Health belief model perspective on the control of COVID-19 vaccine hesitancy and the promotion of vaccination: a web-based cross-sectional

Hao Chen, Xiaomei Li, Xiaoxi Liu, Yimeng Mao, Ruru Wang, Junming Dai, Junling Gao, Hua Fu, Pinpin Zheng, Qianyi Xiao, Yingnan Jia

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Table of Contents

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Abstract

Background: The control of vaccine hesitancy and the promotion of vaccination are key protective measures against COVID-19.

Objective: This study assesses the prevalence of vaccine hesitancy and the vaccination rate and examines the association between factors of the health belief model and vaccination.

Methods: A convenience sample of 2,531 valid participants from 31 provinces and autonomous regions of mainland China were enrolled in this online survey study from January 1st to 24th, 2021. Multivariable logistic regression was used to identify the associations of the vaccination rate and health belief model factors with the prevalence of vaccine hesitancy after other covariates were controlled.

Results: The prevalence of vaccine hesitancy was 44.3% (95% CI: 42.3%-46.2%), and the vaccination rate was 10.4% (9.2%-11.6%). The direct promoting factors of vaccination were a lack of vaccine hesitancy (OR=7.75, 95% CI: 5.03-11.93), agreement with recommendations from friends/family for vaccination (OR=3.11, 95% CI: 1.75-5.52) and agreement with the vaccination of friends/family (OR=4.88, 95% CI: 3.41-6.99). The factor associated with a lower vaccination rate was a high level of perceived barriers to COVID-19 vaccination (OR=0.51, 95% CI: 0.35-0.75). Furthermore, high perceived barriers to vaccination (OR=1.63, 95% CI: 1.36-1.95), high perceived benefits of vaccination (OR=0.51, 95% CI: 0.32-0.79), high self-efficacy for vaccination (OR=0.41, 95% CI: 0.32-0.79) and agreement with recommendations from authorities (OR=0.74, 95% CI: 0.57-0.98) were associated with vaccine hesitancy and were indirectly correlated with vaccination.

Conclusions: It may be beneficial to increase the vaccination rate by reducing vaccine hesitancy and perceived barriers to vaccination and encouraging volunteers to advocate vaccination to their friends and family members. It is also important to reduce vaccine hesitancy by enhancing self-efficacy for vaccination and the perceived benefits of the COVID-19 vaccine.

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Health belief model perspective on the control of COVID-19 vaccine hesitancy and the promotion of vaccination: a web-based cross-sectional study in China

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Abstract

Background: The control of vaccine hesitancy and the promotion of vaccination are key protective measures against COVID-19. Objective: This study assesses the prevalence of vaccine hesitancy and the vaccination rate and examines the association between factors of the health belief model and vaccination. **Methods:** A convenience sample of 2,531 valid participants from 31 provinces and autonomous regions of mainland China was enrolled in this online survey study from January 1st to 24th, 2021. Multivariable logistic regression was used to identify the associations of the vaccination rate and health belief model factors with the prevalence of vaccine hesitancy after other covariates were controlled. **Results:** The prevalence of vaccine hesitancy was 44.3% (95% CI: 42.3%-46.2%), and the vaccination rate was 10.4% (9.2%-11.6%). The direct promoting factors of vaccination behaviour were a lack of vaccine hesitancy (OR=7.75, 95% CI: 5.03-11.93), agreement with recommendations from friends/family for vaccination (OR=3.11, 95% CI: 1.75-5.52) and absence of perceived barriers to COVID-19 vaccination (OR=0.51, 95% CI: 0.35-0.75). The direct factors associated with a higher vaccine hesitancy rate were a high level of perceived barriers (OR=1.63, 95% CI: 1.36-1.95), and perceived benefits (OR=0.51, 95% CI: 0.32-0.79). A mediating effect of self-efficacy, influenced by perceived barriers (SSC = −0.71, $p < 0.001$), perceived benefits (SSC = 0.58, $p < 0.001$), agreement with recommendations from authorities (SSC = 0.27, $p < 0.001$), and agreement with recommendations from friends/family (SSC = 0.31, $p < 0.001$), was negatively associated with vaccination (SSC = −0.45, $p < 0.001$), via vaccine hesitancy (SSC = −0.32, $p < 0.001$).

Conclusion: It may be beneficial to increase the vaccination rate by reducing vaccine hesitancy and perceived barriers to vaccination and encouraging volunteers to advocate vaccination to their friends and family members. It is also important to reduce vaccine hesitancy by enhancing self-efficacy for vaccination due to its crucial mediating function.

Keywords: COVID-19 pandemic; vaccination behaviour; vaccine hesitancy; health belief model

Introduction

Coronavirus disease 2019 (COVID-19) has spread worldwide, causing more than 88 million infections and more than 1.9 million deaths as of January 2021[1]. Due to the lack of effective treatments, the development and use of a new COVID-19 vaccine has become an important strategy to control the epidemic. Since COVID-19 broke out, according to the World Health Organization (WHO), 60 new coronavirus inactivated vaccines, and more than 10 nucleic acid vaccines, vector vaccines, and protein subunit vaccines have been developed[2]. Vaccination is recognized as the most successful and cost-effective public health intervention in the world today, and it has made a very large contribution to improving global health by reducing the incidence and deaths of many infectious diseases[3, 4]. China and whole world are experiencing the second wave of epidemics, so it is especially important to get herd immunity by vaccinating COVID-19[5].

On 30th December, 2020, the first China's homegrown COVID-19 vaccine was approved for marketing by the China National Medical Products Administration (NMPA) and open volunteer vaccination to the public was announced through official media. On January 9th, 2021, the National Health Commission promised free vaccinations for the Chinese population[6]. At this time, the COVID-19 vaccine in China is suitable for people aged 18 to 59 years, and the people who are not suitable for the COVID-19 vaccine include pregnant women, lactating women, acute stage of fever, infection and other diseases, immune deficiency or immune disorders, serious liver and kidney diseases, hypertension, diabetic complications, and malignant tumours with uncontrolled drugs[7]. At present, the common adverse reactions of vaccines in China mainly include headache, fever, local redness or lumps at the inoculation site, and cough, loss of appetite, vomiting and diarrhoea in some people[8]. In first month of start of COVID-19 vaccination, 22.767 million doses of COVID-19 vaccine have been administered in China up to 26 January 2021, and less than 5% of the vaccinable population among them, the main group, was at high risk of infection in all regions[9]. Considering the occupational exposure risk of COVID-19 infection, some occupational populations with priority of vaccination were border ports, in key places such as international and domestic transportation, and in key industries such as medical and health care, social resource guarantees and basic social operation services. These inoculations are all mass vaccinated on the basis of individual willingness[6]. According to the National Health Commission disease control bureau director, all residents could be vaccinated in an orderly manner under ample supply where vaccination units are health service centres, township health centres or general hospitals located in their respective jurisdictions. Local governments have been required to make public in a timely manner the vaccination sites and units that can vaccinate in their respective jurisdictions, including their locations and service hours[8]. From the beginning of 2020 to the present, the State Council Information Office will hold regular press conferences to invite experts from relevant departments to brief us on the joint prevention and control of COVID-19[10]. Not only will the number of new cases, close contacts, and cured or dead for the day be announced, but the latest number of vaccinated people

and cautions for vaccination will also be announced once vaccination begins. In addition to the national level, provinces, municipalities and autonomous regions will release the latest information about the epidemic through various channels, such as press conferences or short videos, according to their own conditions, to ensure the mastery and understanding of the epidemic and vaccine information[11, 12].To date, six months after countries have successively carried out vaccination, the global new crown vaccination has exceeded 1.5 billion doses. Among them, nearly 60% are concentrated in China (420 million doses), the United States (270 million doses) and India (180 million doses). Except for a few countries with a vaccination rate exceeding 50% (e.g., Israel), most countries in the world have a vaccination rate below 20%[13]. According to a recent study, a predicted vaccine coverage of 55% to 82% of the population is needed to achieve COVID-19 herd immunity[5]. In addition to the supply of vaccines, the individual's psychological mechanism of vaccine behaviour is particularly critical to vaccination[14]. Therefore, it is of great significance to explore the possible influencing factors of individuals' vaccination willingness when the vaccination rate is low for the further improvement of vaccination willingness and the coverage rate of the COVID-19 vaccine in China and other parts of the world.

[15]Although vaccines are currently an effective means of improving global health, in many parts of the world, there are still quite a few people who question the necessity of vaccination, postpone vaccination or even refuse vaccination, especially when it first came to market was met with considerable hesitation and even outright opposition[16]. [17][16]In 2012, the WHO established the Strategic Advisory Group of Experts (SAGE) working group to address vaccine hesitancy and define vaccine hesitancy and its scope[18]; vaccination hesitancy was defined as the refusal or delay of vaccination when vaccination services were available[19], and vaccination hesitancy was listed among the ten threats to global health in 2019[15]. Vaccine hesitancy is reflected in many factors, including confidence in the efficacy and safety of the vaccine and in the health service system providing the vaccine, such as the reliability and competence of the health service system and the professionals involved in the vaccination service[20]. In the first month after open vaccination to all vaccinable Chinese public, a nationwide cross-sectional study reported prevalence of COVID-19 vaccination hesitancy was 35.5%. After an instance of the illegal marketing of vaccines, 32.4% of parents were hesitant about vaccines[21]; rapid sociocultural changes have also contributed to vaccine hesitancy[22, 23]. A study on the COVID-19 vaccine hesitancy of Italian college students showed that among the 735 students who answered questions about their vaccination intentions, more than one in ten students showed hesitancy[24]. An investigation during Israel's mandatory quarantine revealed that nurses and medical workers showed higher levels of vaccine hesitancy[25]. According to a literature review, 68.4% of the global population is willing to receive the vaccination[26].[27][21][22, 23][28][24][25][26]Since January 2021, China has offered free vaccination access to the public, but only one-tenth of the participants in this study had been

vaccinated (with both doses), 61.4% of whom were medical personnel.

Current studies of factors associated with COVID-19 vaccination have identified a number of demographic, cognitive, and psychosocial factors, including age, gender, education, insurance status, attitudes towards the vaccine, confidence in government information, perceived susceptibility to COVID-19, and perceived benefits and side effects of the vaccine[29, 30]. In the current "Web 2.0" age, the spread of false news about safety and validity on social media, such as vaccination against COVID-19 can also affect individual reproductive function, influence vaccination willingness and confidence[28]. Several typical behavioural theories, such as the health belief model (HBM), theory of planned behaviour (TPB)[31] and the diffusion of innovations theory (DIT)[14], were used to explain COVID-19 vaccination intent combined with demographic, cognitive, and psychosocial factors. The HBM is a widely used theory that proposes a variety of psychological factors that affect people's health protective behaviours, such as attitudes, beliefs, and intentions[32-34]. The HBM assumes that health-related actions depend on the simultaneous occurrence of three factors[35]: (1) the presence of sufficient motivation (or health concern) to make the health problem salient or relevant; (2) the belief that a person is vulnerable to serious health problems or the sequelae of that illness or condition is often referred to as perceived threat; (3) believing that following a specific health recommendation will help reduce the perceived threat at a subjectively acceptable cost. The TPB believes that an individual's behavioural posture, activity attraction, and behavioural control jointly affect the individual's behaviour, and directly the individual's behaviour[36]. DIT aims to disseminate innovation awareness, technology or innovative ideas related to the masses, so that patients can acquire innovative thinking or health awareness. In recent years, the theory of innovation diffusion has been gradually introduced into the medical and health industry, mainly for the guidance of health education strategies[14]. The Health Belief Model (HBM) has been one of the most widely used theories in understanding health and illness behaviours and due to its design, it has been previously used in vaccination studies to identify behaviour relationships[37, 38]. When compared with other models that explain behaviour and resulting action, the HBM was specifically developed to focus on preventative health research[37-40],which has been modified since its early use in the 1950s to be more inclusive and encourage interventions that improve health behaviours[41]. Thus, HBM was chosen as the preferred model to investigate intention and behaviour regarding COVID-19 vaccination. There are six main components of the HBM perceived susceptibility, perceived severity, perceived benefit, perceived barriers, self-efficacy for health protective behaviour and cues to action[42]. Previous studies, including studies on swine flu[43], hepatitis[44], HPV[45], and measles[46], have identified HBM factors as important predictors of

vaccination intentions. Therefore, it is necessary to explore the possible influence of these factors on people's willingness to vaccinate against the COVID-19 vaccine to improve individual immunity and slow the epidemic. Although aforementioned studies suggested association between HBM constructs and vaccine acceptance or hesitancy, relatively few researches focus on COVID-19 vaccination behaviour, especially in China and other countries where open vaccination to domestic population[47].[32-34][42][43][44][45][46]

In summary, we explored whether HBM constructs were associated with vaccine hesitancy and vaccination at the start of the COVID-19 vaccination open to the public in the mainland of China. A pervious study identified that vaccine intention/willingness was an important predictor of vaccination behaviour, with more than 50% of the explained variance in influenza[48] and HPV[36] vaccines. However, a gap seems to exist between intention and vaccination behaviour[49], such as students' willingness to receive the HPV vaccine predicting less than 10% of actual vaccinations[36]. Our first hypothesis (H1) was that vaccine hesitancy was negatively associated with COVID-19 vaccination behaviour. In particular, we examined our major hypothesis (H2) that HBM constructs such as perceived barriers, self-efficacy and cues to action would predict vaccine hesitancy and vaccination behaviour. As in a previous study, self-efficacy as a confidence in one’s ability to facilitate decisions to carry out a health behaviour such as vaccination which is useful only to the extent that one feels one can adequately implement the steps needed to perform the behaviour[50].Evidence-based on HBM poses a serval mechanism regarding how self-efficacy is associated with vaccine intention and behaviours. Self-efficacy could mediate the relationship between perceived barriers to Human papillomavirus (HPV) vaccination and HPV vaccine intentions among young women[51]. A similar mediation effect was found in the association between perceived severity and perceived susceptibility to Zika vaccine uptake intent [52]. It was also suggested that self-efficacy could influence the path from cues to action(e.g. physician recommendation, family members recommendation, media coverage, public health communication) to HPV vaccine uptake [53] and acceptance of the H1N1 vaccine [54].Aforementioned studies suggested our third major hypothesis (H3) that self-efficacy of the COVID-19 vaccine would mediate the influence of other HBM constructs to vaccine hesitancy and vaccination.

Methods

Study design and participants

From January 1st to 24th, 2021, we used convenience and snowball sampling to recruit a sample of 2,580 participants from 31 provinces and autonomous regions with each area at least 30 participants (China consists of a total of 34 provinces and autonomous regions) and conducted a web-based cross-sectional study. A digital questionnaire link was sent to a WeChat “Moment circle” (a function

that can be used to share personal photos or public website links in one's Moments to make them visible to friends on platforms such as Twitter and Facebook) and could be forwarded or shared by participants who volunteered to share this questionnaire link (Wenjuanxing platform, https://www.wjx.cn/app/survey.aspx) to friends on their WeChat contact list whom they considered appropriate for this survey; and their friends were also encouraged to send link to their friends networks. The snowball sampling process continued until a sufficient sample size was reached and first page of the questionnaire contained an electronic consent form. Each respondent received a small monetary reward (RMB 5 yuan) after completing the questionnaire authentically (taking approximately 5 to 10 minutes to complete the questionnaire). To prevent repeated entry of the same individual for incentive of enrolment, second measures were adopted: (1) The same internet protocol (IP) address was only allowed to fill in the questionnaire for once time which was a built-in function of Wenjuanxing platform and (2) Participants were only allowed to fill questionnaire by login WeChat account, a software need registered with personal identical card, and each WeChat account was also fill in the questionnaire for once time. The minimum sample size was calculated to be 1100 by using the following formula: $\frac{Z^2_{1-\alpha/2}p(1-p)}{d^2}$, where latest reported prevalence of COVID-19 vaccination hesitancy (p) was 35.5% which conducted in nationwide China from January 10 to January 22, 2021[55].The type I error (α) was 0.05 thus $z_{1-\alpha/2}$=1.96, the precision (d) was 0.04, and the design effect (deff) was 2[56]. The inclusion criteria of participants enrolment were: (1) aged between 18 to 59 years old and (2) understand questionnaire by themselves and could use online service, such as mobile phone, computer, flat computer. The questionnaires of participants who met the following exclusion criteria were discarded: (1) aged less than 18 years old (16 participants) or more than 59 years old (32 participants) who were not open to vaccination until April in China and (2) returned invalid questionnaires (32 participants).The standardized invalid questionnaire for data cleaning were: (1) Give the any or both wrong answer of two quality control questions including (Where is capital of China and what's three plus five); (2) logic check result error which reflect in when both select none disease option and any type of disease in question "Do you have any type of the following diseases or medical diagnosed history";(3) took less than the minimum time of 3 minutes to complete the questionnaire. Cognitive interviewing with 5 subjects was done to refine the questionnaires through web-based platform (WeChat). Participants were required to answer each item with 3 question: (1) What does '……' mean to you, (2) Can you repeat this question in your own words? (3) When you think about '……' what comes to your mind? We also asked participants to answer three question for overall survey, including: (1) Are there additional questions you believe

should be asked? (2) Are there questions you believe should be deleted? (3) Are there questions you believe should be modified? The whole questionnaire was tested and modified appropriated to conduct survey. Finally, 2,531 participants were included in the present study. This study was approved by the Institutional Review Board of Fudan University, School of Public Health (IRB00002408&FWA00002399) and expired to March 3, 2021.

Measurements

Vaccine hesitancy and vaccination

Vaccine hesitancy was assessed with a one-item self-report measure that quantified the demand for and acceptance of vaccination: “How willing would you be to get the COVID-19 vaccine?” The respondents were asked to answer on the following seven-point scale recommended by the SAGE Working Group on Vaccine Hesitancy: “accept all [vaccines]”, “accept but unsure”, “accept some”, “delay”, “refuse some”, “refuse but unsure”, and “refuse all”[19]. Vaccine hesitancy was defined as any response on the scale except “accept all” or “accept but unsure”. Vaccination was assessed by asking the participants to answer “Yes” or “No” to a single question: “Have you gotten the COVID-19 vaccine?”

Health belief model

Items derived from the HBM were adopted from a previous study or modified to measure the participants’ beliefs about COVID-19 vaccination. Five essential dimensions of health beliefs were measured as follows: 1) perceived susceptibility to COVID-19 in the future (3 questions), e.g., I was vulnerable to infection with SARS-CoV-2; 2) perceived severity of COVID-19 infection (4 questions), e.g., It would be very harmful for me if I got COVID-19; 3) perceived benefits of COVID-19 vaccination (3 questions), e.g., COVID-19 vaccination can protect me from infection with SARS-CoV-2; 4) perceived barriers to COVID-19 vaccination (6 questions), e.g., The COVID-19 vaccine might have side effects, such as fever or soreness in the arm; and 5) self-efficacy for COVID-19 vaccination (5 questions), e.g., I believe I can deal with side effects of the COVID-19 vaccine with doctors’ help. Cues to action refers to external recommendations that might affect individuals’ health-related behaviours. In the present study, the Cronbach’s alpha coefficients indicating the internal consistency (reliability) of the total HBM factors were 0.78 and five subscales were 0.84 (perceived susceptibility to COVID-19), 0.80 (perceived severity of COVID-19 infection), 0.83 (perceived benefits of COVID-19 vaccination), 0.80 (perceived barriers to COVID-19 vaccination) and 0.82 (self-efficacy for COVID-19 vaccination). The sampling adequacy for the HBM factor scale was excellent (Kaiser-Meyer-Olkin=0.82). Interitem correlations were sufficiently large for principal component (PCA) (Bartlett’s test of sphericity: χ^2 (210) =23,122.6, p<0.001). The

PCA revealed five factors, which in combination explained 68.58% of the variance and each factor accounted for 24.23%, 20.55%, 10.32%, 8.16%, and 5.32% of the explained variance, respectively. An examination of the factor loadings after rotation suggested as expected that factor 1 (perceived barriers to COVID-19 vaccination) had 6 items with loading factors between 0.74 and 0.79; factor 2 (self-efficacy for COVID-19 vaccination) included 5 items with loading factors were between 0.71 and 0.80; factor 3 (perceived severity of COVID-19 infection) included 4 items with loading factors between 0.67 and 0.85; factor 4 (perceived benefits of COVID-19 vaccination) included 3 items with loading factors between 0.68 and 0.85; and factor 5 (perceived susceptibility to COVID-19) included 3 items with loading factors between 0.78 and 0.89.

External cues to action

External cues to action were assessed based on 4 cues used in previous surveys[57, 58]: recommendations from authorities, recommendations from friends/family, vaccination of authorities and vaccination of friends/family. The participants were asked to state their level of agreement with each of the statements, with a score of "1" for positive responses (strongly agree or agree) and a score of "0" for neutral or negative responses (neither agree nor disagree, disagree, or strongly disagree). The Cronbach's alpha coefficient of cues to action was 0.82. The sampling adequacy for cues to action scale was excellent (Kaiser-Meyer-Olkin=0.75). Interitem correlations were sufficiently large for principal component analysis (PCA) (Bartlett's test of sphericity: χ^2 (6) =2,829.1, p<0.001). The PCA revealed a single factor, which in combination explained 59.72% of the variance and an examination of the factor loadings after rotation suggested, as expected, that single factors included 4 items whose loading factors were between 0.65 and 0.84.*Demographic and health-related characteristics*

Demographic characteristics in this study included gender, age, educational level (high school degree and below, bachelor's degree, or master's degree and above), marital status (married or not married [including unmarried, divorced and widowed]), occupation (medical worker or nonmedical worker), region (urban or rural), monthly salary (<6,000 RMB, 6,000-10,000 or >10,000) and family members with backgrounds in medical work or with medical education (yes or no). Health-related characteristics include self-rated health (SRH) and self-reported chronic diseases (CDs) ever diagnosed by doctors. SRH was evaluated by a single question, "How is your perceived health in general?" (excellent, very good, good, general or poor)[59]. We listed 16 common CDs, such as hypertension and diabetes, and categorized the number of reported CDs into 0, 1-2 and over 3.

Statistical analysis

Frequencies were first calculated for all variables, and the prevalence and 95% confidence

intervals (CIs) of vaccine hesitancy and vaccination were determined according to the participants' demographics, health-related characteristics and HBM factors. Multivariable logistic regression analyses were used to explore the demographic and health-related characteristics (see Table 1) as well as the HBM factors (see Table 2) associated with vaccine hesitancy and vaccination. Then, we ran the multivariable logistic regression again to determine the HBM factors associated with vaccine hesitancy and vaccination after controlling for covariates (demographic and health-related characteristics), with a significance level of $p<0.05$. Odds ratios (ORs) with 95% CIs were calculated for each independent variable and were visualized in forest plots (see Figure 1 and Figure 2). All of the analyses were performed using SAS version 9.4 (SAS, Carry, NC, USA), and all tests were two-tailed with a significance level of $p<0.05$. We used the "forest plot" package in R software version 3.5.3 (R; https://www.r-project.org/) to generate the forest plots. We used Mplus version 8.4 to establish structural equation modelling (SEM) and assess the standardized coefficients (SSCs) among the HBM factors, vaccine hesitancy and vaccination. The mean and variance-adjusted weighted least squares (WLSMV) was employed as the method of estimation because of the analyses included categorical endogenous variables (vaccine hesitancy and vaccination), and the link was probit in the current model[60]. We freed covariances between error terms based on their modification indices (M.I.) during the estimation process to improve model fit. The most common indices and acceptable reference values included the magnitude of χ2 divided by its degrees of freedom (χ^2/df, < 5), comparative fit index (CFI, >0.90), Tucker-Lewis index (TLI, >0.90) and root mean square error of approximation (RMSEA, <0.08), which were used to determine whether the data fit the model[61].

Results

Participant characteristics

Our analysis included 2,531 participants who were aged between 18 and 59 (mean, 33.92; SD, 8.94), and 58.7% of them were female. Most of the participants were married (65.6%), had a bachelor's degree (63.6%), were nonmedical personnel (89.4%), lived in urban areas (89.4%), reported good health (79.8%), and did not have CDs (63.9%). Slightly less than half of the participants reported monthly salaries (44.6%) lower than six thousand yuan and had family members with medical personnel backgrounds (41.7%) (Table 1).

Table 1 Distribution of vaccine hesitancy and vaccination by participant demographic and health-related characteristics (n = 2,531)

		Vaccine hesitancy		Vaccination	
	N (%)	VH (%)	OR 95% CI	VC (%)	OR 95% CI
Age (years)					
18-29	926(36.6)	412(44.5)	1	75(8.1)	1

30-39	993(39.2)	467(47.0)	1.11(0.93-1.33)	110(11.1)	1.41(1.04-1.92)*
40-49	410(16.2)	163(39.8)	0.82(0.65-1.04)	55(13.4)	1.76(1.22-2.54)**
50-59	202(8.0)	78(39.6)	0.79(0.58,1.07)	24(11.9)	1.53(0.94-2.49)
Gender					
Male	1045(41.3)	422(40.4)	1	116(11.1)	1
Female	1486(58.7)	698(47.0)	1.31(1.11-1.53)**	148(10.0)	0.89(0.69-1.15)
Marital status					
In Married	1660(65.6)	725(43.7)	1	187(11.3)	1
Not in married	871(34.4)	395(45.4)	1.07(0.91-1.26)	77(8.8)	0.76(0.58-1.01)
Education attainment					
High school degree and below	204(8.0)	83(40.7)	1	9(4.4)	1
Bachelor's degree	1609(63.6)	725(45.1)	1.20(0.89-1.61)	150(9.3)	2.23(1.12-4.43)*
Master's degree and above	718(28.4)	312(43.5)	1.12(0.82-1.54)	105(14.6)	3.71(1.84-7.47)***
Occupation					
Non-medical personnel	2034(80.4)	929(45.7)	1	102(5.0)	1
Medical personnel	497(19.6)	191(38.4)	0.74(0.61-0.91)*	162(32.6)	9.16(6.97-12.04)***
Region					
Urban	2262(89.4)	1016(44.9)	1	242(10.7)	1
Rural	269(10.6)	104(38.7)	0.77(0.60-1.00)	22(8.2)	0.74(0.47-1.17)
Monthly salary (RMB)					
<6,000	1128(44.6)	478(42.5)	1	68(6.0)	1
6,000-10,000	787(31.1)	338(43.0)	1.02(0.85-1.23)	100(12.7)	2.27(1.64-3.13)***
>10,000	616(24.3)	303(49.2)	1.31(1.08-1.60)*	96(15.6)	2.88(2.07-3.99)***
Family members with medical backgrounds					
No	1475(58.3)	667(45.2)	1	88(6.0)	1
Yes	1056(41.7)	453(42.9)	0.91(0.78-1.06)	176(16.7)	3.13(2.28-4.17)***
Self-reported health					
Good	2020(79.8)	849(42.0)	1	230(11.4)	1
Poor	511(20.2)	271(53.0)	1.56(1.28-1.89)***	34(6.7)	0.55(0.38-0.81)***
Number of chronic diseases					
0	1617(63.9)	688(42.3)	1	178(11.0)	1
1	639(25.4)	300(47.0)	0.84(0.70-1.01)	64(10.0)	1.11(0.82-1.50)
2 and above	288(11.2)	136(49.5)	1.13(0.86-1.49)	22(8.0)	0.78(0.47-1.30)
Vaccine hesitancy					

Yes	1120(44.3)	-	-	32(2.9)	1
No	1411(55.7)	-	-	232(16.4)	6.69(4.58-9.77)***

Distribution of vaccine hesitancy and vaccination by participant characteristics and health belief model factors

Overall, 44.3% (42.3%-46.2%) of the participants were classified as vaccine hesitant (1.4% responded “refuse all”, 5.3% responded “refuse but unsure”, 3.7% responded “refuse some”, 18.8% responded “delay”, and 15.1% responded “accept some”), and 55.7% (1411/2531) were classified as vaccine accepting (25.1% responded “accept but unsure”, and 30.6% responded “accept all”). Only 10.4% (9.2%-11.6%) of the participants had been vaccinated for COVID-19, while the majority (89.6%) had not.

According to the multivariable logistic regression analyses including participant characteristics (Table 1), the participants were more likely to be vaccine hesitant if they were female (OR=1.31, 95% CI: 1.11-1.53), were nonmedical personnel (OR=1.35, 95% CI: 1.10-1.64), had poor self-rated health (OR=1.56, 95% CI: 1.28-1.89), or had a monthly salary over 10,000 yuan (OR=1.31, 95% CI: 1.08-1.60). The participants were more likely to have been vaccinated if they were 30-39 years old (OR=1.41, 95% CI: 1.04-1.92), were 30-39 years old (OR=1.41, 95% CI: 1.04-1.92), had a bachelor’s degree (OR=2.23, 95% CI: 1.12-4.43), had a master’s degree and above (OR=3.71, 95% CI: 1.12-4.43), were medical personnel (OR=3.71, 95% CI: 1.12-4.43), had good self-rated health (OR=1.82, 95% CI: 1.23-2.63), were not vaccine hesitant (OR=6.69, 95% CI: 4.58-9.77), had a monthly salary between 6,000-10,000 (OR=2.27, 95% CI: 1.64-3.13), had monthly salary over 10,000 yuan (OR=2.88, 95% CI: 2.07-4.17), or had family members with medical personnel backgrounds (OR=3.13, 95% CI: 2.28-4.17).

According to the multivariable regression analyses including the HBM factors (Table 2), the participants were more likely to be vaccine hesitant if they had high perceived susceptibility to COVID-19 (OR=1.34, 95% CI: 1.07-1.69) or had high perceived barriers to vaccination (OR=1.84, 95% CI: 1.56-2.17), and they were less likely to be vaccine hesitant if they had high perceived benefits of vaccination (OR=0.34, 95% CI: 0.23-0.50), had high self-efficacy for vaccination (OR=0.26, 95% CI: 0.20-0.34), agreed with recommendations from authorities (OR=0.47, 95% CI: 0.38-0.58), agreed with recommendations from friends/family (OR=0.19, 95% CI: 0.14-0.24), agreed with the vaccination of authorities (OR=0.46, 95% CI: 0.36-0.60), or agreed with the vaccination of friends/family (OR=0.77, 95% CI: 0.66-0.91). The participants were more likely to have been if they had high self-efficacy for vaccination (OR=3.39, 95% CI: 1.92-6.00), agreed with recommendations

from authorities (OR=2.89, 95% CI: 1.75-4.78), agreed with the vaccination of authorities (OR=2.94, 95% CI: 1.62-5.31), or agreed with the vaccination of friends/family (OR=5.05, 95% CI: 3.77-6.76).

Table 2 Distribution of vaccine hesitancy and vaccination by health belief model factors and cues to action (n = 2,531)

		Vaccine hesitancy		Vaccination	
	N (%)	VH (%)	OR 95% CI	VC (%)	OR 95% CI
Perceived susceptibility					
Low	2191(86.6)	948(43.3)	1	231(10.4)	1
High	340(13.4)	172(50.6)	1.34(1.07-1.69)**	33(9.7)	0.91(0.62-1.34)
Perceived severity					
Low	292(11.5)	126(43.2)	1	42(14.4)	1
High	2239(88.5)	994(44.4)	1.05(0.82-1.36)	222(9.9)	0.66(0.46-0.93)*
Perceived benefits					
Low	125(4.9)	86(68.8)	1	12(9.6)	1
High	2406(95.1)	1034(43.0)	0.34(0.23-0.50)***	252(10.5)	1.01(0.95-1.07)
Perceived barriers					
Low	1622(64.1)	630(38.8)	1	219(13.5)	1
High	909(35.9)	490(53.9)	1.84 (1.56-2.17)***	49(5.0)	0.33(0.24-0.47)***
Self-efficacy					
Low	352(13.9)	252(71.6)	1	13(3.7)	1
High	2179(86.1)	868(39.8)	0.26(0.20-0.34)***	251(11.5)	3.39(1.92-6.00)***
Recommendations from authorities					
Disagree	393(15.5)	236(60.1)	1	17(4.3)	1
Agree	2138(84.5)	884(41.4)	0.47(0.38-0.58)***	247(11.6)	2.89(1.75-4.78)***
Recommendations from friends/family					
Disagree	367(14.5)	283(77.1)	1	28(7.6)	1
Agree	2164(85.5)	837(38.7)	0.19(0.14-0.24)***	236(10.9)	1.48(0.99-2.23)
Vaccination of authorities					
Disagree	290(11.5)	177(61.0)	1	12(4.1)	1
Agree	2241(88.5)	943(42.1)	0.46(0.36-0.60)***	252(11.2)	2.94(1.62-5.31)***
Vaccination of friends/family					
Disagree	1488(58.8)	696(46.8)	1	66(4.4)	1
Agree	1043(41.2)	424(40.7)	0.77(0.66-0.91)**	198(19.0)	5.05(3.77-6.76)***

Influencing factors of vaccine hesitancy and vaccination

We included the participant characteristics and HBM factors in the vaccine hesitancy logistic regression, and the influencing factors are shown in Figure 1. The risk factors for vaccine hesitancy were female sex (prevalence (p)=47.0%, 95% CI: 44.4%-49.5%; OR=1.12, 95% CI: 1.01-1.44), monthly salary over 10,000 (p=49.2%, 95% CI: 45.2%-53.1%; OR=1.45, 95% CI: 1.16-1.80), poor self-rated health (p=53.0%, 95% CI: 48.7%-57.4%; OR=1.46, 95% CI: 1.18-1.80), high perceived susceptibility to COVID-19 (p=50.6%, 95% CI: 45.3%-55.9%; OR=1.30, 95% CI: 1.01-1.67), and high perceived barriers to vaccination (p=53.9%, 95% CI: 50.7%-57.2%; OR=1.63, 95% CI: 1.36-1.95). Additionally, the protective factors against vaccine hesitancy were occupation as medical personnel (p=38.4%, 95% CI: 34.2%-42.7%; OR=0.74, 95% CI: 0.59-0.93), high perceived benefits of vaccination (p=43.0%, 95% CI: 41.0%-45.0%; OR=0.51, 95% CI: 0.32-0.79), high self-efficacy for vaccination (p=38.4%, 95% CI: 48.7%-57.4%; OR=1.46, 95% CI: 1.18-1.80), agreement with recommendations from authorities (p=41.4%, 95% CI: 39.3%-43.4%; OR=0.74, 95% CI: 0.57-0.98), and agreement with recommendations from friends/family (p=41.4%, 95% CI: 39.3%-43.4%; OR=0.74, 95% CI: 0.57-0.98).

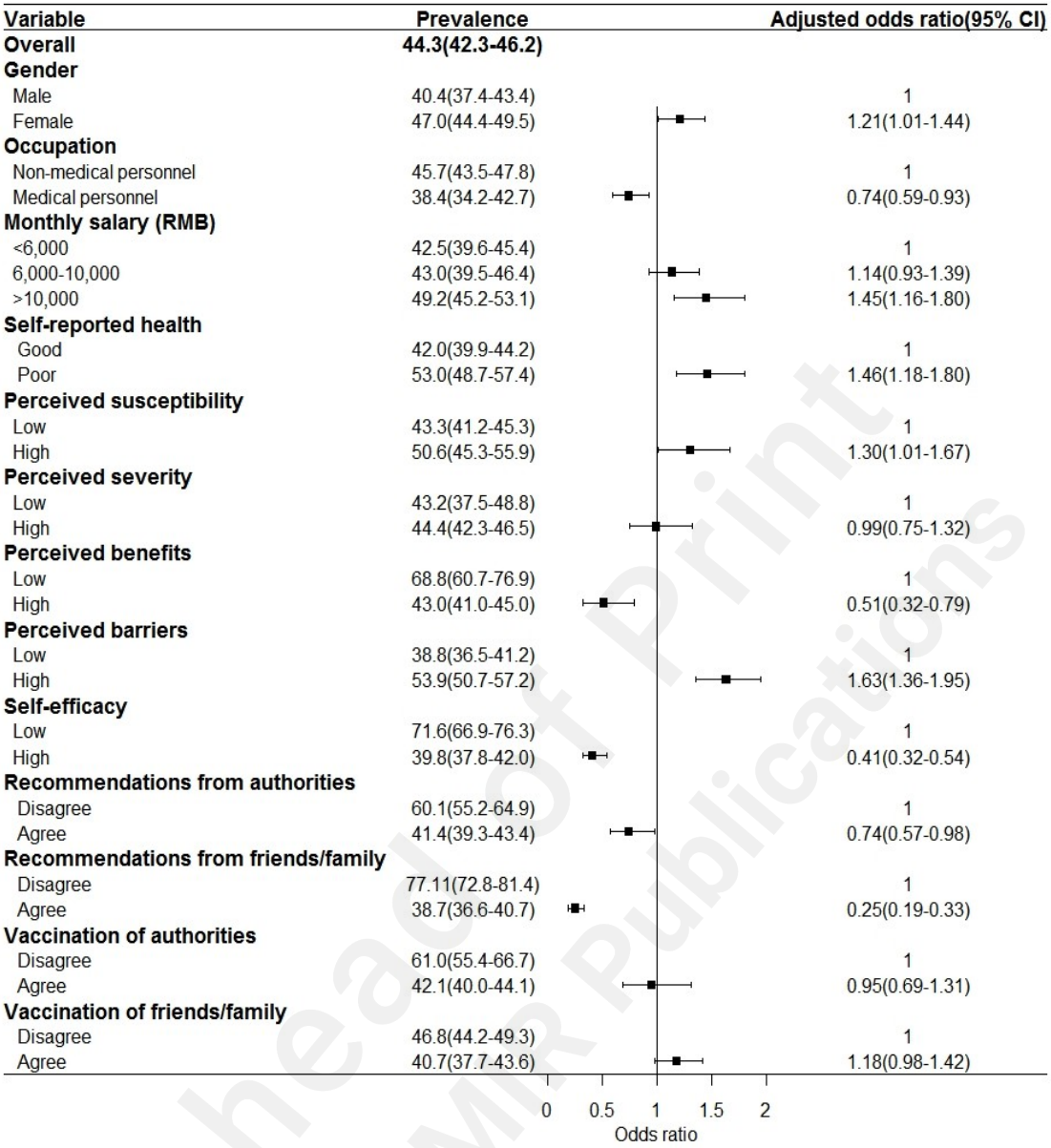

Figure 1. The association between HBM and vaccine hesitancy

We included the participant characteristics, the HBM factors and vaccine hesitancy in the vaccination logistic regression, and the influencing factors are shown in Figure 2. The promoting factors of vaccination were occupation as medical personnel (prevalence (p)=32.6%, 95% CI: 28.5%-36.7%; OR=6.52, 95% CI: 4.51-9.41), monthly salary between 6,000-10,000 (p=12.7%, 95% CI: 10.4%-15.0%; OR=2.05, 95% CI: 1.38-3.04), monthly salary over 10,000 (p=15.6%, 95% CI: 12.7%-18.5%; OR=2.15, 95% CI: 1.40-3.30), family members with medical personnel backgrounds (p=16.7%, 95% CI: 14.4%-18.9%; OR=1.51, 95% CI: 1.07-2.13), a lack of vaccine hesitancy (p=16.4%, 95% CI: 14.5%-18.4%; OR=7.75, 95% CI: 1.01-1.67), agreement with recommendations from friends/family (p=10.9%, 95% CI: 9.6%-12.2%; OR=3.11, 95% CI: 1.75-5.52) and agreement with the vaccination of friends/family (p=19.0%, 95% CI: 19.6%-21.4%; OR=4.88, 95% CI: 3.41-

6.99). Additionally, a lower vaccination rate was associated with higher perceived barriers to COVID-19 vaccination (p=5.0%, 95% CI: 3.5%-6.4%; OR=0.51, 95% CI: 0.35-0.75).

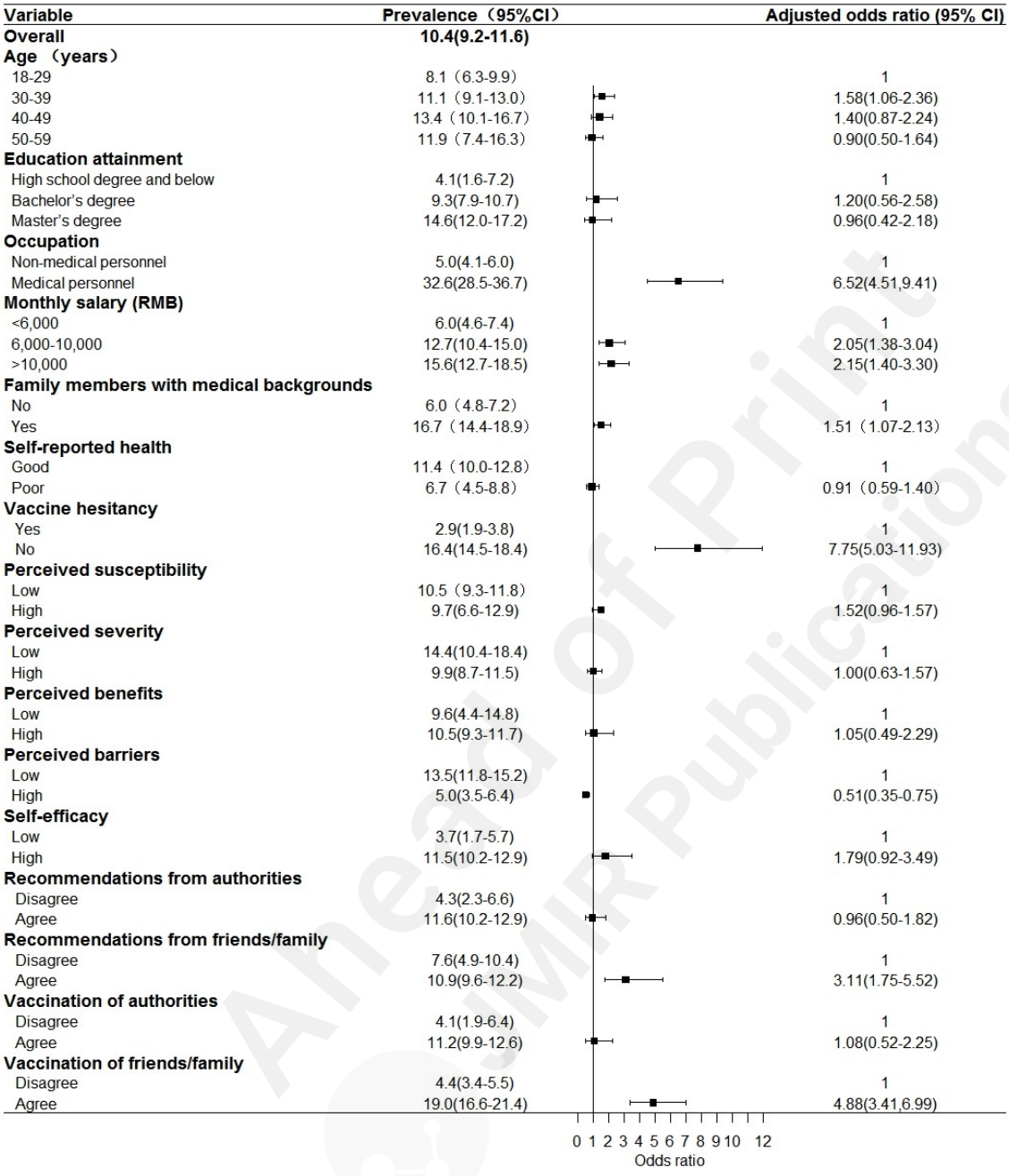

Figure 2. The associations between HBM and vaccination rate

Structured equation model of vaccination

We used structural equation modelling (SEM) to examine the underlying psychological mechanism of vaccination behaviour (see Figure 3). Based on the goodness-of-fit statistics, the structural equation model showed a better fit to the data than the regression models (χ^2/df=4.62; RMSEA = 0.05; CFI = 0.95; TLI = 0.91), and all of the paths were statistically significant ($p < 0.05$). The findings suggested a mediating effect of self-efficacy, influenced by perceived barriers (SSC = −0.71,

$p < 0.001$), perceived benefits (SSC = 0.58, $p < 0.001$), agreement with recommendations from authorities (SSC = 0.27, $p < 0.001$), agreement with recommendations from friends/family (SSC = 0.31, $p < 0.001$), being negatively associated with vaccination (SSC = −0.45, $p < 0.001$), and via vaccine hesitancy (SSC = −0.32, $p < 0.001$). Additionally, perceived barriers (SSC = 0.53, $p < 0.001$) and perceived benefits (SSC = -0.21, $p < 0.001$) were directly associated with vaccine hesitancy. Perceived barriers (SSC = -0.20, $p < 0.001$) and recommendations from friends/family (SSC = 0.14, $p < 0.001$) were directly correlated with vaccination behaviour.

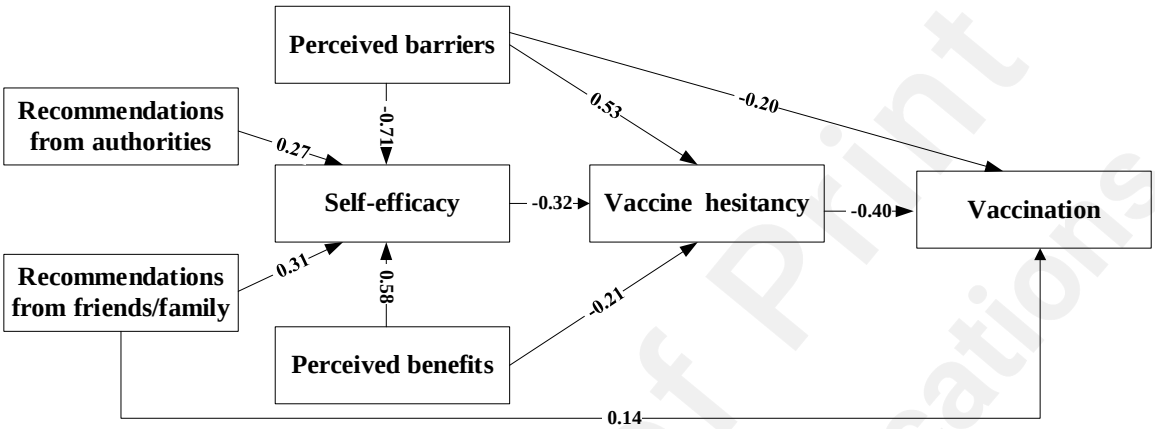

Figure 3. The paths among vaccine hesitancy, vaccination and health belief model factors.

Discussion

Primary Findings

Our findings of this study suggest that five HBM constructs—in the absence of perceived barriers, a high level of perceived benefits and self-efficacy—individuals' agreement with recommendations from authorities and friends/family were negatively associated with COVID-19 vaccine hesitancy and positively associated with vaccination behaviour. Furthermore, psychological mechanisms were found to mediates the relationship between perceived barriers, perceived benefits, recommendations from authorities and friends/family and vaccination uptake behaviour, via vaccine hesitancy. Self-efficacy, perceived barriers, and perceived benefits were correlated with vaccine hesitancy, while perceived barriers and recommendations from friends/family were directly correlated with vaccination directly.

In the present study in China, the prevalence of vaccine hesitancy was 44.3% (42.3%-46.2%), and the vaccination rate was 10.4% (9.2%-11.6%), representing high vaccine hesitancy and low vaccination behaviour. Vaccine hesitancy has been universally reported in recent research, with over half of participants (53%) across 19 countries showing vaccine hesitancy, which is similar to our results[62] and in accordance with the decline in vaccine acceptance (from >70% in March to <50%

in October) reported by a recent review[63]. Undoubtedly, eliminating vaccine hesitancy would be beneficial to voluntary vaccination behaviour, as shown in the present study, which showed that the vaccination rate was nearly 8 times higher among the participants who were vaccine accepting than among those who were vaccine hesitant. In the SEM results, vaccine hesitancy was also strongly negatively associated with vaccination behaviour (Hypothesis 1 confirmed). Therefore, the control of vaccine hesitancy and the promotion of voluntary vaccination still seem to be challenges in the context of the COVID-19 pandemic.

In the present study, female participants showed more COVID-19 vaccine hesitancy, which is consistent with the previous literature[64, 65]; a possible reason for this finding is that women are more likely to be concerned about side effects [66] and take nonpharmaceutical protective measures (e.g., masking and maintaining social distance)[67], while men are more inclined to adopt medical intervention[68]. Medical personnel showed less vaccine hesitancy and a much higher vaccination rate in the present study, which may be inconsistent with the general argument that health workers have strong negative attitudes towards vaccines, with strong scepticism about their safety and effectiveness, especially regarding the influenza vaccine [69, 70]. Another finding seems unexpected, i.e., that the participants with higher monthly salaries were associated with both vaccine hesitancy and a higher vaccination rate; in other words, even though these individuals were vaccine hesitant, they were still vaccinated. Vaccine hesitancy was not only a direct determinant of vaccination but also a perceived barrier. Participants with higher salaries were more likely to have higher socioeconomic status[71], so they could more easily access social sources; that is, they had lower barriers to obtaining vaccines, which could then increase the vaccination rate among this group.

Although some of the HBM factors were not directly associated with the vaccination rate, perceived benefits of vaccination, perceived barriers to vaccination, self-efficacy for vaccination and recommendations from authorities were correlated with vaccine hesitancy (Hypothesis 2 partially confirmed), which was consistent with previous research among the Malaysian public[57] and the Chinese general population[72]. In all HBM constructs associated with vaccine hesitancy and vaccination, self-efficacy to the COVID-19 vaccine was an important predictor of vaccination behaviour, via vaccine hesitancy. This result is similar to the findings of previous studies on influenza vaccination, according to which self-efficacy is a key factor of willing, which in turn predicts behaviour[48, 73].Self-efficacy also plays a mediating role between vaccine hesitancy and other HBM components including perceived barriers, benefits, recommendations from authorities and friends/family, and indirectly influences vaccination uptake. This finding was

supported by the HBM hypothesis (Hypothesis 3 partially confirmed) that HBM constructs and cues to action may not share a juxtaposition or parallel relationship but self-efficacy functioned as serial mediation[74]. Hilyard noted that public self-efficacy in the COVID-19 vaccine could be promoted by enhancing the perceived benefits of vaccination, confidence in overcoming possible side effects (perceived barriers) and recommendations from authorities (such as the Obamas' modelling of H1N1 vaccine acceptance for their daughters)[75].In the current study, self-efficacy was measured as a specific domain with confidence in safety and a low prevalence of side effects of the COVID-19 vaccine and success in dealing with side effects. Vaccine safety or side effects which are regarded as contributing to the development of disease, are of paramount importance to individual efficacy when deciding whether to vaccinate[76, 77], and even are a relevant aspect to explain anti-vaccine movement in Europe[78]. A study argues that a perceived risk-benefit balance may influence confidence in vaccine uptake; in other words, a combined decision-making process relies on a trade-off between benefits and risk[79]. In addition to cues to action, the current result was consistent with a previous study showing that compliance with recommendations from health workers may also be correlated with confidence in vaccine efficacy[77], because they can share personal knowledge about being immunized and motivate the vaccine uptake efficacy[80].

In addition to the direct and mediation effect of self-efficacy, some HBM constructs were directly associated with vaccine hesitancy and vaccination behaviour. Perceived barriers were both positively correlated with vaccine hesitancy and detrimental to vaccination, measuring the safety, side effects and inaccessibility of the COVID-19 vaccine, in which the former (safety) may influence self-efficacy as aforementioned while the latter (inaccessibility) would hinder the perceived convenience of COVID-19 vaccination behaviour directly. With a more specific formulation, a controlled before-after trial study showed that arranging time and transportation were key predictors of both intention and influenza vaccination behaviour[81]. A previous survey also found that the side effects and safety of the influenza vaccination were the most common reasons for vaccine hesitancy[82].Perceived benefits were associated with vaccine hesitancy which was measured by preventing the self and their family from being infected after COVID-19 vaccination. From altruistic motivation perspective, people would be vaccinated to protect not only themselves but also their loved ones; in other words, there could be more willingness to receive the vaccine if individuals believe that it helps reduce the transmission of COVID-19[83]. Recommendations from family were found to be directly associated with vaccination behaviour in the present study. An online survey in Canada showed that respondents reported that encouragement from both colleagues and employers

were beneficial their vaccination decision-making process[58]. Another finding implies that a recommendation from spouse and friends is an important cue to action in determining willingness to accept the Zika virus vaccine[84]. However, susceptibility and severity were to not enough to reduce vaccine hesitancy and promote vaccination behaviour. A review indicated that perceived barriers were the most powerful single predictor of preventive health behaviour across all studies and behaviours, and perceived severity was the least powerful predictor[74].

From perspective of HBM on understanding vaccination behaviour, it is valuable that self-efficacy as an important and directly predictor to COVID-19 vaccine hesitancy because it can also mediate the influences from cues to action, perceived barriers and perceived benefits. Furthermore, vaccine hesitancy was strongly correlated with vaccination behaviour but was not only determinant for reason that perceived barriers and recommendation from friends/family associated with vaccination behaviour directly. In practice, it would be use of reference to other nations that Chinese vaccine hesitancy and vaccination status at a start and critical period when COVID-19 vaccine open to public under a free charge policy. This finding indicates that health authorities or doctors may be less effective in motivating people to action, while it may be useful to advocate that more volunteers engage in motivating their friends or family members. Although anti-vaccine movement similar to other nations was not popular in China mainland, the vaccine hesitancy and refuse were not rare without mandatory vaccination in present study. Moreover, it is essential to reinforce publish regarding the safety and validity of COVID-19 vaccine and incentives of vaccination completion then promote public confidence in overcome vaccinated barriers and benefits after vaccination.

In summary, there is currently a high prevalence of vaccine hesitancy and low vaccination behaviour in China at the start of the first moth of opening to vaccinable population during January. The HBM framework is a useful framework to guide the development of future campaigns to reduce vaccine hesitancy and promote COVID-19 vaccination.

Limitations

There are some potential limitations to this study. First, due to the convenience sampling and snowball recruitment of the online survey process, selection bias, such as the participation of fewer respondents with low education attainment and fewer older adults (aged over 50 years old), may have affected the generalizability of the results. Second, vaccine hesitancy was measured by single item derived from definition from the SAGE group which may promote a scale measurement in further research. Furthermore, the vaccination rate in this study may not reflect future trends because only some participants had received the vaccine in a timely manner and open vaccination to the public for only one month with no-incentive public health policy except free-vaccination before

participating in the study.

Abbreviations

CI: confidence interval; HBM: health belief model; OR: odds ratio; SAS: Statistical Analysis System; USA: United States of America.

Declarations

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Not applicable.

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Competing interests
The authors declare that they have no competing interests.X

Availability of data and materials
The data that support the findings of this study are available from the School of Public Health, Fudan University. The data were used under licence for the current study, and they are not publicly available. The data are, however, available from the authors upon reasonable request and with permission from the School of Public Health, Fudan University.

Authors' contributions
JD, JG, HF, PZ and YJ designed the study and obtained the data. HC and XML undertook the analysis supervised by JD, JG and HF and wrote the manuscript. XXL translated the questionnaire. HC, XML, XXL, YM and RW performed the survey. All authors read the final manuscript and agreed with the text.

Ethics approval and consent to participate
All participants consented to written ethics approval before the survey was conducted. The Institutional Review Board of Fudan University, School of Public Health (IRB00002408&FWA00002399), approved the study protocol.

Consent for publication
Not applicable.

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8. **Who can vaccinate?**

Where can I get the vaccine?

Have adverse reaction how to do?

...

Authorities respond to seven questions about novel coronavirus vaccine [http://www.gov.cn/xinwen/2020-12/19/content_5571273.htm]

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