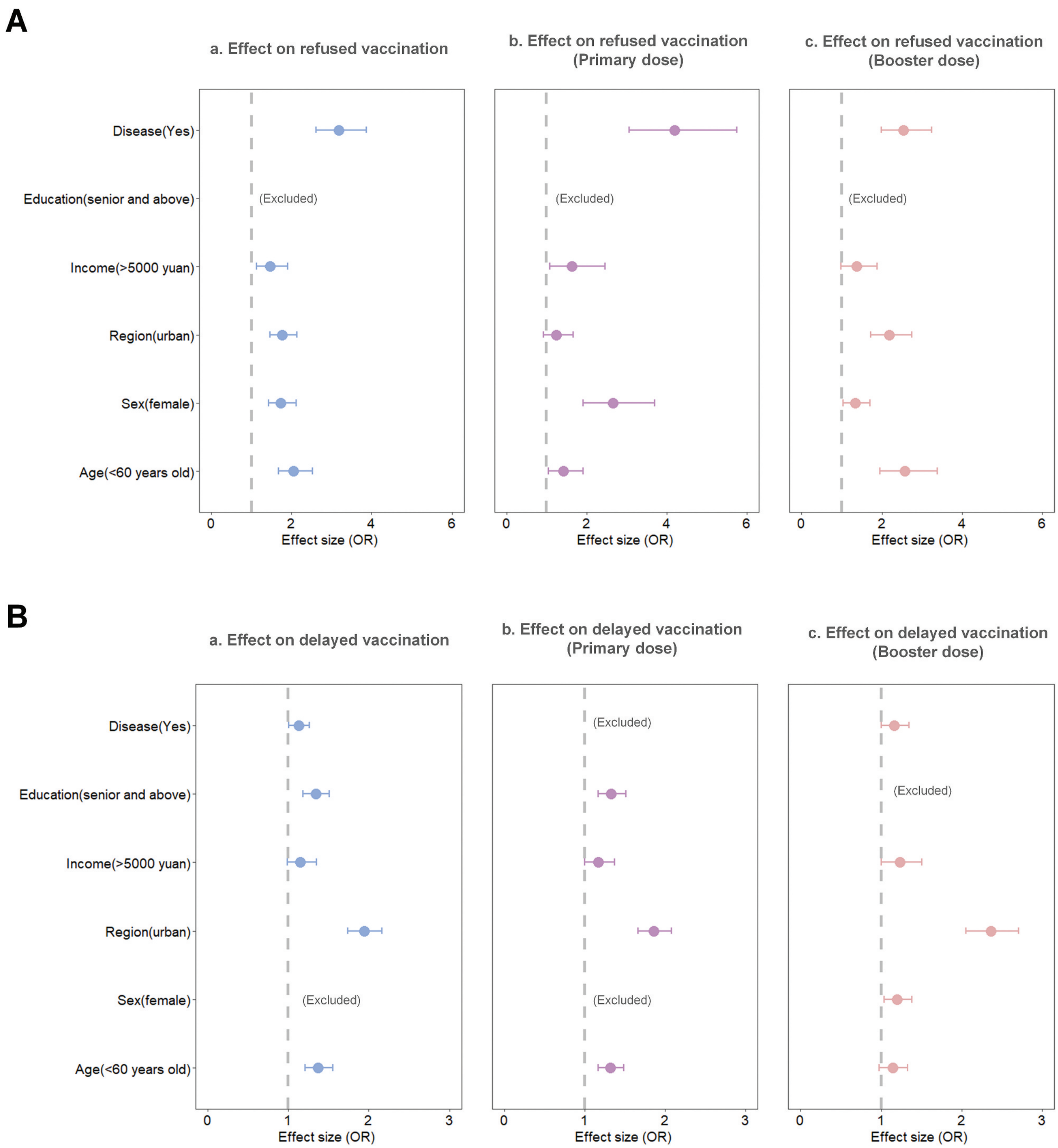

Figure 2. The forest plots of stepwise logistic regressions on the influencing factors of COVID-19 vaccine hesitancy. (a) Logistic regression of effects on refused vaccination. (b) Logistic regression of effects on delayed vaccination.

significant moderating effects on refusal and delayed behavior ($p < .05$). Elder residents aged 60 and above had a greater perception of benefit and less perception of barriers than those under 60 in the refused models (−0.098 vs. −0.078, 0.071 vs. 0.089), while they had more perception of benefits and barriers in the delayed model (−0.135 vs. −0.104, 0.098 vs. 0.084). Similarly, male residents had a greater perception of benefit and less perception of barriers than females in the refused models (−0.096 vs. −0.084, 0.060 vs. 0.088), and more perception of benefits and barriers in the delayed model (−0.117 vs. −0.110, 0.114 vs. 0.079). Residents without self-reported diseases had less perception of benefits and barriers than those with diseases in the refused models (−0.090 vs. −0.096, 0.067 vs. 0.104), and more perception of benefit and less perception of barriers in the delayed model (−0.124 vs. −0.119, 0.096 vs. 0.150).

Discussion

Refusal is a tip of massive iceberg for delayed administration

Vaccine hesitancy has a negative impact on the control of infectious diseases.[16] Although the COVID-19 pandemic is

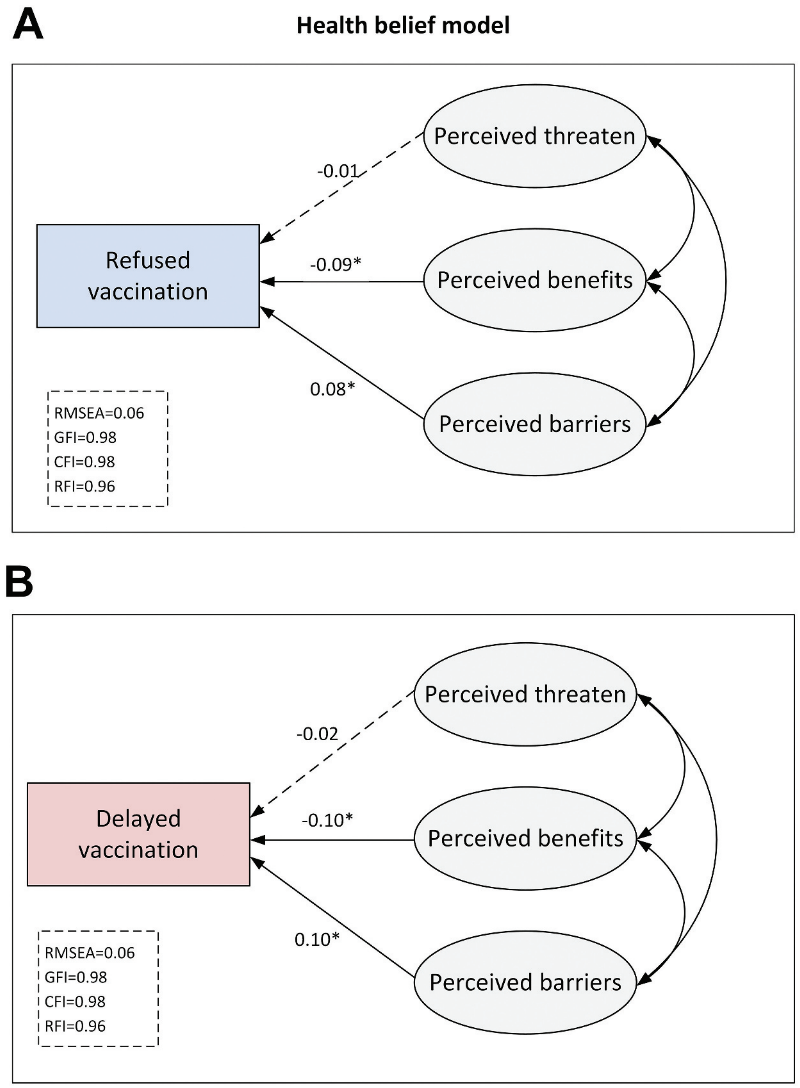

Figure 3. Health belief of COVID-19 vaccine hesitancy based on structural equation model. (a) Health belief model of refused vaccination (*$p < .05$). (b) Health belief model of delayed vaccination (*$p < .05$).

effectively under control in China, it remains highly vulnerable to the spread of imported SARS-CoV-2.[17] China has gradually expanded the coverage of COVID-19 vaccine from key population to the whole population since the end of 2020 and started booster administration around October 2021. Therefore, this investigation was based on China's nationwide vaccination of primary and booster doses. Thus, the highlight of this study was that real refusal and postponement behaviors could be collected rather than vaccination intention or wiliness, which had great variability. Considering the potential clustering nature of vaccine hesitancy, in this study, we conducted a survey of vaccine-related behavior at the community level and used an HBM for evaluation.

In this study, 7.0% of the residents refused to receive the COVID-19 vaccine, 30.4% had delayed administrations, and the variation attributable to community clustering was 2.4–3.7% and 8.5–9.6%, respectively. Previous studies on COVID-19 vaccine acceptance in China have reported relatively low refusal rates, with some studies noting figures as low as less than 10%,[18,19] which was lower than in most countries.[20,21] In contrast, global studies have highlighted higher refusal rates, with the average rate of vaccine hesitancy exceeding 20%.[21] For instance, a study in the United States found a refusal rate of approximately 30%, while some European countries reported even higher figures.[22,23] This trend is consistent with findings from other regions, such as parts of the Middle East and Eastern Europe, where vaccine hesitancy has been attributed to factors including political polarization, misinformation, and lower trust in government health agencies.[24,25] In comparison, China's vaccine hesitancy has generally been lower, possibly due to strong government advocacy, widespread public health campaigns, and the overall public trust in the national healthcare system.[26] However, these studies often overlook the issue of delayed vaccination, which is a key focus of this research. In comparison, the delayed vaccination rate in this study is found to be four to five times higher than the refusal rate, suggesting that while most residents ultimately agree to receive the vaccine, significant hesitancy and delays persist. This finding aligns with a growing body of literature highlighting the importance of addressing vaccine hesitancy beyond outright refusal.[27–29]

While the overall vaccine refusal rate in China remains relatively low, this study emphasizes that delayed vaccination could serve as a hidden risk factor, leaving room for pathogen transmission despite widespread vaccine uptake.[30] This issue has been less explored in the literature, and our study contributes to the understanding of vaccine hesitancy by identifying delayed vaccination as a critical component that warrants further attention from health policymakers.

Factors contributing to vaccine hesitancy are variable and interactive

We identified that vaccine hesitancy was associated with lower age, female gender, living in urban communities, and having underlying diseases, which was similar to previous studies.[31,32] However, there were varying degrees of correlation between income and education with vaccine hesitancy.[33] Residents living in urban or with greater levels of education and middle-high incomes may be more likely to acquire administrations, but also more prone to put off getting their shots. The effects of education and income on vaccine hesitancy tend to be non-linear and complex, presumably because the groups make more trade-offs before making decisions to improve the effectiveness of it. It also confirmed that the potential mechanisms of vaccine hesitancy were extremely complex and that effective responses should be implemented simultaneously.[34] At the same time, the interaction between the factors can synergistically increase the risk and consequences of vaccine hesitancy.

This study applied the HBM to assess COVID-19 vaccine hesitancy, focusing on threat, barrier, and benefit perceptions. HBM was widely used in vaccine hesitancy research, emphasizing individual health beliefs about risks and benefits. Compared to other models, such as the Theory of Planned Behavior (TPB) and Social Cognitive Theory (SCT), HBM is more focused on health threat perceptions and easier to understand, which are particularly relevant in the context of a health crisis like COVID-19.[35] The items used in this study align with key HBM constructs but also reflect unique concerns raised by the pandemic, such as the perception of virus transmission velocity and the long-term effects of COVID-19.[36] These items focus on perceived severity and susceptibility. And similar items on vaccine efficacy and safety were also used in other studies.[37] This difference in vaccine acceptance may stem from residents' health beliefs, particularly their perceptions of vaccine benefits and barriers.[38] Research indicates that individuals with higher perceived barriers (e.g., safety concerns) or lower perceived benefits are more likely to delay or refuse vaccination.[37] Trust in vaccine safety plays a crucial role, as individuals are more likely to vaccinate if they believe the vaccine is safe and effective.[39] This aligns with previous studies that have applied the HBM to predict various health behaviors, including vaccination.

Considering the global COVID-19 pandemic, the perception of disease threat and the expectation of vaccine efficacy promoted the rapid realization of the primary-dose coverage target in the early stage.[32,40] It can be concluded that most of the reasons for refusing the primary dose were their own health problems, pregnancy/lactation, and other objective physical factors (although most of these are not contraindications for COVID-19 vaccines). However, the reasons for refusal of booster dose were more due to the convenience of vaccination, such as inadequate notice and time, or personal willingness, and the contribution of sociodemographic factors such as region and age to the booster dose. The findings suggest that vaccine promotion activities need to be flexible, and we need to understand that the needs and willingness of the residents vary greatly at different stages of the epidemic of disease and implementation of health policy.[41] Furthermore, these patients with severe diseases or comorbidities should be the priority for vaccination and would benefit more from vaccines. However, this study and previous ones have shown a contradiction in that they were more likely to refuse vaccination. This study identified concerns regarding the contradiction, which could be explained as a higher perceived barrier offsetting slightly higher perceived benefits when refusing, and a higher barrier perception combined with a lower benefit perception when delaying.

It is worth noting that females in this study had higher levels of vaccine hesitancy than males, both in terms of refusal and delay. And there was a synergistic interaction between females and younger age, which increased the risk of delayed vaccination in the younger female group. However, the association between sex and vaccine hesitancy is indeterministic. Previous studies suggested that males were more likely to refuse vaccination because of their higher belief in conspiracy theories, which was contrary to our study.[18]

Rational publicity and reduction of avoiding misinformation are pivotal for policymakers

COVID-19 has been effectively controlled in China with the improvement of emergency response measures and systematic government control policies.[42] The perceived threat of disease would be downplayed,[40] which was exactly what the government needs to be vigilant about. In middle-income and low-income countries with poor health infrastructure and scarce health resources, the cross-country spread and new variants of SARS-CoV-2 remained a major threat to public health in the event of another pandemic.[3] Efforts to address vaccine hesitancy should be cross-regional in nature. Because misinformation may be affecting and hindering COVID-19 vaccination in different regions faster than the viral transmission, aided by the Internet and social media.[43] In addition, overemphasizing the role of vaccination in containing the pandemic should be discouraged in government propaganda and doctor-patient communication, which may be detrimental to risk mitigation. Vaccination is a crucial component of non-pharmaceutical interventions, but additional steps, such as mask use, good hygiene, or physical distancing, are also necessary.[44]

Given the unexpectedly high rate of delayed vaccinations observed in this study, it is crucial for policymakers and public health practitioners to implement targeted interventions. While vaccine refusal rates in China remain relatively low, the substantial delay in vaccination suggests that many individuals, despite eventually consenting to vaccination, hesitate due to concerns regarding vaccine safety and efficacy.

To address this, it is essential to enhance public health campaigns that focus on the safety and benefits of vaccination, particularly at the community level, where community health workers can play a pivotal role in educating the public and addressing vaccine-related concerns.[45,46] Furthermore, the implementation of a personalized vaccination reminder system is recommended to track delayed vaccinations and send timely notifications through text messages, phone calls, or mobile applications.[47] Policymakers should also prioritize post-vaccination safety monitoring and establish transparent feedback mechanisms to foster public trust in vaccines.[48] In regions with higher rates of delayed vaccination, targeted interventions – such as extended vaccination hours, additional vaccination sites, and incentives – could be particularly effective.[49] Additionally, strengthening the training of primary health workers is vital, as they serve as the primary point of contact for residents and are instrumental in alleviating vaccine hesitancy through effective communication.[49,50] By adopting these strategies, policymakers and public health professionals can mitigate delayed vaccinations and enhance overall vaccination uptake. Future research should explore the long-term impact of these interventions and identify other effective strategies tailored to specific demographic groups to further enhance vaccination uptake.

This study had some limitations. First, the existence and coexistence of diseases were based on the self-report of residents rather than the diagnosis of doctors; therefore, we were not able to accurately exclude inaccessible residents with vaccine contraindications. Second, the administration time, which is based on the recall of residents, left recall bias because of the unacceptable inoculation certificate. The primary doses became widely available in December 2020, and booster doses were introduced in October 2021. The survey was conducted in 2022, meaning participants had to recall their vaccination decisions made approximately 1 y earlier. This recall period may have introduced some bias, particularly among older participants or those who delayed vaccination. Third, good reliability and validity indicate that this questionnaire has good internal-external consistency in the survey population, but its robustness in the application of other population or in other areas still needs more practice to verify. Fourth, stepwise selection has a higher chance of type I error, but this can be circumvented by also coupling the selected variables with factors outlined in the literature. Fifth, nonrandom cluster sampling based on the community makes the sample less representative than random sampling. And the results would be biased toward those who had time and were able to complete the survey, therefore not capturing responses from a whole subset of the population. Additionally, while WeChat provided a convenient platform for recruitment and data collection, its use may introduce selection biases. It is primarily accessed by individuals with smartphones and basic digital literacy, potentially excluding groups with lower technological proficiency, who may have different views or behaviors. To minimize missing and invalid data, the online questionnaire incorporated mandatory item checks and logical consistency validations, and participants were prompted to correct any inconsistencies before submission. While these checks helped mitigate missing data, it is important to acknowledge that response biases, such as social desirability bias or self-selection bias, could still influence the results. The use of mandatory questions may also have led to some participants providing forced or less thoughtful responses. Finally, the big COVID-19 outbreak in China occurred between December 2022 and February 2023, prior to which the infection rate in the Chinese population was extremely low. We therefore did not consider this portion of the group with overlapping infections.

Conclusion

Vaccine hesitancy, encompassing both refusal and delayed vaccination, signals a critical need for more targeted vaccination campaigns, particularly for COVID-19 and other vaccine-preventable diseases. Based on our findings, public health policies should prioritize tailored interventions to address vaccine hesitancy. Specifically, targeted health education campaigns are needed to counteract misinformation and perceived barriers, particularly in communities with higher rates of delayed vaccination. These campaigns should provide clear, accurate, and scientifically grounded information on vaccine safety and efficacy. Given the complex and diverse reasons for vaccine hesitancy across demographic groups, interventions must be adapted to specific populations, considering factors such as age, education, and geographic location. For example, messaging for younger individuals may differ from that for older adults or rural populations facing greater logistical challenges.

Policy development should focus on increasing investment in healthcare infrastructure to ensure equitable access to vaccination, especially in underserved areas. Practical measures, such as financial incentives or mobile vaccination units, can help overcome barriers and encourage timely vaccination. By implementing these tailored strategies, policymakers can more effectively reduce vaccine hesitancy, increase vaccination uptake, and protect public health.

Disclosure statement

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Author contributions

CFQ designed the study. ZTS, LYQ, and LQB designed the survey instrument. SXH, WL, HY, LXK, WZY, LH, ZSH, CLY, and CXM all contributed to the conceptual design of the research and to the data collection. ZTS conducted the statistical analysis and wrote the manuscript.

Data availability statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethical considerations

This study was approved by the Ethics Committee of Peking University Health Science Center (IRB00001052–22037). Before completing the online questionnaire, the participants were informed that their participation was voluntary, and that their informed consent was obtained by submitting the questionnaire. The study data were anonymous to protect the privacy and confidentiality.

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