

COVID-19 Vaccine Hesitancy Among Different Population Groups in China: a National Multi-Center Online Survey

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Abstract

Background: COVID-19 vaccine has been available in China since the beginning of the 2021, however, certain numbers of people are reluctant for some reasons to vaccinate. The high vaccine coverage is crucial for controlling disease transmission. Meanwhile, the vaccine hesitancy might be a barrier to the establishment of sufficient herd immunization. This study aims to investigate the prevalence of vaccine hesitancy towards the COVID-19 vaccine among different population groups, and explores the characteristics of different groups about vaccine hesitancy and common barriers and facilitators to vaccination decisions.

Methods: The current survey was performed among students, public health professionals, medical workers and general population from January to March 2021 among Chinese from seven cities located in seven geographical territories of China. The questionnaire contained sociodemographic information, concerns about COVID-19 epidemic, general vaccination behavior and attitudes, the General Vaccine Hesitancy Scale, the COVID-19 Vaccine Hesitancy Scale and other potential factors of vaccine hesitancy. Univariate analysis was conducted by chi-squared test, and variables were significant at $P < 0.10$ were then included in a multivariable regression model.

Results: The prevalence of COVID-19 vaccine hesitancy was 64.1% in our study, and a higher prevalence (73.7%) was in public health professionals compared to students (58.3%), medical workers (64.9%) and general population (61.1%). The results of multivariate analysis indicated that public health professionals were more likely to be hesitant against COVID-19 vaccine than general population (OR: 1.469, 95% CI: 1.069-2.019). And participants who needed transparent information about COVID-19 vaccine development, efficacy and safety (OR: 1.609, 95% CI: 1.343-1.928) and who have received negative information of COVID-19 vaccine (OR: 1.300, 95% CI: 1.130-1.496) were more likely to have vaccine hesitancy.

Conclusions: Appropriate training in knowledge and communication skills about vaccines are necessary for public health professionals to help themselves and the public to increase their willingness of vaccination. Reducing the spread of misinformation and disseminating facts in a timely and accurate way will likely reduce vaccine hesitancy. Also, to establish suitable communication strategies between the government and the public and a warning system on infodemic would be helpful to improve public's confidence in vaccination.

1 Background

COVID-19 (coronavirus disease 2019) was first noticed in late 2019 and soon caused a pandemic over the world(1). There is no doubt that COVID-19 has been an unprecedented crisis for global public health and is expected to continue to cause an enormous burden of morbidity and mortality while severely disrupting societies and economies. The spread of COVID-19 as a pandemic disease in the world requires immediate action to prevent the increase of cases and curb its worldwide spread, including the production of vaccines, which can be an effective measure to protect people against this disease (2, 3).

Thus, China and some other countries have been devoted to develop safe and effective vaccines, and several vaccines are available at present. Although the COVID-19 vaccine is free for all citizens in China, it does not guarantee sufficient herd immunization due to widespread hesitancy. Therefore, compared to the availability of the vaccine, getting the COVID-19 vaccination is more important.

Vaccination was recognized as one of the most successful public health measures, and vaccination programs have contributed to the decline in mortality and morbidity of various infectious diseases (4). However, general public still have significant doubts and concerns regarding vaccination due to the multiple historical, political, socio-cultural context and personal factors (5). This phenomenon is described as vaccine hesitancy. Vaccine hesitancy refers to delay in acceptance or refusal of vaccination despite availability of vaccination services. Vaccine hesitancy is complex and context specific, varying across time, place and vaccines (6). Vaccination can prevent lots of diseases, especially infectious diseases, hence vaccine hesitancy can result in apparently increases in outbreaks, morbidity and mortality of some vaccine-preventable diseases. Indeed, the concept of “vaccine hesitancy” has been considered by the World Health Organization (WHO) as “one of the top-ten threats to global health” (7).

Various countries started rolling out vaccines in late 2020, prioritizing healthcare and other front-line workers and those with high-risk health conditions. But when the vaccine become fully available, certain amount of individuals are still unsure whether they should get the COVID-19 vaccine or not. According to the results of a previous study, respondents from China gave the highest proportion (88.6%) of positive responses when asked if they would take a “proven, safe and effective vaccine” (8). Among healthcare workers in China, 76.63% declared they would accept the vaccine when it becomes available (9). Approximately 68% of all respondents were supportive of being vaccinated for COVID-19 in the United States, while side effects, efficacy and length of testing remained their major concerns (10–12). An online survey found that about one-third of the participants in Turkey and 14% in the UK were unsure about getting COVID-19 vaccine (13). Overall, there will always be people who are reluctant for some reasons to vaccinate, such as concerns over the short period of time of vaccine development and concerns about safety and efficacy. As we all known, the extraordinary herd protection is essential to the success of vaccination campaigns, but it can only be obtained with high vaccine coverage and the effectiveness of the COVID-19 vaccine in controlling disease transmission also depends on it (14).

However, the prevalence of COVID-19 vaccine hesitancy among different population groups in China was still unclear. It is also an urgent need to be investigated what factors may have influenced their hesitancy. To understand the prevalence of public’s hesitancy on COVID-19 vaccines and related factors plays a principal role in implementing evidence-based interventions to increase the vaccination rate. This study investigates the prevalence of vaccine hesitancy towards the COVID-19 vaccine among different population groups from seven geographical territories of China, and explores the characteristics of different groups about vaccine hesitancy and common barriers and facilitators to vaccination decisions.

2 Methods

2.1 study design and participants

The current survey was performed from January to March 2021 among Chinese from seven cities (from Henan Province, Sichuan Province, Shandong Province, Guangdong Province, Inner Mongolia, Xinjiang Uygur Autonomous Region, and Liaoning Province respectively) located in seven geographical territories of China by distributing online questionnaire via an investigation platform named wenjuanxing. The participants were recruited from four different population groups, including students, public health professionals, medical workers and general population.

The eligibility criteria included age more than or equal to 18 and an ability to read, understand and complete an online questionnaire. Those who were younger than 18, had barriers to use mobile phone or computer, or had cognitive impairment were excluded. To confirm the quality of the online survey, the members of research team were trained on data collection and inclusion criteria procedure.

2.2 Measurements

The survey questionnaire contained sociodemographic information, concerns about COVID-19 epidemic, general vaccination behavior and attitudes, the General Vaccine Hesitancy Scale, the COVID-19 Vaccine Hesitancy Scale and other potential factors of vaccine hesitancy.

2.2.1 Sociodemographic information

Sociodemographic variables included age, gender, ethnicity, residence place, marital status, education level, household income (during past 1 year), smoking and drinking history, and COVID-19 test results.

2.2.2 Concerns of COVID – 19 pandemic

We assessed the concerns of participants about COVID – 19 pandemic by a 3-items scale, which included “I am scared about getting infected with COVID-19,” “The possibility of getting infected with COVID-19 in the future concerns me,” and “I don’t really worry about getting infected with COVID-19”. This 3-item scale was developed and utilized from several studies, participants responded to each item on a 5-point Likert-type scale (1 = strongly disagree to 5 = strongly agree) (15, 16). After reverse coded the last item, the three items were highly correlated with satisfactory reliability (Cronbach’s $\alpha = 0.702$).

2.2.3 The General Vaccine Hesitancy Scale

The General Vaccine Hesitancy Scale composed of 10 items which was revised on the base of previous studies (17, 18). In this study, we used the 10 items of the Vaccine Hesitancy Scale (VHS) developed by the SAGE Working Group on Vaccine Hesitancy that are measured on a five-point Likert-type rating scale ranging from “strongly disagree” to “strongly agree”. Corresponding changes were made to the wordings of the 10 items to make the study participants fully understand the meanings. We reversed seven items in the scoring of the scale so that higher scores indicated more hesitancy on all items. The reliability of the General Vaccine Hesitancy Scale was satisfactory in our study (Cronbach’s $\alpha = 0.930$).

2.2.4 The COVID-19 Vaccine Hesitancy Scale

The COVID-19 Vaccine Hesitancy Scale was measured by 15 items based on previous studies to identify vaccine-hesitant parents (19, 20). We collapsed responses of scale items into 3 categories: hesitant responses, “not sure or don’t know”, and non-hesitant responses. For the 6 items with a 5-point Likert-scale ranging from “strongly agree to strongly disagree”, hesitant responses were the answer of “strongly agree/agree” for 3 items and “strongly disagree/disagree” for 3 items. For 3 items with a 5-point Likert-scale ranging from “not at all concerned to very concerned”, hesitant response corresponded to the responses of “somewhat or very hesitant”. For yes/no items, “yes” was considered to be the hesitant response and “no” the non-hesitant response. Lastly, for the items with an 11-point Likert-scale, hesitant responses corresponded to the collapsed responses 0–5, not sure responses to 6–7, and non-hesitant responses to 8–10. Totally, the score was higher than or equal to 50 was indicated having COVID-19 vaccine hesitancy (20). The Cronbach’s alpha of the 15-item scale in the current study was 0.719.

2.2.5 General vaccination behavior and attitudes

The questionnaire used a series of questions to investigate respondents’ vaccination history, including the following items: “Do you agree that vaccines can protect you from diseases?” “Do you agree that you will get all vaccines that National Immunization Program or government recommended?” “Have you ever hesitated to get vaccination?” “Have you ever refused to get vaccination?” “Have you ever hesitated or refused to be get Pneumococcal Vaccine?” “Have you ever hesitated or refused to get Influenza Vaccine?”

2.2.6 Potential factors of COVID-19 vaccine hesitancy

In this section, the following items were designed to explore the barriers of get COVID-19 vaccine and related factors of COVID-19 vaccine hesitancy: (1) individual attitudes to COVID-19: “Do you agree that COVID-19 epidemic is a severe problem affecting the health of the community?” “Do you agree that COVID-19 will be a great threat to your health if you are infected?” (2) significant people’s advice: “Do you agree that you will get COVID-19 vaccine if doctors recommend?”, “Do you agree that the advice of your family members or friends will affect your intention of getting COVID-19 vaccine?” (3) information about COVID-19 vaccine: “Do you need transparent information about COVID-19 vaccine development, efficacy and safety?” “Do you have doubts about the source of information about the COVID-19 vaccine?” “Have you ever received negative information about getting the COVID-19 vaccine?” “Would you like to get the COVID-19 vaccine after receiving the negative information about it?” (4) cost or time to get COVID-19 vaccine: “Do you agree that the time costs in waiting for the vaccination or staying at the clinic will be a barrier for you to get COVID-19 vaccine?” “Do you agree that the environment of the clinic will be a barrier for you to get COVID-19 vaccine?” “Do you agree that the cost of going to the clinic will be a barrier for you to get COVID-19 vaccine?” (5) personal conditions: “Do you agree that you have no need of getting COVID-19 vaccine because you are healthy?” “Have you gotten emergency COVID-19 vaccination for some reasons?”.

2.3 Statistical analysis

This study described the sociodemographic information by counts and proportions among participants. The chi-squared test was utilized to compare the differences of various factors in different population groups. Survey responses were combined into two categories (having or not having COVID-19 vaccine hesitancy) according to whether the score of the COVID-19 Vaccine Hesitancy Scale was higher than or equal to 50. And ordinal regression models were run to examine demographic and attitudinal factors predictive of respondents' hesitancy to get vaccinated against COVID-19. To identify suitable candidate variables for regression models, univariate analysis was first conducted by chi-squared test, and variables were significant at $P < 0.10$ were then included in a multivariable regression model. The level of significance was set at $P < 0.05$. Data were analyzed by using SPSS version 24.0.

3 Results

3.1 sociodemographic characteristics

Table 1 summarized the characteristics distributions of participants by different population groups. A total of 4289 respondents (response rate 95.37%) completed the online questionnaire, and 62 questionnaires were excluded due to the age limitations. Of them, there were 2656 (62.8%) medical workers, 753 (17.8%) students, 434 (10.3%) general population, and 384 (9.1%) public health professionals. The mean age was 33.02 years. In total, 2818 (66.7%) respondents were female, 89.1% of them were Han ethnicity, the majority of participants (85.6%) lived in urban areas and 56.9% of them were married, 41.3% were single. The education level of most of them (93.8%) were college and above. For the household income during the past year, nearly half of them were in 50000–100000 Yuan per year. Most of participants self-reported they have not ever smoking (88.3%) or drinking (84.6%).

Table 1
Sociodemographic characteristics of participants by different population groups

Variables	Medical workers(n = 2656)	Students(n = 753)	General population (n = 434)	Public health professionals(n = 384)	Total (n = 4227)
Age (years) (mean ± SD)	35.89± 9.33	22.47± 3.13	29.73± 7.78	37.52± 9.03	33.02± 9.90
Gender, n (%)					
Male	732 (27.6)	334 (44.4)	193 (44.5)	150 (39.1)	1409 (33.3)
Female	1924 (72.4)	419 (55.6)	241 (55.5)	234 (60.9)	2818 (66.7)
Ethnicity, n (%)					
Han	2339 (88.1)	654 (86.9)	415 (95.6)	357 (93.0)	3765 (89.1)
Other	317 (11.9)	99 (13.1)	19 (4.4)	27 (7.0)	462 (10.9)
Residence place, n (%)					
Urban	2408 (90.7)	496 (65.9)	355 (81.8)	361 (94.0)	3620 (85.6)
Rural	248 (9.3)	257(34.1)	79 (18.2)	23 (6.0)	607 (14.4)
Marital status, n (%)					
Single	667 (25.1)	721 (95.8)	263 (60.6)	93 (24.2)	1744 (41.3)
Married	1927 (72.6)	27 (3.6)	165 (38.0)	285 (74.2)	2404 (56.9)
Others	62 (2.3)	5 (0.7)	6 (1.4)	6 (1.6)	79 (1.9)
Education level, n (%)					
≤High school	160 (6.0)	25 (3.3)	53 (12.2)	22 (5.7)	260 (6.2)
College and above	2496 (94.0)	728 (96.7)	381 (87.8)	362 (94.3)	3967 (93.8)
Household income (past 1 year), n (%)					

Variables	Medical workers(n = 2656)	Students(n = 753)	General population (n = 434)	Public health professionals(n = 384)	Total (n = 4227)
≤ 40000 Yuan	431 (16.2)	256 (34.0)	84 (19.4)	43 (11.2)	814 (19.3)
50000–100000 Yuan	1233 (46.4)	285 (37.8)	185 (42.6)	132 (34.4)	1835 (43.4)
110000–350000 Yuan	920 (34.6)	178 (23.6)	137 (31.6)	193 (50.3)	1428 (33.8)
> 350000 Yuan	72 (2.7)	34 (4.5)	28 (6.5)	16 (4.2)	150 (3.5)
Ever smoking, n (%)					
No	2369 (89.2)	679 (90.2)	347 (80.0)	339 (88.3)	3734 (88.3)
Yes	287 (10.8)	74 (9.8)	87 (20.0)	45 (11.7)	493 (11.7)
Ever drinking, n (%)					
No	2276 (85.7)	668 (88.7)	329 (75.8)	303 (78.9)	3576 (84.6)
Yes	380 (14.3)	85 (11.3)	105 (24.2)	81 (21.1)	651 (15.4)
COVID-19 test results, n (%)					
Positive	12 (0.5)	19 (2.5)	6 (1.4)	2 (0.5)	39 (0.9)
Negative	2056 (77.4)	438 (58.2)	272 (62.7)	332 (86.5)	3098 (73.3)
Haven't tested	588 (22.1)	296 (39.3)	156 (35.9)	50 (13.0)	1090 (25.8)

3.2 General vaccination behavior and vaccine hesitancy among different population groups

Differences of general vaccination behavior and vaccine hesitancy in different population groups were shown in Table 2. For public health professionals, 94.3% of them agreed that vaccines can protect them from diseases, which was higher than in medical workers (90.5%), students (87.5%) and general population (88.7%). Among medical workers, the majority of them (80.0%) agreed that they will get all vaccines that the National Immunization Program or government recommended, however, a lower proportion was in students (76.5%), general population (72.6%) and public health professionals (75.0%). When the participants were asked about whether they were hesitated to get vaccination, 39.4% of general

population were self-reported “yes” which were higher than in other three population groups. Regarding the sorts of vaccines, they were hesitated or refused, general population had the highest proportion (27.4%) of those who hesitated to get Pneumococcal Vaccine and the highest proportion of medical workers (9.8%) refused to vaccinate against pneumococcal bacteria compared to other groups. Comparison of the General Vaccine Hesitancy Scale scores in different groups, medical workers had a higher score (20.33 ± 8.59) than students (20.32 ± 8.11), general population (19.87 ± 7.61) and public health professionals (18.48 ± 7.51).

Table 2

General vaccination behavior and vaccine hesitancy among participants by different population groups

Variables	Medical workers	Students	General population	Public health professionals	<i>P</i>
	n (%)	n (%)	n (%)	n (%)	
Do you agree that vaccines can protect you from diseases?					
No	253 (9.5)	94 (12.5)	49 (11.3)	22 (5.7)	0.002
Yes	2403 (90.5)	659 (87.5)	385 (88.7)	362 (94.3)	
Do you agree that you will get all vaccines that the National Immunization Program or government recommended?					
No	530 (20.0)	177 (23.5)	119 (27.4)	96 (25.0)	0.001
Yes	2126 (80.0)	576 (76.5)	315 (72.6)	288 (75.0)	
Have you ever hesitated to get vaccination?					
No	1806 (68.0)	506 (67.2)	263 (60.6)	257 (66.9)	0.026
Yes	850 (32.0)	247 (32.8)	171 (39.4)	127 (33.1)	
Have you ever refused to get vaccination?					
No	2222 (83.7)	646 (85.8)	365 (84.1)	320 (83.3)	0.542
Yes	434 (16.3)	107 (14.2)	69 (15.9)	64 (16.7)	
Have you ever hesitated or refused to get Pneumococcal Vaccine?					
No	1759 (66.2)	509 (67.6)	293 (67.5)	267 (69.5)	0.000
Ever hesitated	636 (23.9)	204 (27.1)	119 (27.4)	82 (21.4)	
Ever refused	261 (9.8)	40 (5.3)	22 (5.1)	35 (9.1)	
Have you ever hesitated or refused to get Influenza Vaccine?					
No	1789 (67.4)	514 (68.3)	294 (67.7)	274 (71.4)	0.180
Ever hesitated	622 (23.4)	188 (25.0)	109 (25.1)	84 (21.9)	
Ever refused	245 (9.2)	51 (6.8)	31 (7.1)	26 (6.8)	
The General Vaccine Hesitancy Scale scores					
(mean \pm SD)	20.33 \pm 8.59	20.32 \pm 8.11	19.87 \pm 7.61	18.48 \pm 7.51	0.001

3.3 COVID-19 vaccine hesitancy and relevant factors among different population groups

In this study, 64.1% (2710) of participants were observed having COVID-19 vaccine hesitancy. Among different groups of people, 283 (73.7%) public health professionals, 1723 (64.9%) of medical workers, 265 (61.1%) general population and 439 (58.3%) students were self-reported having COVID-19 vaccine hesitancy. Compared to medical workers, students and public health professionals, the general population had the highest score (10.06 ± 1.79) of the concerns of COVID-19 epidemic. Regarding to the attitudes of respondents to COVID-19 epidemic, 75.8% of public health professionals agreed that COVID-19 epidemic is a severe problem affecting people's health, which was significantly higher than other groups. And a statistically higher proportion of medical workers (89.9%) thought that COVID-19 will be a great threat to their health if they infected.

Among different groups, 94.3% of public health professionals would get COVID-19 vaccine if doctors recommend, more than half of students (57.6%) would be affected by their family members or friends, the ratings were significantly higher. Similarly, responses also significantly varied among the four groups ($P < 0.01$) when asked the information about COVID-19 vaccine, public health professionals had the highest proportions of those (90.1%) who need transparent information about COVID-19 vaccine development, efficacy and safety and 63.5% had received negative information, 42.0% of students had doubts about the source of information. When participants were asked if the time costs in waiting for the vaccination or staying at the clinic would be barriers for them to vaccinate, a higher proportion of students were responded "Yes". For public health professionals, 9.6% of them self-reported that they have no need of getting COVID-19 vaccine because they are healthy, however, 42.2% of them had gotten emergency COVID-19 vaccination for some reasons (Table 3).

Table 3

Relevant factors of COVID-19 Vaccine Hesitancy among participants by different population groups

Variables	Medical workers	Students	General population	Public health professionals	<i>P</i>
	n (%)	n (%)	n (%)	n (%)	
Have COVID-19 vaccine hesitancy					
No	933 (35.1)	314 (41.7)	169 (38.9)	101 (26.3)	0.000
Yes	1723 (64.9)	439 (58.3)	265 (61.1)	283 (73.7)	
The concern of COVID-19 epidemic					
(mean \pm SD)	9.83 \pm 2.10	9.80 \pm 2.13	10.06 \pm 1.79	9.56 \pm 1.88	0.007
Do you agree that COVID-19 epidemic is a severe problem affecting the health of the community?					
No	698 (26.3)	242 (32.1)	146 (33.6)	93 (24.2)	0.000
Yes	1958 (73.7)	511 (67.9)	288 (66.4)	291 (75.8)	
Do you agree that COVID-19 will be a great threat to your health if you are infected?					
No	269 (10.1)	108 (14.3)	47 (10.8)	46 (12.0)	0.012
Yes	2387 (89.9)	645 (85.7)	387 (89.2)	338 (88.0)	
Do you agree that you will get COVID-19 vaccine if doctors recommend?					
No	221 (8.3)	101 (13.4)	68 (15.7)	22 (5.7)	0.000
Yes	2435 (91.7)	652 (86.6)	366 (84.3)	2435 (94.3)	
Do you agree that the advice of your family members or friends will affect your intention of getting COVID-19 vaccine?					
No	1721 (64.8)	319 (42.4)	237 (54.6)	254 (66.1)	0.000
Yes	935 (35.2)	434 (57.6)	197 (45.4)	130 (33.9)	
Do you need transparent information about COVID-19 vaccine development, efficacy and safety?					
No	456 (17.2)	142 (18.9)	62 (14.3)	38 (9.9)	0.001

Variables	Medical workers	Students	General population	Public health professionals	<i>P</i>
	n (%)	n (%)	n (%)	n (%)	
Yes	2200 (82.8)	611 (81.1)	372 (85.7)	346 (90.1)	
Do you have doubts about the source of information about the COVID-19 vaccine?					
No	2064 (77.7)	437 (58.0)	276 (63.6)	308 (80.2)	0.000
Yes	592 (22.3)	316 (42.0)	158 (36.4)	76 (19.8)	
Have you ever received negative information about getting the COVID-19 vaccine?					
No	1260 (47.4)	373 (49.5)	203 (46.8)	140 (36.5)	0.000
Yes	1396 (52.6)	380 (50.5)	231 (53.2)	244 (63.5)	
Would you like to get the COVID-19 vaccine after receiving the negative information about it?					
No	932 (35.1)	357 (47.4)	205 (47.2)	104 (27.1)	0.000
Yes	1724 (64.9)	396 (52.6)	229 (52.8)	280 (72.9)	
Do you agree that the time costs in waiting for the vaccination or staying at the clinic will be a barrier for you to get COVID-19 vaccine?					
No	2033 (76.5)	444 (59.0)	290 (66.8)	281 (73.2)	0.000
Yes	623 (23.5)	309 (41.0)	144 (33.2)	103 (26.8)	
Do you agree that the environment of the clinic will be a barrier for you to get COVID-19 vaccine?					
No	1708 (64.3)	331 (44.0)	208 (47.9)	217 (56.5)	0.000
Yes	948 (35.7)	422 (56.0)	226 (52.1)	167 (43.5)	
Do you agree that the costs of going to the clinic will be a barrier for you to get COVID-19 vaccine?					
No	2011 (75.7)	376 (49.9)	271 (62.4)	270 (70.3)	0.000
Yes	645 (24.3)	377 (50.1)	163 (37.6)	114 (29.7)	
Do you agree that you have no need of getting COVID-19 vaccine because you are healthy?					

Variables	Medical workers	Students	General population	Public health professionals	<i>P</i>
	n (%)	n (%)	n (%)	n (%)	
No	2364 (89.0)	582 (77.3)	354 (81.6)	347 (90.4)	0.000
Yes	292 (11.0)	171 (22.7)	80 (18.4)	37 (9.6)	
Have you gotten emergency COVID-19 vaccination for some reasons?					
No	1610 (60.6)	638 (84.7)	373 (85.9)	222 (57.8)	0.000
Yes	1046 (39.4)	115 (15.3)	61 (14.1)	162 (42.2)	

3.4 The predictors for COVID-19 vaccine hesitancy among participants

According with results from the multivariate analyses (Table 4), gender was significantly associated with hesitancy, female was more likely to be hesitant about COVID-19 vaccine than male (OR: 1.247, 95% CI: 1.060–1.467). With comparison of general population, public health professionals were more likely to have COVID-19 vaccine hesitancy, while compared to students and medical workers there were no statistically differences. A significant association was noted between household income (past 1 year) and hesitancy ($P < 0.001$), higher levels of household income were significantly associated with higher hesitancy. COVID-19 test results had a significant correlation with vaccine hesitancy, but no significant differences were observed between people who were affected and who were not and also were not reported between those who were affected and who haven't tested. Participants who ever hesitated to get vaccination were more likely to be hesitant (OR: 1.360, 95% CI: 1.151–1.608)), but there are no significant differences between those who ever refused to get vaccination and hesitancy. The results showed that respondents' concerns about the epidemic were associated with hesitancy, and those with higher self-report scores were more likely to be hesitant (OR: 1.068, 95% CI: 1.033–1.103). However, a lower score of the General Vaccine Hesitancy Scale was associated with more hesitancy towards COVID-19 vaccination (OR: 0.979, 95% CI: 0.971–0.988). Participants who needed transparent information about COVID-19 vaccine (OR: 1.609, 95% CI: 1.343–1.928) and received negative information about the vaccine before (OR: 1.300, 95% CI: 1.130–1.496) were both more likely to be hesitant to get COVID-19 vaccine.

Table 4 Analysis of the predictors for COVID-19 vaccine hesitancy among participants

Variables	Univariate analysis			Multivariate analysis	
	No Hesitancy (n=1517)	Hesitancy (n=2710)	<i>P</i>	OR* (95%CI*)	<i>P</i>
Age (years), (mean ± SD)					
	32.21 ± 10.02	33.47 ± 9.80	0.000	1.004 (0.994-1.015)	0.424
Gender, n (%)					
Male	572 (37.7)	837 (30.9)	0.000	1.000	
Female	945 (62.3)	1873 (69.1)		1.247 (1.060-1.467)	0.008
Ethnicity, n (%)					
Han	1326 (87.4)	2439 (90.0)	0.010	1.000	
Other	191 (12.6)	271 (10.0)		0.821 (0.668-1.010)	0.062
Residence place, n (%)					
Urban	1244 (82.0)	2376 (87.7)	0.000	1.000	
Rural	2732 (18.0)	334 (12.3)		0.933 (0.763-1.140)	0.497
Marital status, n (%)					0.954
Single	692 (45.6)	1052 (38.8)	0.000	1.000	
Married	797 (52.5)	1607 (59.3)		1.011 (0.820-1.246)	0.918
Others	28 (1.8)	51 (1.9)		0.939 (0.563-1.569)	0.811
Education level, n (%)					
≤High school	98 (6.5)	162 (6.0)	0.531	—	
College and above	1419 (93.5)	2548 (94.0)			
Population groups					0.098
General population	169 (11.1)	265 (9.8)	0.000	1.000	
Students	314 (20.7)	439 (16.2)		1.075 (0.829-1.394)	0.586
Medical workers	933 (61.5)	1723 (63.6)		1.107 (0.880-1.393)	0.384
Public health	101 (6.7)	283 (10.4)		1.469 (1.069-	0.018

professionals				2.019)	
Household income (past 1 year), n (%)					0.000
>350000	32 (2.1)	118 (4.4)	0.000	1.000	
110000-350000	465 (30.7)	963 (35.5)		0.476 (0.312-0.726)	0.001
50000-100000	657 (43.3)	1178 (43.5)		0.465 (0.306-0.707)	0.000
≤40000	363 (23.9)	451 (16.6)		0.391 (0.253-0.605)	0.000
Ever smoking, n (%)					
No	1322 (87.1)	2412 (89.0)	0.071	1.000	
Yes	195 (12.9)	298 (11.0)		1.018 (0.805-1.288)	0.881
Ever drinking, n (%)					
No	1256 (82.8)	2320 (85.6)	0.015	1.000	
Yes	261 (17.2)	390 (14.4)		0.900 (0.731-1.109)	0.323
COVID-19 test results, n (%)					0.002
Positive	18 (1.2)	21 (0.8)	0.000	1.000	
Negative	1024 (67.5)	2074 (76.5)		0.996 (0.502-1.973)	0.990
Haven't tested	475 (31.3)	615 (22.7)		0.757 (0.380-1.509)	0.429
Do you agree that vaccines can protect you from diseases?					
No	190 (12.5)	228 (8.4)	0.000	1.000	
Yes	1327 (87.5)	2482 (91.6)		1.219 (0.978-1.519)	0.078
Do you agree that you will get all vaccines that National Immunization Program or government recommended?					
No	343 (22.6)	579 (21.4)	0.347	—	
Yes	1174 (77.4)	2131 (78.6)			
Have you ever hesitated to get vaccination?					
No	1079 (71.1)	1753 (64.7)	0.000	1.000	
Yes	438 (28.9)	957 (35.3)		1.360 (1.151-1.608)	0.000

Have you ever refused to get vaccination?					
No	1309 (86.3)	2244 (82.8)	0.003	1.000	
Yes	208 (13.7)	466 (17.2)		1.142 (0.923-1.413)	0.221
Have you ever hesitated or refused to be get Pneumococcal Vaccine?					
No	1032 (68.0)	1796 (66.3)	0.009	1.000	0.399
Ever hesitated	383 (25.2)	658 (24.3)		0.998 (0.810-1.229)	0.984
Ever refused	102 (6.7)	256 (9.4)		1.233 (0.892-1.705)	0.205
Have you ever hesitated or refused to get Influenza Vaccine?					
No	1044 (68.8)	1827 (67.4)	0.074	1.000	0.345
Ever hesitated	366 (24.1)	637 (23.5)		0.899 (0.730-1.107)	0.316
Ever refused	107 (7.1)	246 (9.1)		1.116 (0.814-1.532)	0.495
The General Vaccine Hesitancy Scale scores					
(mean \pm SD)	21.01 \pm 8.07	19.61 \pm 8.43	0.000	0.979 (0.971-0.988)	0.000
The concern of COVID-19 epidemic					
(mean \pm SD)	9.65 \pm 2.00	9.92 \pm 2.08	0.000	1.068 (1.033-1.103)	0.000
Do you agree that COVID-19 epidemic is a severe problem affecting the health of the community?					
No	470 (31.0)	709 (26.2)	0.001	1.000	
Yes	1047 (69.0)	2001 (73.8)		1.080 (0.926-1.260)	0.327
Do you agree that COVID-19 will be a great threat to your health if you are infected?					
No	205 (13.5)	265 (9.8)	0.000	1.000	
Yes	1312 (86.5)	2445 (90.2)		1.100 (0.881-1.373)	0.401
Do you agree that you will get COVID-19 vaccine if doctors recommend?					
No	170 (11.2)	242 (8.9)	0.017	1.000	
Yes	1347 (88.8)	2468 (91.1)		0.873 (0.687-1.110)	0.267

Do you agree that the advice of your family members or friends will affect your intention of getting COVID-19 vaccine?

No	909 (59.9)	1622 (59.9)	0.965	–
Yes	608 (40.1)	1088 (40.1)		

Do you agree that you have no need of getting COVID-19 vaccine because you are healthy?

No	1280 (84.4)	2367 (87.3)	0.007	1.000
Yes	237 (15.6)	343 (12.7)		0.827 (0.678-1.009)

Do you need transparent information about COVID-19 vaccine development, efficacy and safety?

No	347 (22.9)	351 (13.0)	0.000	1.000
Yes	1170 (77.1)	2359 (87.0)		1.609 (1.343-1.928)

Do you have doubts about the source of information about the COVID-19 vaccine?

No	1129 (74.4)	1956 (72.2)	0.115	–
Yes	388 (25.6)	754 (27.8)		

Have you ever received negative information about getting the COVID-19 vaccine?

No	817 (53.9)	1159 (42.8)	0.000	1.000
Yes	700 (46.1)	1551 (57.2)		1.300 (1.130-1.496)

Would you like to get the COVID-19 vaccine after receiving the negative information about it?

No	652 (43.0)	946 (34.9)	0.000	1.000
Yes	865 (57.0)	1764 (65.1)		1.143 (0.985-1.325)

Do you agree that the time costs in waiting for the vaccination or staying at the clinic will be a barrier for you to get COVID-19 vaccine?

No	1087 (71.7)	1961 (72.4)	0.623	–
Yes	430 (28.3)	749 (27.6)		

Do you agree that the environment of the clinic will be a barrier for you to get COVID-19 vaccine?

No	892 (58.8)	1572 (58.0)	0.616	–
Yes	625 (41.2)	1138 (42.0)		

Do you agree that the cost of going to the clinic will be a barrier for you to get COVID-19 vaccine?

No	1030 (67.9)	1898 (70.0)	0.148	–
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Yes	487 (32.1)	812 (30.0)		
Have you gotten emergency COVID-19 vaccination for some reasons?				
No	1056 (69.6)	1787 (65.9)	0.015	1.000
Yes	461 (30.4)	923 (34.1)	1.030 (0.886-1.197)	0.704

*Abbreviations: OR, odds ratio; CI: confidence interval.

4 Discussion

In current study, 64.1% of all participants were self-reported having COVID-19 vaccine hesitancy. While 35.9% were non-hesitant for get vaccination against COVID-19, this rate was lower than the findings in most of the previous other studies, 77.6% in France, 91.3% in China, 74.5% in India, 70.8% in Italy and 62.6% in Ethiopia (21–24). Among the study participants, the public health professionals (73.7%) had the highest rate of hesitancy, followed by medical workers (64.9%), general population (61.0%) and students (58.4%). Compared to the hesitancy rate of 47.5% among college students in United states, it was noteworthy that the Chinese college students had a higher rate of hesitancy toward COVID-19 vaccine (9, 25, 26). Apart from the change of people’s attitude with the increasingly severe COVID-19 pandemic over the world and different study time, different socio-demographic factors, levels of health literacy, particularly with respect to immunization schedules, as well as changes in local health policies over time and advances in the development of the COVID-19 vaccines are possible reasons of the differences on COVID-19 vaccine hesitancy. At present, the COVID-19 vaccine is available in China, however, not everyone in the cities or areas with accessible vaccination has been vaccinated. This level of hesitancy is very likely to be a barrier to or delay the establishment of herd immunity.

Among different population groups, this study indicated that public health professionals were more likely to have COVID-19 vaccine hesitancy than the general population. Most of the public health professionals in our study were healthcare workers from local CDCs who had more specialized knowledge. Previous studies had reported that healthcare workers or providers were instead more likely to have a low willingness to be vaccinated (27, 28). Public health professionals did not want to receive the shot might probably due to their low perception of risk on contracting the disease, or they would pay more attention to individual protection. On the other hands, they might consider the COVID-19 as common flu and not a much dangerous disease, or thought that they would be infected even though they get vaccination, due to the doubts of the efficacy of the vaccine. Additionally, we assumed public health professionals had more sources or approaches to receive information about the vaccine, including some negative news or information, which in turn affected their willingness to get a shot to some extent(29). Public health professionals always serve as the most trusted advisors and influencers of vaccination decisions and their recommendations are important facilitators for vaccine acceptance (28). If the attitudes or behaviors of them towards getting COVID-19 vaccine are hesitant, the public would have doubts or concerns about the vaccine. Therefore, interventions focusing on increasing the health care workers’

willingness to be vaccinated is an urgent need. Another study showed that knowledge about particular vaccines, their efficacy and safety, would help healthcare workers to build their own confidence in vaccines and willingness to recommend vaccines to others (30). To develop education campaigns based on accurate and authoritative knowledge or information might be working for reducing their hesitancy.

Besides, participants who have ever hesitated to get vaccination were more likely to be hesitant for the vaccination against COVID-19. Similarly, another survey found that a prominent determinant of COVID-19 vaccine avoidance is whether a person had the flu shot in the last two years (31). In our research, a lower score of the General Vaccine Hesitancy Scale was correlated to a higher possibility to be hesitant towards COVID-19 vaccines. It is surprising those who were not hesitant against other vaccines during pre-COVID era were more likely to be hesitant towards the COVID-19 vaccine. This might be because the COVID-19 epidemic has posed unprecedented health threats to the public's health and the COVID-19 vaccines were not undergone long-term clinical trials as others for emergency use as a strategy of controlling the pandemic. All individuals may have preoccupation and anxiety on safety and efficacy issues of COVID-19 vaccination, even if they were not previously hesitant to uptake the general vaccines. Therefore, the concerns about vaccine's safety and efficacy is one of the most important sources of vaccine hesitancy, as demonstrated in as other studies (32).

In the past several months, the negative news about the safety and efficacy of COVID-19 vaccines have been widely spread on the Internet, both before and during vaccination. During the COVID-19 pandemic, governments and the public were unavoidably exposed to huge amount of rapid and far-reaching spread of questionable information, namely infodemic. Fake news and misinformation have become prevalent in various social media and have been skyrocketed since the beginning of the COVID-19 pandemic(33). Some media or websites would exaggerate or make unreliable news, because negative tweets expressing misinformation on vaccine confidence and even rumors, had more followers and attracted more public engagement online (34). Our study highlighted the needs of transparent information about COVID-19 vaccine development, efficacy and safety and the negative roles of misinformation on COVID-19 vaccine in vaccine hesitancy. The COVID-19 vaccine was developed at an alarming rate, unlike other vaccines in the past, so people may have more concerns about it, which has frequently been reported as the major obstacle to vaccination decision-making, especially for newly introduced vaccines which have not been fully tested in the real world (21, 35, 36). Meanwhile, risk information in the news had direct effects on people's health behavior during the pandemic (37). Indeed, some other studies reported perceived effectiveness of the vaccine increased vaccination intention(32, 38). Therefore, providing reliable information on the disease and the relevant vaccines by the authorities and establishing suitable communication strategies between the government and the public would be helpful to create a trustworthy environment and hence improve public's confidence in vaccination. Also, a warning system on infodemic is needed, apart from the monitoring of the disease itself in the similar circumstances.

In the information age, people can be easily influenced by false information and negative news, and thus may led to fear or panic and make arbitrary decisions (39). In the meantime, social medias play an increasingly important role in spreading both accurate information and misinformation, hence we can

also use medias or websites to inform people in a positive way. To increase vaccination rates, information and education campaigns on the safety and efficacy of the COVID-19 vaccine will enhance public confidence in the COVID-19 vaccine (40, 41). People who have received vaccines, such as respected celebrities, those with influencing popularity and health care professionals with high click rate can be used as vaccination advocates to promote the benefits of vaccines to increase public's willingness of vaccination (42).

In general, our study suggested a high prevalence of vaccine hesitancy against the COVID-19 vaccine among Chinese, especially among public health professionals. In addition, the spread of inaccurate information can cause, even increase vaccine hesitancy. Nowadays, especially after the outbreak, people are more likely to get information about vaccines on the Internet, which always containing incorrect, false and negative information. As a result, people may have further doubts about the safety or efficacy of the vaccine and refusal or delay vaccination. Consequently, proactive work against possible misinformation is needed during the development and vaccination phases of the COVID-19 vaccine, and more focused and nuanced public health information from trusted members of the population, including physicians, journalists, and experts is necessary and useful. More importantly, educating social media users on how to distinguish reliable information and to encourage them not to circulate false information are helpful for tackling COVID-19-related misinformation (39). For healthcare workers, to improve their knowledge, confidence of COVID-19 vaccine and communication skills is essential both for their own health and for the guiding effects on the general public. However, vaccine hesitancy is a complex phenomenon that does not depend only on a sufficient knowledge of vaccinations or perceived correct information, further study is necessary to explore other factors and effective prevention or intervention to reduce vaccine hesitancy.

Limitations

Our survey was conducted before the COVID-19 vaccine became widely available in China. Therefore, there might have differences between the prevalence of hesitancy in our study and the actual vaccination rate later on. However, our study still provided meaningful results in terms of the prevalence and related factors of the vaccine hesitancy among various populations. Although four different population groups were surveyed in our study, the generalizability of our results will still be limited in certain aspects due to the nonprobability sampling we used. Also, the questionnaires were self-reported online, thus the information bias probably existed in this study.

5 Conclusions

Given the influence of public health workers on vaccination acceptance of public and the relatively high rate of vaccine hesitancy among them, providing appropriate information to them and training on communicating skills are of most important for their own benefit and the public's. Since the negative information of COVID-19 vaccine could cause and increase vaccine hesitancy, transparent information about the vaccine was vital for public to make vaccination decisions. Evidence-based information

strategies where the potential benefits and risks of vaccination are properly explained, reducing the spread of misinformation and disseminating facts in a timely and accurate way, will likely reduce vaccine hesitancy.

Declarations

Ethics approval and consent to participate

This study has been approved by the Ethical Review Committee of Chinese Center for Disease Control and Prevention on December 4th, 2020 (approval number: 202020). An electronic informed consent was provided before the start of the questionnaire survey, upon completion of the informed consent, participants filled in the on-line questionnaire.

Consent for publication

Not applicable.

Availability of data and materials

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

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Xiaoyou Su, Yiman Huang prepared the first draft. Xiaoyou Su, Youlin Qiao and Yiman Huang managed the overall project. Mingyu Si, Weijun Xiao and Hao Wang provided writing-review. Xiaoyou Su, Wenjun Wang, Xiaofen Gu, Li Ma, Li Li, Shaokai Zhang, Chunxia Yang and Yanqin Yu were responsible for the questionnaire survey of people in seven geographical regions of China. Xiaoyou Su and Yiman Huang analyzed data.

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