

RESEARCH PAPER



## Factors associated with COVID-19 vaccination acceptance among industrial workers in the post-vaccination era: a large-scale cross-sectional survey in China

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### ABSTRACT

**Background:** COVID-19 pandemic continues to pose a huge threat to public health. Mass vaccination is needed to achieve herd immunity against SARS-CoV-2. Currently, several vaccines are being inoculated on a large-scale. The willingness of COVID-19 vaccination had been well investigated in the pre-vaccination era, but no reported data in the post-vaccination era yet.

**Methods:** We conducted a large-scale survey among industrial workers during the vaccination campaign in China. Chi-square test and rank sum test were used to identify differences for various intentions regarding COVID-19 vaccination. Univariate analysis and multivariate regression models were utilized to analyze the relationship among demographic factors, related influencing factors and acceptance of COVID-19 vaccination.

**Results:** A total of 23,940 industrial workers were included, 66.0% were willing to take COVID-19 vaccine, 16.6% were unwilling, and 17.4% were unsure. Participants were more likely to get vaccinated if they were male, aged 45–65, being good educated, married, or being recommended by doctors or nurses. Participants with strong risk perception of COVID-19 infection, strong confidence in COVID-19 vaccine, high attention to COVID-19 vaccine, good health status, bad health habit, and a history of vaccination within three months were also more likely to be vaccinated.

**Conclusions:** This study calls for more attention and health-related education among industrial workers to improve their acceptance of COVID-19 vaccination.

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COVID-19; vaccine; industrial workers; willingness; attitude



## Introduction

The pandemic of coronavirus disease 2019 (COVID-19) is a huge challenge for public health worldwide. As of September 15, 2021, more than 227 million cases of COVID-19 have been confirmed globally, 4.6 million people have died from COVID-19.<sup>1</sup> Several measures have been adopted by governments to control the spread of COVID-19.<sup>2</sup> Among them, mass vaccination is considered to be the most cost-effective strategy. Currently, a variety of COVID-19 vaccines are being inoculated globally, such as inactivated vaccine, subunit protein vaccine, Ad5-vectored vaccine, mRNA vaccine, etc.<sup>3</sup>


According to previous studies, a minimum coverage of 67–80% of COVID-19 vaccination was required to achieve the herd immunity against COVID-19.<sup>4,5</sup> In order to increase the coverage of COVID-19 vaccine, the government needs to develop vaccination strategies based on the current willingness of different populations. Our previous studies in the era without available COVID-19 vaccine had reported a high acceptance of COVID-19 vaccination among the Chinese population.<sup>6</sup> However, mass vaccination campaigns and changes in the pandemic situation may change attitudes

toward the COVID-19 vaccine in people who have not yet been vaccinated.<sup>7</sup> Understanding the current acceptability of COVID-19 vaccination is an urgent need, and will be critical in guiding the next stage of the vaccination campaign.

Industrial workers are the backbone to implement the strategy of manufacturing power, and also are the key population to create social wealth. Because of their large number and highly dense population, they will play an important role in achieving herd immunity against COVID-19 in China. Previous study reported that Chinese industrial workers possessed a high sense of protective behaviors against COVID-19.<sup>8</sup> However, another study showed that industrial workers were at a high risk of infection and transmission of SARS-CoV-2, and many of whom suffered more severe conditions when infected.<sup>9</sup> Based on the experience of influenza vaccination, the vaccination coverage among industrial workers was usually lower than that of the general population.<sup>10</sup> So far, it is not clear whether the similar situation would be encountered when promoting of COVID-19 vaccination plan. Investigating the willingness and related factors of COVID-19 vaccination in this population will help formulate tailor-made vaccination strategies and ultimately increase vaccination coverage.

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In the present study, based on a sample of 23,940 industrial workers in China, we designed a cross-sectional study to evaluate the potential acceptance of COVID-19 vaccine and influencing factors in this population. This work would provide critical information to improve the acceptance and coverage of COVID-19 vaccination among industrial workers, and eventually to achieve the herd immunity against SARS-CoV-2 according to Chinese vaccination plan.

## Methods

### Participants and study design

This survey is a cross-sectional study with a convenience sample of industrial workers in Shenzhen, China. A web-based anonymous survey was conducted on March 25, 2021 to April 2, 2021 to investigate the acceptance of COVID-19 vaccine and influencing factors among this population. Data were collected via an online survey website, wenjuanxing (<https://www.wjx.cn/>). To ensure the uniqueness and authenticity of each participant, the IP address and telephone number of the participant were checked. Those who are not between the ages of 18 and 65 were excluded. Additionally, those who completed the questionnaire for less than 300 seconds or longer than 3,000 seconds were also excluded.

### Measures

The questionnaire used in this study was developed based on our previous study,<sup>6</sup> and the items of the Vaccine Hesitancy Scale (VHS) were referred to the Report of the Sage Working Group on Vaccine Hesitancy by WHO Strategic Advisory Group on Experts (SAGE) Working Group.<sup>11,12</sup> The influencing factors for vaccine hesitancy were mainly according to the “Working Group Determinants of Vaccine Hesitancy Matrix,” which is an extensively adopted framework and developed by the SAGE Working Group.<sup>11</sup> In brief, our questionnaire was composed of three sections. The first section was demographic questions, including age, gender, education level, marital status, monthly per capita household income, and ethnicity. In the second section, participants were asked about their willingness to get the COVID-19 vaccine, and whether they would be willing to get the COVID-19 vaccine if it would require multiple doses of self-funded vaccinations in the future. The third section was composed of items regarding the risk perception, confidence and attention to COVID-19 vaccine, personal health habits, history of vaccination, health status, and professionals’ recommendation. As previously described,<sup>6</sup> our questionnaire was performed a pre-investigation, and reviewed by five public health scholars to improve its quality and validity. We also conducted the confirmatory factor analysis (CFA) and exploratory factor analysis (EFA) to confirm its reliability and validity.

### Primary outcome

The main outcome of this study was accessed by the following question:

Would you like to be vaccinated against COVID-19?

(1) Yes; 2) No; 3) Not sure

Those industrial workers who chose “No” and “not sure” were classified as vaccine hesitancy.

### Data analysis

For descriptive analysis, chi-square test and rank sum tests were used to identify differences for various intentions regarding COVID-19 vaccination. As mentioned above, we grouped those industrial workers who chose ‘no’ or ‘not sure’ on the question ‘would you like to be vaccinated against COVID-19’ as the vaccine hesitant population. Thus, the outcome was a binary variable. Univariate analysis was employed to analyze the relationship between demographic factors, as well as related influencing factors and acceptance of COVID-19 vaccination. Those factors with *P* value less than 0.05 were all included in the multivariate logistic regression model. Adjusted odds ratios (aOR) and its 95% confidence interval (95% CI) were calculated by multiple logistic regression as the indicators of association strength. Data analysis was performed by SPSS (version 25.0).

### Ethical approval

This study was approved by the Ethics Committee of the School of Public Health (Shenzhen), Sun Yat-sen University (Approval number: SYSU-PHS-IACUC-2021-019).

## Results

### Demographic characteristics

Overall, 25,781 industrial workers responded to our survey. After data cleaning according to exclusion criteria, a total of 23,940 industrial workers were included. Of total, 78.6% were aged 25–45 years, 57.6% were unmarried, and 68.5% were male. Most participants had a junior high or high school education (34.4% and 37.2%, respectively). 64.1% of participants had a monthly income level lower than 5000 RMB, and 87.6% of participants were the Han nationality. Detailed demographic information of the participants was presented in Table 1.

### Acceptance and hesitancy of COVID-19 vaccination among industrial workers

Of total, 15,811 (66.0%) participants were willing to take COVID-19 vaccine, while 3,965 (16.6%) expressed resistance to COVID-19 vaccine, and 4,561 (17.4%) were unsure. When asked whether they would vaccinate at their own expenses, only 57.2% of industrial workers expressed their willingness (Table S1).

### Factors associated with acceptance of COVID-19 vaccination

#### Demographic factors

In univariate analysis, acceptance was significantly related to all demographic factors ( $P < 0.01$ ). However, there was no significant correlation between acceptance and nationality in

**Table 1.** Demographic characteristics of the industrial workers involved in this study.

Characteristics	No. (%) (n = 23,940) <sup>a</sup>
<b>Gender</b>	
Male	16,402 (68.5)
Female	7,538 (31.5)
<b>Age ranges(yrs)</b>	
18–24	4,292 (17.9)
25–34	13,332 (55.7)
35–44	5,487 (22.9)
45–65	829 (3.5)
<b>Marital status</b>	
Unmarried	13,787 (57.6)
Married	9,426 (39.4)
Divorced	727 (3.0)
<b>Education level</b>	
Primary school	395 (1.6)
Junior high school	8,246 (34.4)
High school	8,914 (37.2)
Junior college	3,857 (16.1)
College or above	2,528 (10.6)
<b>Monthly per capita household income (RMB)</b>	
≤5000	15,349 (64.1)
5001–10000	6,679 (27.9)
10001–15000	1,011 (4.2)
15001–20000	400 (1.7)
>20000	501 (2.1)
<b>Nationality</b>	
Han	20,981 (87.6)
Minority	2,959 (12.4)

<sup>a</sup>Percentages for some items may not sum up to 100% due to rounding.

multivariate analysis, as well as monthly per capita household income. Those industrial workers who were aged 45 to 65 (aOR = 1.50, 95% CI: 1.21–1.86), married (aOR = 1.25, 95%

CI: 1.16–1.35) and industrial workers with junior college degree (aOR = 1.59, 95% CI: 1.23–2.06) were more likely to receive COVID-19 vaccination, while female industrial workers were less likely to receive COVID-19 vaccination (aOR = 0.90, 95% CI: 0.83–0.96) (Table 2).

### Risk perception

We found that 78.3% of industrial workers who were extremely worried about contracting COVID-19 expressed that they would like to be vaccinated, while only 39.3% of industrial workers who were not concerned about contracting COVID-19 expressed that they would like to be vaccinated. 85.1% of industrial workers who believed COVID-19 would rebound expressed acceptance to receive COVID-19 vaccine, compared to 66.1% of workers who did not believe it. The results of univariate and multivariate analysis were similar, which revealed that those participants who thought the COVID-19 epidemic in China would not break out again (aOR = 0.68, 95% CI: 0.58–0.81), or didn't care about whether they will be infected with COVID-19 (aOR = 0.40, 95% CI: 0.34–0.47) were more likely to hesitant about COVID-19 vaccine (Table 3).

### Confidence in COVID-19 vaccine

In both univariate and multivariate analysis, high confidence in COVID-19 vaccine was significantly associated with higher willingness to receive a COVID-19 vaccine. Those participants who

**Table 2.** Willingness to take COVID-19 vaccine in different demographic group of industrial works and the results of univariate and multivariate analysis.<sup>a</sup>

Items	Willing to receive COVID-19 vaccine No. (%)	cOR (95%CI) <sup>b</sup>	aOR (95%CI) <sup>c</sup>
<b>Demographic characteristics</b>			
<b>Gender</b>			
Male	10,930 (66.6) ***	Re	Re
Female	4,881 (64.8)	0.92 (0.87,0.97)	0.90 (0.83,0.96)
<b>Age ranges (yrs)</b>			
18–24	2,671 (62.2) ***	Re	Re
25–34	8,681 (65.1)	1.11 (1.06,1.22)	1.02 (0.93,1.11)
35–44	3,827 (69.7)	1.40 (1.29,1.52)	1.14 (1.01,1.27)
45–65	632 (76.2)	1.95 (1.64,2.31)	1.50 (1.21,1.86)
<b>Marital status</b>			
Unmarried	8,663 (62.8) ***	Re	Re
Married	6,667 (70.7)	1.43 (1.35,1.51)	1.25 (1.16,1.35)
Divorced	481 (66.2)	1.16 (0.99,1.35)	1.20 (0.99,1.44)
<b>Education level</b>			
Primary school	227 (57.5) ***	Re	Re
Junior high school	5,017 (60.8)	1.15 (0.94,1.41)	1.00 (0.78,1.29)
High school	5,870 (65.9)	1.43 (1.16,1.75)	1.22 (0.95,1.56)
Junior college	2,867 (74.3)	2.14 (1.73,2.65)	1.59 (1.23,2.06)
College or above	1,830 (72.4)	1.94 (1.56,2.41)	1.43 (1.10,1.87)
<b>Monthly per capita household income (RMB)</b>			
≤5000	9,781 (63.7) ***	Re	Re
5001–10000	4,688 (70.2)	1.34 (1.26,1.43)	N/A <sup>d</sup>
10001–15000	735 (72.7)	1.52 (1.32,1.75)	N/A <sup>d</sup>
15001–20000	271 (67.8)	1.20 (0.97,1.48)	N/A <sup>d</sup>
>20000	336 (67.1)	1.16 (0.96,1.40)	N/A <sup>d</sup>
<b>Nationality</b>			
Han	13,925 (66.4) ***	Re	Re
Minority	1,886 (63.7)	0.89 (0.82,0.97)	N/A <sup>d</sup>

<sup>a</sup>Confidence intervals that do not overlap the null value of OR = 1 are shown in bold.

<sup>b</sup>Crude Odd Ratio and Confidence intervals.

<sup>c</sup>Adjusted Odd Ratio and Confidence intervals.

<sup>d</sup>Not included in final model as not significant ( $P > 0.05$ ).

\* $P < 0.05$ , \*\* $P < 0.01$ , \*\*\* $P < 0.001$ .

**Table 3.** Willingness to take COVID-19 vaccine cross different influencing factors and the results of univariate and multivariate analysis.

Items	Willing to receive COVID-19 vaccine No. (%)	cOR (95%CI) <sup>b</sup>	aOR (95%CI) <sup>c</sup>
<b>Risk perception of COVID-19</b>			
<i>Are you worried that you will be infected with COVID-19?</i>			
Extremely worried	3,592 (78.3) ***	Re	Re
Worried	7,183 (72.2)	0.72 (0.67,0.78)	0.80 (0.73,0.88)
Not worried	4,669 (55.1)	0.34 (0.32,0.37)	0.44 (0.40,0.49)
Don't care	367 (39.3)	0.18 (0.16,0.21)	0.40 (0.34,0.47)
<i>Will the COVID-19 epidemic in China break out again?</i>			
Yes	228 (85.1) ***	Re	Re
No	9,987 (66.1)	0.58 (0.50,0.67)	0.68 (0.58,0.81)
Unsure	5,596 (35.4)	0.52 (0.45,0.61)	0.85 (0.72,1.00)
<b>Confidence in COVID-19 Vaccine</b>			
<i>Will it be possible to control the pandemic if the COVID-19 vaccine is widely used?</i>			
Certainly	6,734 (82.2) ***	Re	Re
Possibly	6,116 (64.3)	0.39 (0.36,0.42)	0.55 (0.50,0.59)
Impossibly	125 (33.6)	0.11 (0.09,0.14)	0.31 (0.24,0.40)
Don't know	2,836 (48.3)	0.20 (0.19,0.22)	0.43 (0.39,0.48)
<i>Do you think COVID-19 vaccination is the most effective way to prevent COVID-19?</i>			
Yes	11,512 (79.1) ***	Re	Re
No	1,399 (44.7)	0.21 (0.20,0.23)	0.36 (0.33,0.39)
Unsure	2,900 (46.4)	0.23 (0.22,0.24)	0.41 (0.38,0.44)
<i>What is the effective rate of COVID-19 vaccine that you would like to be vaccinated?</i>			
≤70%	1,490 (79.8) ***	Re	Re
71–80%	1,903 (83.7)	1.29 (1.11,1.52)	1.34 (1.13,1.59)
81–90%	3,299 (75.3)	0.77 (0.67,0.88)	0.87 (0.75,1.00)
≥90%	7,399 (63.2)	0.43 (0.39,0.49)	0.52 (0.45,0.59)
Unsure	1,452 (56.7)	0.33 (0.29,0.38)	0.48 (0.41,0.55)
Refusal to vaccination regardless of efficiency	268 (23.3)	0.08 (0.06,0.09)	0.15 (0.12,0.18)
<b>Attention to COVID-19 Vaccine</b>			
<i>Are you concerned about the information about COVID-19 vaccines?</i>			
Very concerned	4,571 (79.9) ***	Re	Re
Occasional concerned	10,124 (63.9)	0.45 (0.42–0.48)	0.74 (0.68,0.81)
Never concerned	1,116 (47.1)	0.22 (0.20–0.25)	0.68 (0.59,0.77)
<i>Will you take the initiative to understand the mechanism of COVID-19 vaccine?</i>			
Yes	12,547 (71.8) ***	Re	Re
No	3,264 (50.6)	0.40 (0.38–0.43)	0.69 (0.64,0.74)
<b>Personal health habits</b>			
<i>Do you exercise regularly?</i>			
Continued	2,891 (67.9) ***	Re	Re
Occasionally	8,323 (67.5)	0.98 (0.91–1.06)	1.19 (1.09,1.31)
Seldom	3,859 (64.5)	0.86 (0.79–0.93)	1.31 (1.18,1.45)
Never	738 (54.3)	0.56 (0.50–0.64)	1.38 (1.18,1.61)
<i>Frequency of physical examination</i>			
Once half a year	2,116 (60.9) ***	Re	Re
Once a year	12,005 (68.1)	1.37 (1.27–1.48)	1.37 (1.25,1.50)
Once every 2 years	539 (62.4)	1.07 (0.91–1.24)	1.31 (1.10,1.57)
Once every 3 years	318 (57.9)	0.89 (0.74–1.06)	1.10 (0.89,1.36)
No health checkups for more than 3 years	833 (58.7)	0.92 (0.81–1.04)	1.34 (1.16,1.56)
<b>History of vaccination</b>			
<i>When was the last time you were vaccinated?</i>			
Within 3 months	3,505 (81.8) ***	Re	Re
Within half a year	584 (65.0)	0.41 (0.35–0.48)	0.49 (0.41,0.59)
Within a year	951 (61.4)	0.35 (0.31–0.40)	0.42 (0.35,0.47)
Within 3 years	692 (62.8)	0.38 (0.33–0.44)	0.37 (0.32,0.44)
Within 3 to 5 years	743 (63.4)	0.39 (0.37–0.45)	0.40 (0.34,0.48)
More than 5 years	9,336 (62.5)	0.37 (0.34–0.40)	0.42 (0.38,0.47)
<i>Have you received a 23-valent pneumonia vaccine or influenza vaccine in the last 3 years?</i>			
Pneumonia vaccine only	399 (80.9) ****	Re	Re
Influenza vaccine only	487 (66.5)	0.47 (0.36–0.62)	0.57 (.41,0.78)
Both of them	336 (63.5)	0.41 (0.31–0.55)	0.58 (0.42,0.81)
Neither	14,589 (65.8)	0.45 (0.36–0.57)	0.69 (0.53,0.90)
<b>Health status</b>			
<i>How do you feel about your current health status?</i>			
Good	13,128 (67.0) ***	Re	Re
General	2,568 (62.8)	0.83 (0.77–0.89)	0.91 (0.83,0.98)
Bad	115 (44.1)	0.39 (0.30–0.50)	0.62 (0.46,0.82)
<i>Do you have chronic respiratory disease (Such as bronchitis, chronic bronchitis)?</i>			
Yes	705 (60.6) ***	Re	Re

(Continued)

Table 3. (Continued).

Items	Willing to receive COVID-19 vaccine No. (%)	cOR (95%CI) <sup>b</sup>	aOR (95%CI) <sup>c</sup>
No	15,106 (66.3)	1.28 (1.13–1.44)	1.30 (1.12,1.50)
<i>Do you have any other chronic diseases?</i>			
Chronic cancer	59 (57.3) ***	Re	Re
Cardiovascular disease	98 (59.0)	1.08 (0.65–1.77)	1.26 (0.70,2.28)
Diabetes	72 (59.5)	1.10 (0.64–1.87)	1.13 (0.60,2.12)
Other chronic diseases	771 (56.2)	0.96 (0.64–1.44)	1.35 (0.83,2.19)
No chronic disease	14,811 (66.8)	1.50 (1.01–2.22)	1.98 (1.24,3.18)
<b>Professionals' recommendation</b>			
<i>Have you ever been recommended to be vaccinated by doctors or nurses?</i>			
Yes	3,419 (76.8) ***	Re	Re
No	12,392 (63.6)	0.57 (0.49–0.57)	0.86 (0.79,0.94)

thought 'the large-scale vaccination of COVID-19 vaccine was impossible to control the epidemic' (aOR = 0.31, 95% CI: 0.24–0.40), or 'COVID-19 vaccination was not the most effective way to prevent COVID-19' (aOR = 0.36, 95%CI: 0.33–0.39), or 'refuse vaccination regardless of the protective effect' (aOR = 0.15, 95% CI: 0.12–0.18) were more likely to reject to be vaccinated (Table 3).

### Attention to COVID-19 vaccine

High attention to COVID-19 vaccine was a strong predictor of willingness to vaccination in univariate analysis. After adjusting the effects of other factors, workers who were never concerned about COVID-19 vaccine were less likely to get vaccinated than workers who were very concerned (aOR = 0.68, 95% CI: 0.59–0.77). The level of vaccine hesitancy was also higher among those who would not take the initiative to understand the mechanism of COVID-19 vaccine (aOR = 0.69, 95% CI: 0.64–0.74) (Table 3).

### Health habits

In univariate analysis, healthy habits were significantly associated with higher willingness, whereas multivariate analysis indicated that those who never did regular physical exercise (aOR = 1.38, 95% CI: 1.18–1.61) and those who did not have a physical examination for more than three years (aOR = 1.34, 95% CI: 1.16–1.56) had a higher likelihood to accept a COVID-19 vaccine (Table 3).

### History of vaccination

Most industrial workers had little vaccination experience in the past five years. 62.4% of industrial workers have never been vaccinated for more than five years, and 92.7% have not received either a pneumonia vaccine or an influenza vaccine in the last three years. Univariate and multivariate analysis showed a significant correlation between vaccination history and willingness of COVID-19 vaccination. Industrial workers who have not been vaccinated in the last five years were less likely to be vaccinated (aOR = 0.42, 95% CI: 0.38–0.47) (Table 3).

### Health status

In general, most industrial workers were confident about their current health status (81.8%). Among all the patients with chronic diseases, cancer patients had the lowest acceptance of COVID-19 vaccination (57.3%). Univariate analysis and multivariate analysis also revealed that those who rated their current health status as bad (aOR = 0.62, 95% CI: 0.46–0.82) were less likely to take a COVID-19 vaccine. Those workers without chronic respiratory disease (aOR = 1.30, 95% CI: 1.12–1.50) and other chronic diseases (aOR = 1.98, 95% CI: 1.24–3.18) were more willing to be vaccinated (Table 3).

### Recommendation by professionals

Only 18.6% of industrial workers have been recommended to be vaccinated by doctors or nurses in this survey. Industrial workers who have been recommended to be vaccinated by doctors or nurses were more likely to take the COVID-19 vaccine, as shown in multivariate analysis (aOR = 0.86, 95% CI: 0.79–0.94) (Table 3).

### Discussion

In this survey, we found that 66.0% of participants were willing to receive the COVID-19 vaccine, 16.6% were unwilling, and the remaining 17.4% were unsure. During the early stage of COVID-19 outbreak without available vaccine, some studies showed that vaccination acceptance among the general population in China was 83.3–91.3%,<sup>13,14</sup> which were higher than our study. This is consistent with previous experience that subgroups in a population may differ from the main population in terms of vaccine hesitation.<sup>11</sup> The younger age of industrial workers might be one of the reasons for this difference. Industrial workers under the age of 45 made up the majority of our sample, and several studies indicated that young people tended to be more susceptible to vaccine hesitation than older people.<sup>15</sup> In addition, participants in this survey generally had a low level of education. According to our findings, industrial workers with low education levels were less likely to receive COVID-19 vaccination.



Previous studies in the general population had also confirmed this observation.<sup>16</sup> Based on these findings, we suggest that more attention should be paid to industrial workers, and vaccination strategies suitable to industrial workers should be adjusted to improve their acceptance, such as access convenience, appropriate on-site interventions, organization of vaccine education campaigns, and incentives policies. Actually, Chinese government has set up the corresponding vaccination sites for industrial workers in populous factories, so these groups can easily access to the COVID-19 vaccine if they want to.

In this study, we observed a correlation between marital status and vaccination willingness among industrial workers, and the married individuals were more willing to accept COVID-19 vaccine than unmarried, reflecting that family factors may play a certain role in determining whether to receive the COVID-19 vaccine. Actually, this observation is consistent with some previous studies.<sup>14</sup> Further studies are needed to better understand why marital status affects the willingness of vaccination. We also emphasized the impact of risk perception on vaccination willingness among industrial workers. Industrial workers with stronger risk perception were more likely to be vaccinated. Similar conclusion has been reached in previous study.<sup>17</sup> Most industrial workers possessed a lower risk perception in our study, which may be related to the well-controlled epidemic in China. However, this inevitably caused people's relaxation of the pandemic and increased people's hesitation about the COVID-19 vaccine. On the other hand, other vaccination experience shows that the epidemic situation in the local city is a key factor in people's willingness to vaccinate.<sup>18,19</sup> Consistent with this finding, it is worth noting that one of the factors included in our study, the risk perception of COVID-19 infection, was associated with the willingness of COVID-19 vaccination. This may help to understand the impact of the outbreak of COVID-19 in local cities on COVID-19 vaccination intentions among industrial workers. Therefore, governments should alert the public to the possibility of rebound of the COVID-19 pandemic to realign their vigilance against COVID-19, which may help to increase the acceptance of vaccination.

People's confidence in the safety and efficacy of COVID-19 vaccines is essential to promote mass vaccination. Another observation in this study is that only 33.6% of industrial workers with low confidence in COVID-19 vaccine expressed their willingness of vaccination. Due to the unprecedented speed of COVID-19 vaccine development, marketing and large-scale promotions,<sup>20</sup> people's concern about the safety of COVID-19 vaccine has aggravated, especially for some reported adverse events following immunization (AEFI).<sup>11,21</sup> Thus, an effective monitoring system for vaccine safety is essential to be established even in low-resource settings. Strengthening the supervision of vaccine production, storage and transportation may help to alleviate people's concerns in this regard. Of note, the influence of personal health habits on the acceptance of COVID-19 vaccine has been ignored in mostly previous studies, and we therefore investigated this issue among industrial workers. To our surprise, results showed that people who exercised regularly and had regular physical examination

were more likely to be hesitant to get vaccination. Based on the theory of Information, Motivation, Behavioral Skills (IMB),<sup>22</sup> one explanation to understand this phenomenon might be that the complacency about one's own health has weakened the motivation of industrial workers to vaccinate to a certain extent, leading to vaccine hesitation. Further studies should be performed to verify this finding among different population. In addition, history of vaccination has also been proven as a strong predictor of willingness to receive the COVID-19 vaccine.<sup>23</sup> To a certain extent, the vaccination willingness is like a habit of personal health. In this study, the similar phenomenon was also observed among industrial workers, suggesting that those industrial workers who had no history of other vaccination should be given more consideration. The protective efficacy and side effects of the COVID-19 vaccine might vary among people with different health conditions. Patients with progressive chronic diseases have been identified as high-risk groups for COVID-19 infection.<sup>24</sup> However, clinical data of COVID-19 vaccines in this group are insufficient yet. In our study, we found that the personal health status might be a factor affecting the acceptance of COVID-19 vaccine among industrial workers. Industrial workers with poor health conditions were more likely to refuse COVID-19 vaccination, which was consistent with previous survey.<sup>25</sup> More clinical data are needed to demonstrate the efficacy of the COVID-19 vaccine for people with different health status. In addition, it may be necessary to vaccinate multiple COVID-19 vaccines in the future to deal with virus mutations or maintain neutralizing antibody titers. Given the financial burden, COVID-19 vaccination might change from free to self-funded, which might lead to a decline in the acceptability of COVID-19 vaccine among industrial workers according to our results. The government and relevant departments need to schedule ahead for this issue. Our study has some limitations. First of all, we adopted a convenient sampling method, which may cause selection bias. We conducted a large-scale sampling to reduce the impact of this problem. Secondly, online survey may limit the representativeness of our samples, and some participants may not understand the meaning of the questions, which would cause self-reported information bias. Thirdly, the causal relationship between influencing factors and vaccination acceptance cannot be obtained from our study, more researches are needed to reveal how influencing factors affect COVID-19 vaccination intentions. Finally, a theoretical framework should be adopted to integrate the studied factors to get the COVID-19 vaccine in the future study. Thus, our results should be interpreted with caution.

## Conclusion

This work represents the latest research on the willingness of Chinese industrial workers to get COVID-19 vaccine. A total of 66.0% of participants were willing to accept COVID-19 vaccination. Factors that affect the willingness of vaccination include age, education level, gender, marital status, risk perception, confidence and concern about COVID-19 vaccine, history of vaccination, health habits and health status, and professionals' recommendations. Our results suggest that

more attention should be paid to industrial workers to increase the coverage of COVID-19 vaccine.

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CJS and HBC conceived and designed this project; DY, ZMD, YY, MSC performed this project and analyzed the data; HC, XFZ, LJW, ZW, ZHG, ZYW contributed the resources and discussion; DY, ZMD, and CJS drafted the manuscript, and all authors reviewed the final manuscript.

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