Quantifying Disparities in COVID-19 Vaccination Rates by Rural and Urban: A Cross-Sectional Observational Study

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Abstract

Background: Vaccination plays an important role in preventing Corona Virus Disease 2019 (COVID-19) infection and reducing the severity of the disease. However, the influencing factors of COVID-19 vaccination are complex and partially uncovered. There were differences in vaccination rates between urban and rural areas, not only for COVID-19, but also for other vaccines.

Objective: To evaluate the disparities in the rate of fourth COVID-19 (second booster) vaccination between urban and rural areas in China.

Methods: The cross-sectional study utilized a stratified random sampling approach to select representative samples from 11 communities and 10 villages in eastern (Changzhou), central (Zhengzhou), western (Xining) and northeast (Mudanjiang) in Chinese Mainland from February 1 to February 18, 2023. The vaccination of the participants was evaluated based on self-reported information provided. Binary logistic regression models were performed to explore influencing factors of vaccination among urban and rural participants, respectively. Urban-rural disparities in vaccination rate was assessed using Propensity Score Matching (PSM).

Results: A total of 5780 participants (53.04% females) were included. The vaccination rate was 12.18% (95%CI: 11.34–13.02) in total sample, with 13.76% (95%CI: 12.40–15.12) in rural participants and 10.99% (95%CI: 9.93–12.06) in urban participants, respectively. For rural participants, self-report health condition, self-efficacy, educational level, vaccine knowledge, susceptibility, benefits, and trust in the healthcare system were independent factors associated with vaccination (all P?0.05). For urban participants, chronic condition, COVID-19 infection, subjective community level, vaccine knowledge, self-efficacy, and trust in the healthcare system were independent factors associated with vaccination (all P?0.05). PSM analysis uncovered a 3.42% difference in vaccination between urban and rural participants.

Conclusions: The fourth COVID-19 (second booster) vaccination coverage rate among the Chinese population was extremely low and was significantly lower than the previous vaccine coverage rate. Given COVID-19 infection is still prevalent at a low level currently, efforts should be focused on enhancing self-efficacy to expand vaccine coverage rate among the Chinese. For rural residents, building the confidence of vaccination benefits and improving the health status of the population should be prioritized. In urban areas, a larger proportion of people infected with COVID-19 and chronic patients should be vaccinated.

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Abstract

Background: Vaccination plays an important role in preventing Corona Virus Disease 2019 (COVID-19) infection and reducing the severity of the disease. There were differences in vaccination rates between urban and rural areas. Measuring differences in vaccination rates between urban and rural areas can help to develop more coordinated and sustainable solutions, it also provides a reference for the prevention and control of emerging X infectious diseases in the future.

Objective: The study aims to assess the current coverage rate and influencing factors of COVID-19 (second booster) vaccination among Chinese residents, as well as the disparities between urban and rural areas in China.

Methods: The cross-sectional study utilized a stratified random sampling approach to select representative samples from 11 communities and 10 villages in eastern (Changzhou), central (Zhengzhou), western (Xining) and northeast (Mudanjiang) in Chinese Mainland from February 1 to February 18, 2023. The questionnaires were developed by experienced epidemiologists, and contained the following parts: sociodemographic information, health condition, vaccine related information, information related to the Protective Motivation Theory (PMT), and the level of trust in healthcare system. The vaccination of the participants was evaluated based on self-reported information provided. Binary logistic regression models were performed to explore influencing factors of vaccination among urban and rural participants, respectively. Urban-rural disparities in vaccination rate was assessed using Propensity Score Matching (PSM).

Results: A total of 5780 participants (53.04% females) were included. The vaccination rate was 12.18% (95%CI: 11.34–13.02) in total sample, with 13.76% (95%CI: 12.40–15.12) in rural participants and 10.99% (95%CI: 9.93–12.06) in urban participants, respectively. For rural participants, self-report health condition, self-efficacy, educational level, vaccine knowledge, susceptibility, benefits, and trust in the healthcare system were independent factors associated with vaccination (all $P<0.05$). For urban participants, chronic condition, COVID-19 infection, subjective community level, vaccine knowledge, self-efficacy, and trust in the healthcare system were independent factors associated with vaccination (all $P<0.05$). PSM analysis uncovered a 3.42% difference in vaccination between urban and rural participants.

Conclusions: The fourth COVID-19 (second booster) vaccination coverage rate among the Chinese population was extremely low, and was significantly lower than the previous vaccine coverage rate. Given COVID-19 infection is still prevalent at a low level currently, efforts should be focused on enhancing self-efficacy to expand vaccine coverage rate among the Chinese. For rural residents, building the confidence of vaccination benefits and improving the health status of the population should be prioritized. In urban areas, a larger proportion of people infected with COVID-19 and chronic patients should be vaccinated.

Keywords: COVID-19 vaccination, urban and rural, the fourth COVID-19 (second booster) vaccine, China

Introduction

Vaccination plays an important role in preventing COVID-19 infection, reducing the severity of the disease, and reducing case fatality rate[1-4]. At present, the prevalence of COVID-19 infection rate is at a low level[5]. However, COVID-19 still has a certain impact on people's health, such as long COVID-19, preterm birth, stillbirth, myocarditis, and pericarditis[6-8]. A study from Australia has shown that vaccination is effective in providing protection to the population[9]. Similar studies carried out in American indicated that the use of COVID-19 vaccines has reduced the severity of the disease and prevented serious consequences such as respiratory failure and death to some extent[10]. Some other studies have shown that individuals who received booster doses of COVID-19 vaccine have stronger immune protection than those who received only a single dose [11, 12]. Therefore, for countries and regions trying to end or reduce COVID-19 infection by expanding the protection of immune barriers, increasing vaccination rates remains an important task for healthcare systems in current stage [13].

The premise of establishing herd immunity through COVID-19 vaccination requires a certain vaccination rate, ranging from 50% to 85%, among the population [14, 15]. An intensive vaccination campaign in the initial phase of pandemic wave leads to a lower optimal level of doses administered per 100 inhabitants (roughly 47 doses of vaccines administered) for reducing infected individuals; however, the growth of pandemic wave moves up the optimal level of vaccines to about 90 doses for reducing the numbers of COVID-19 related infected individuals[16]. The maximum vaccination rate that can be achieved without a mandate is 70%, the remaining share of about 30% is associated with a natural hesitancy of people to vaccinations[17]. The influencing factors of COVID-19 vaccination are complex and partially uncovered. Some previous studies have shown that COVID-19 vaccination was related to the severity of the outbreak, perceived susceptibility to the disease, and concerns related to the safety and effectiveness of the vaccine [18-21]. Our previous researches reported correlations between COVID-19 vaccination and trust in the health care system, vaccine accessibility, lifestyle, and psychological experience [22, 23]. In addition, our previous nationwide investigation conducted during primary COVID-19 vaccination hesitancy confirmed a 2.38% gap between Chinese rural residents and their urban compatriots[24]. Similar findings were reported within studies related to influenza vaccine and HPV vaccine[25, 26].

Disparities in COVID-19 vaccination rates by rural and urban are meaningful[27]. In China and many developing countries, the movement of population between urban and rural areas is frequent[28]. Given the extremely high transmission capacity of COVID-2019, increasing vaccination rates among urban or rural residents unilaterally is not cost-effective in building herd immunity [29]. Currently, India, Brazil, and many developing countries are experiencing a massive migration similar to China's [30, 31]. Effective public governance improves prevention and preparedness to face pandemic threats[32-34]. Quantifying disparities in COVID-19 vaccination rates by rural and urban based on Chinese national-level evidence is beneficial to end the COVID-19 infection globally and can also provide a reference for the prevention and control of emerging major infectious diseases in the future.

Therefore, we conducted a nationwide survey during the period of the fourth COVID-19 (second booster) vaccination. The present study is aimed to assess the current coverage rate and influencing factors of COVID-19 vaccination among Chinese residents, as well as the disparities between urban and rural areas in China. The findings of this study will reveal the real-time status of COVID-19 vaccination. Quantitative assessment of the disparity between urban and rural areas will deepen the understanding of the complexity of COVID-19 infection prevention, and help to produce a more coordinated and sustainable solution to end the pandemic.

Methods

Sample and data

From February 1 to February 18, 2023, we selected 11 communities and 10 villages in eastern, central, western and northeastern within Chinese mainland as representative samples by stratified random sampling. Within each region, namely Changzhou, Zhengzhou, Xining, and Mudanjiang, a random sampling approach was employed to select representative urban and rural areas. Specifically, two or more communities and villages were randomly chosen within each city. Furthermore, to ensure comprehensive coverage, households were also randomly selected within each region. Finally, all members of the selected family (aged ≥ 18 years) participated in this survey and completed an online or offline questionnaire survey with the assistance of the investigator. Questionnaires that contained contradictory responses to key questions were excluded to ensure data consistency and reliability. Additionally, questionnaires that be completed in less than 5 minutes were excluded to ensure an adequate level of response detail. Furthermore, questionnaires that were filled out repeatedly by the same individuals were excluded to avoid duplicate entries and potential bias in the analysis. Lastly, questionnaires that lacked clear identification of the survey object's source were excluded to ensure transparency and accuracy in the data collection process. Following the exclusion criteria, the questionnaires underwent a thorough review process conducted by trained staff. From this review, a total of 5891 questionnaires were collected. Subsequently, after further screening and data validation, a final sample of 5780 participants was included in our study. A flowchart for the study is demonstrated in **Figure 1.**

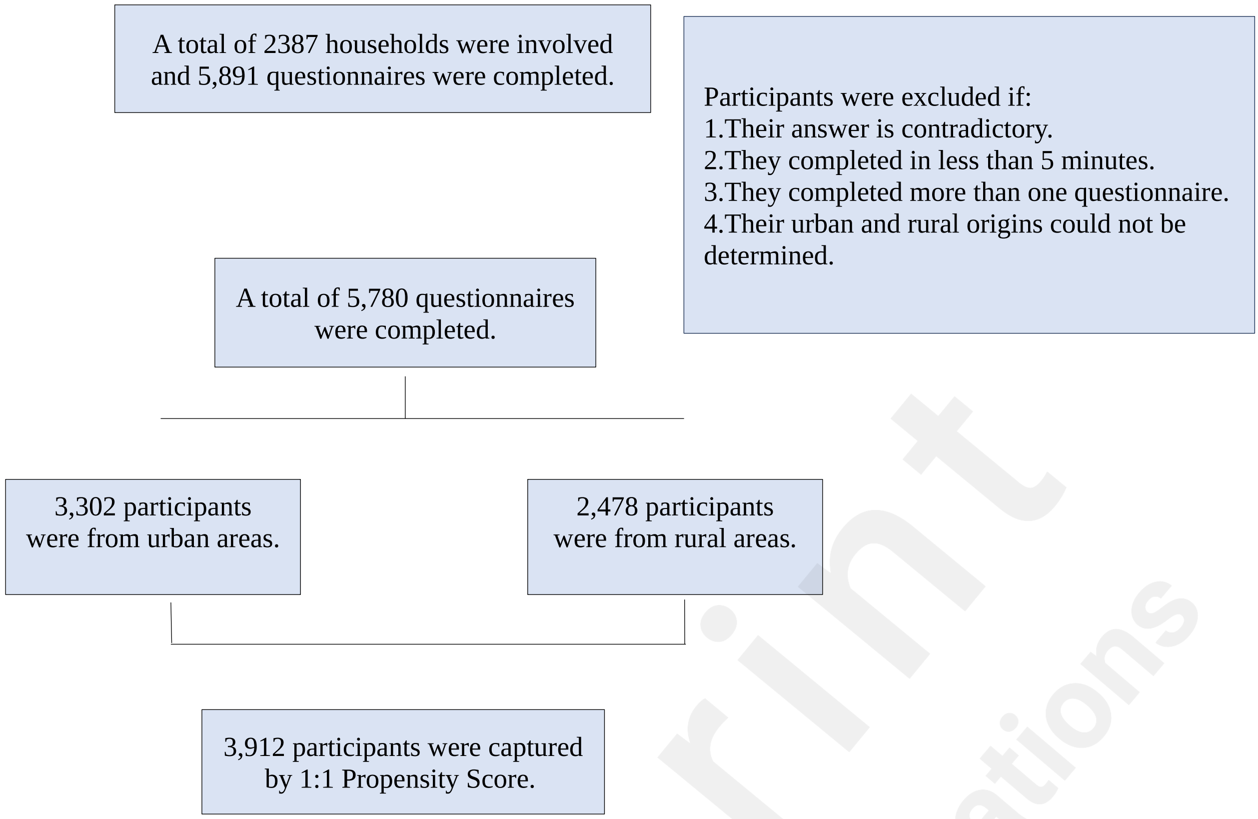

Figure 1 Flowchart on participants selection of this study.

Measures of variables

The questionnaires were developed by experienced epidemiologists, and contained the following parts: sociodemographic information (sex, age, religion, marital status, educational level, career, social status in China and social status in community), health condition(chronic disease, the history of allergic, self-report health condition and COVID-19 infection), vaccine related information (vaccine knowledge and vaccine accessibility), information related to the Protective Motivation Theory (PMT) (severity, susceptibility, benefits, barriers and self-efficacy) , and the level of trust in healthcare system (trust in doctors and trust in vaccine developers).

We assigned a unique code to each participant, which included the region and urban-rural sources of the participants. The unique code was used to distinguish the region where the participants come from urban or rural areas.

The COVID-19 vaccination status was measured based on participants' responses to the following items: 1. Have you been vaccinated with COVID-19 basic vaccine? We set three answers:1= "Yes, I have completed COVID-19 basic vaccination"; 2= "Yes, but I haven't completed COVID-19 basic vaccination"; 3= "No". 2. Have you been vaccinated with the third COVID-19 (first booster) vaccine? We set two answers: 1= "Yes"; 2= "No". 3. Have you been vaccinated with the fourth COVID-19 (second booster) vaccine? We set two answers: 1= "Yes"; 2= "No". We defined participants who have completed both item 1, item 2 and item 3 as those who have been vaccinated with the fourth COVID-19 (second booster) vaccine.

Data analysis procedure

An independent samples t-test or chi-square test was carried out to test differences in COVID-19 vaccination across groups between urban and rural participants. Binary logistic regression models were performed to explore influencing factors of vaccination among urban and rural participants, respectively. Both univariate and multivariate analyses for urban and rural participants were conducted separately. PSM was used to minimize potential confounding biases. A probit regression model was performed to estimate the propensity scores for urban and rural participants. Finally, 1956 pairs of homogeneous participants were matched by 1:1 using propensity scores from the total of 5,780 participants. Differences were regarded as statistically significant if *P*-values were less than 0.05. We performed all statistical analyses using STATA version 16.1.

Ethical considerations

This study was reviewed and approved by the Life Science Ethics Review Committee of Zhengzhou University (Approval number: 2021-01-12-05). Written informed consents clarifying the study purposes were obtained from each participant before the survey. All data were used merely for research purposes. The study data are anonymous. The answers were protected by privacy law.

Results

Prevalence of COVID-19 vaccination and characteristics among urban and rural participants

A total of 5,780 participants (57.13% urban residents) completed the survey. A summary of COVID-19 vaccination with sociodemographic, health condition, vaccine related information, information related to PMT and trust in healthcare system characteristics of urban and rural participants is shown in **Table 1**. In the total sample, 12.18% (704/5780, 95% CI: 11.34–13.02) participants expressed they have been vaccinated with the fourth COVID-19 (second booster) vaccine. Additionally, urban participants 10.99% (363/3302, 95% CI: 9.93–12.06) had a relatively lower COVID-19 vaccination rate than rural participants 13.76% (341/2478, 95% CI: 12.40–15.12). Age between 30-39, without chronic disease, without COVID-19 infection, higher subjective community level, higher level of vaccine knowledge, higher level of benefits, higher level of self-efficacy, trust in doctors and vaccine developers at level 1 and level 4 were associated with higher odds of COVID-19 vaccination in urban areas (all $P < 0.05$). Age between 18-29, without chronic disease, vaccine accessibility<15m, higher self-report health condition, lower level of vaccine knowledge, lower level of benefits, higher level of barriers, lower level of self-efficacy, lower level of trust in doctors and lower level of trust in vaccine developers were associated with higher odds of COVID-19 vaccination in rural areas (all $P < 0.05$).

Table 1 The characteristics and overall COVID-19 vaccination of all study participants from February 1 to February 18, 2023 in China(n=5780).

Covariates	Total		Urban			Rural		
	N (%)	*P* value[a]	N (%)	Completed (%,95%CI)	*P* value[b]	N (%)	Completed (%,95%CI)	*P* value[c]
Total	5780(100)		3302(100)	10.99(9.93~12.06)		2478(100)	13.76(12.40~15.12)	
Sex		0.774			0.195			0.463
Male	2714(46.96)		1488(45.06)	10.22(8.67~11.76)		1226(49.48)	14.27(12.31~16.23)	

Female	3066(53.04)		1814(54.94)	11.63(10.15~13.11)		1252(50.52)	13.26(11.38~15.14)	
Age		0.001			0.020			0.009
18-29	659(11.40)		369(11.18)	10.57(7.42~13.72)		290(11.70)	17.24(12.87~21.61)	
30-39	1556(26.92)		1027(31.10)	12.66(10.62~14.70)		529(21.35)	16.45(13.28~19.62)	

Table 1 Continued

Covariates	Total		Urban			Rural		
	N (%)	*P* value[a]	N (%)	Completed (%,95%CI)	*P* value[b]	N (%)	Completed (%,95%CI)	*P* value[c]
40-49	1141(19.74)		729(22.08)	12.07(9.70~14.44)		412(16.63)	12.62(9.40~15.84)	
50-59	1191(20.61)		540(16.35)	10.74(8.12~13.36)		651(26.27)	14.13(11.45~16.82)	
≥60	1233(21.33)		637(19.29)	7.54(5.48~9.59)		596(24.05)	10.07(7.64~12.49)	
Religion		0.939			0.587			0.887
Atheist	5514(95.40)		3215(97.37)	11.04(9.96~12.13)		2299(92.78)	13.79(12.38~15.20)	
Others	266(4.60)		87(2.63)	9.20(3.00~15.39)		179(7.22)	13.41(8.37~18.45)	
Marital status		0.424			0.247			0.816
Married	5112(88.44)		2894(87.64)	11.23(10.08~12.38)		2218(89.51)	13.71(12.27~15.14)	
Others	668(11.56)		408(12.36)	9.31(6.48~12.15)		260(10.49)	14.23(9.96~18.51)	
Educational level		0.099			0.486			0.186
Below high school	2487(43.03)		1054(31.92)	10.53(8.68~12.39)		1433(57.83)	13.68(11.90~15.46)	
High school	1445(25.00)		913(27.65)	12.05(9.93~14.16)		532(21.47)	15.79(12.68~18.90)	
University graduate	1848(31.97)		1335(40.43)	10.64(8.98~12.29)		513(20.70)	11.89(9.08~14.70)	
Career		0.133			0.313			0.226

Others	5523(95.55)		3146(95.28)	10.87(9.78~11.96)		2377(95.92)	13.59(12.21~14.97)	
Medical staff	257(4.45)		156(4.72)	13.46(8.05~18.88)		101(4.08)	17.82(10.23~25.41)	
Chronic condition		<0.001			<0.001			0.002
Yes	1003(17.35)		553(16.75)	6.33(4.29~8.36)		450(18.16)	9.11(6.44~11.78)	
No	4777(82.65)		2749(83.25)	11.93(10.72~13.14)		2028(81.84)	14.79(13.25~16.34)	
Allergy history		0.215			0.374			0.124
Yes	409(7.08)		282(8.54)	8.51(5.23~11.79)		127(5.13)	15.75(9.33~22.17)	
No	4766(82.46)		2638(79.89)	11.26(10.05~12.47)		2128(85.88)	14.10(12.62~15.58)	
Unclear	605(10.47)		382(11.57)	10.99(7.84~14.15)		223(9.00)	9.42(5.55~13.28)	

Table 1 Continued

Covariates	Total		Urban			Rural		
	N (%)	*P* value[a]	N (%)	Completed (%,95%CI)	*P* value[b]	N (%)	Completed (%,95%CI)	*P* value[c]
COVID-19 infection		<0.001			<0.001			0.395
Yes	3165(54.76)		1913(57.93)	8.21(6.98~9.44)		1252(50.52)	13.18(11.30~15.06)	
No	2615(45.24)		1389(42.07)	14.83(12.96~16.70)		1226(49.48)	14.36(12.39~16.32)	
Vaccine accessibility		0.107			0.413			0.003
<15m	2453(42.44)		1497(45.34)	11.29(9.68~12.89)		956(38.58)	15.06(12.79~17.33)	
15-30m	2569(44.45)		1423(43.10)	10.19(8.62~11.76)		1146(46.25)	12.83(10.89~14.77)	
>30m	436(7.54)		163(4.94)	14.11(8.71~19.51)		273(11.02)	9.52(6.02~13.03)	

Table 1 Continued

Covariates	Total N (%)	*P* value[a]	Urban N (%)	Urban Completed (%,95%CI)	*P* value[b]	Rural N (%)	Rural Completed (%,95%CI)	*P* value[c]
Unclear	322(5.57)		219(6.63)	11.87(7.55~16.19)		103(4.16)	23.30(15.00~31.60)	
Self-report health condition	80.83(80.42~81.24)	<0.001	80.38(79.82~80.95)[d]	81.23(79.42~83.03)[d]	0.099	81.42(80.83~82.01)[d]	83.30(81.47~85.12)[d]	<0.001
Subjective social level	5.00(4.94~5.05)	0.137	5.07(5.00~5.13)[d]	5.27(5.04~5.49)[d]	0.078	4.90(4.81~4.99)[d]	5.02(4.77~5.27)[d]	0.574
Subjective community status	5.05(5.00~5.11)	0.026	5.13(5.06~5.20)[d]	5.37(5.15~5.60)[d]	0.016	4.95(4.86~5.04)[d]	5.12(4.87~5.37)[d]	0.315
Vaccine knowledge		<0.001			0.001			<0.001
Level1	1872(32.39)		1111(33.65)	10.71(8.89~12.53)		761(30.71)	19.32(16.51~22.13)	
Level2	1551(26.83)		839(25.41)	11.92(9.72~14.12)		712(28.73)	13.20(10.71~15.69)	
Level3	1058(18.30)		535(16.20)	14.77(11.75~17.78)		523(21.11)	11.28(8.56~14.00)	
Level4	1299(22.47)		817(24.74)	7.96(6.10~9.82)		482(19.45)	8.51(6.01~11.01)	
Severity		0.736			0.591			0.136
Level1	2791(48.29)		1688(51.12)	11.14(9.64~12.64)		1103(44.51)	14.69(12.59~16.78)	
Level2	515(8.91)		320(9.69)	11.25(7.77~14.73)		195(7.87)	15.38(10.28~20.49)	
Level3	1667(28.84)		955(28.92)	10.05(8.14~11.96)		712(28.73)	14.04(11.49~16.60)	
Level4	807(13.96)		339(10.27)	12.68(9.12~16.25)		468(18.89)	10.47(7.69~13.25)	
Susceptibility		0.146			0.147			0.242
Level1	1450(25.09)		934(28.29)	11.03(9.02~13.04)		516(20.82)	15.89(12.73~19.06	

							)	
Level2	2071(35.83)		1211(36.67)	12.30(10.45~14.16)		860(34.71)	14.19(11.85~16.52)	
Level3	1013(17.53)		616(18.66)	8.77(6.53~11.01)		397(16.02)	13.35(9.99~16.71)	
Level4	1246(21.56)		541(16.38)	10.54(7.94~13.13)		705(28.45)	11.91(9.52~14.31)	
Benefits		0.009			<0.001			<0.001
Level1	1908(33.01)		1221(36.98)	10.57(8.84~12.29)		687(27.72)	19.94(16.95~22.94)	
Level2	2869(49.64)		1652(50.03)	9.87(8.43~11.31)		1217(49.11)	12.49(10.63~14.35)	
Level3	1003(17.35)		429(12.99)	16.55(13.02~20.08)		574(23.16)	9.06(6.70~11.41)	
Barriers		<0.001			0.228			<0.001
Level1	2436(42.15)		1193(36.13)	10.90(9.13~12.67)		1243(50.16)	9.98(8.31~11.64)	
Level2	530(9.17)		321(9.72)	7.79(4.84~10.74)		209(8.43)	8.61(4.78~12.45)	
Level3	1998(34.57)		1261(38.19)	11.42(9.66~13.18)		737(29.74)	18.86(16.03~21.69)	
Level4	816(14.12)		527(15.96)	12.14(9.35~14.94)		289(11.66)	20.76(16.06~25.47)	
Self-efficacy		0.033			0.001			0.012
Level1	1914(33.11)		1202(36.40)	8.65(7.06~10.24)		712(28.73)	14.04(11.49~16.60)	
Level2	2758(47.72)		1627(49.27)	11.62(10.06~13.18)		1131(45.64)	15.47(13.36~17.58)	
Level3	1108(19.17)		473(14.32)	14.80(11.59~18.01)		635(25.63)	10.39(8.01~12.77)	
Trust in doctors		<0.001			<0.001			<0.001
Level1	1564(27.06)		991(30.01)	13.52(11.39~15.65)		573(23.12)	22.51(19.08~25.94)	
Level2	1895(32.79)		1182(35.80)	8.38(6.79~9.96)		713(28.77)	15.01(12.38~17.63)	
Level3	989(17.11)		547(16.57)	9.51(7.04~11.97)		442(17.84)	11.99(8.95~15.03)	
Level4	1332(23.04)		582(17.63)	13.40(10.63~16.18)		750(30.27)	6.93(5.11~8.76)	

Table 1 Continued

Covariates	Total		Urban			Rural		
	N (%)	*P* value[a]	N (%)	Completed (%,95%CI)	*P* value[b]	N (%)	Completed (%,95%CI)	*P* value[c]
Trust in vaccine developers		<0.001			<0.001			<0.001
Level1	2065(35.73)		1320(39.98)	12.12(10.36~13.88)		745(30.06)	19.33(16.49~22.17)	
Level2	1012(17.51)		665(20.14)	10.23(7.92~12.53)		347(14.00)	20.46(16.20~24.73)	
Level3	1512(26.16)		826(25.02)	7.63(581~9.44)		686(27.68)	11.66(9.25~14.07)	
Level4	1191(20.61)		491(14.87)	14.66(11.52~17.80)		700(28.25)	6.57(4.73~8.41)	

Note:
CI, confidence interval.
COVID-19, Coronavirus disease 2019.
[a] Differences between categories within each variable in total samples.
[b] Differences between categories within each variable in urban samples.
[c] Differences between categories within each variable in rural samples.
[d] Mean and 95% confidence interval for variables.

We categorized the score of vaccine knowledge by quartiles as level 1 (1-2 points), level 2 (3-4 points), level 3 (5-6 points), and level 4 (7-9 points) , the score of severity by quartiles as level 1 (3-9 points), level 2 (10 points), level 3 (11-12 points), and level 4 (13-15 points), the score of susceptibility by quartiles as level 1 (3-7 points), level 2 (8-9 points), level 3 (10-11 points), and level 4 (12-15points), the score of benefits by quartiles as level 1 as (3-9 points), level 2 (10-12 points), and level 3 (13-15 points), the score of barriers by quartiles as level 1 as (4-8 points), level 2 (9-10 points), level 3 (11-12 points), and level 4 (13-20 points), the score of self-efficacy by quartiles as level 1 as (4-12 points), level 2 (13-16 points), and level 3 (17-20 points), the score of trust in doctors by quartiles as level 1(11-29 points), level 2 (30-34 points), level 3 (35-36 points), and level 4 (37-45 points) and the score of trust in vaccine developers by quartiles as level 1 (5-15 points), level 2 (16-19 points), level 3 (20 points), and level 4 (21-25 points).

Additionally, we discovered that rural participants were older, less educated and less respondents had a history of COVID-19 infection than urban participants. In both rural and urban participants, the proportion of male and female participants was relatively similar (45.06%vs.

49.48%). And 45.34% of urban participants and 38.58% of rural participants took less than 15 minutes to reach the vaccination site. (**Appendix file: Table S1**).

Factors influencing COVID-19 vaccination among urban and rural participants

After adjusting for potential confounding variables, we discovered that urban participants without chronic disease (Adjusted odds ratio(AOR): 1.629,95% Confidence interval(CI):1.108-2.396), without COVID-19 infection (AOR:1.977,95%CI:1.977-2.479), who had higher subjective community level (AOR:1.073,95%CI:1.013-1.136), who had level 2 self-efficacy (AOR:2.162,95%CI:1.550-3.014) and level 3 self-efficacy (AOR:1.842,95%CI:1.120-3.029) had higher COVID-19 vaccination rate. Participants from urban areas who had level 4 vaccine knowledge (AOR:0.667,95%CI:0.476-0.935), who had level 2 trust in doctors (AOR:0.530: 95%CI:0.377-0.743) and who had level 3 trust in developers (AOR:0.638,95%CI:0.425-0.959) had lower COVID-19 vaccination rate. The results showed that rural participants who had higher self-report health condition (AOR:1.009,95%CI:1.001-1.017), who had level 2 self-efficacy (AOR:2.524,95%CI:1.753-3.633) and who had level 3 self-efficacy (AOR:4.162,95%CI:2.369-7.315) had higher COVID-19 vaccination rate. Participants from rural areas who had a university degree or above (AOR:0.619,95%CI:0.427-0.898), who had level 2 vaccine knowledge (AOR:0.680,95%CI:0.501-0.923), who had level 4 vaccine knowledge (AOR:0.522,95%CI:0.351-0.776), who had level 2 susceptibility (AOR:0.591, 95%CI: 0.416-0.840), who had level 2 benefits (AOR:0.537, 95%CI:0.376-0.765), who had level 3 benefits (AOR:0.539, 95%CI:0.312-0.933), who had level 2 trust in doctors (AOR:0.665,95%CI:0.456-0.969), who had level 3 trust in doctors (AOR:0.545, 95%CI: 0.340-0.874), who had level 4 trust in doctors (AOR:0.364,95%CI:0.200-0.661) and who had level 4 trust in developers (AOR:0.489, 95%CI:0.253-0.945) had lower COVID-19 vaccination rate.(**Table 2**)

Table 2 Associations between COVID-19 vaccination and sociodemographic, health condition, vaccine related information, severity, susceptibility, benefits, barriers, self-efficiency and trust in healthcare system in urban and rural areas of all participants from February 1 to February 18, 2023 in China(n=5780).

Covariates	Urban	Rural

	Model 1	*P*	Model 2	*P*	Model 1	*P*	Model 2	*P*
Sex								
Male	1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)	
Female	1.157(0.928~1.443)	0.196	1.140(0.908~1.431)	0.258	0.918(0.730~1.154)	0.463	0.932(0.734~1.182)	0.560
Age								
18-29	1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)	

Table 2 Continued

Covariates	Urban				Rural			
	Model 1	*P*	Model 2	*P*	Model 1	*P*	Model 2	*P*
30-39	1.226(0.839~1.792)	0.292	1.352(0.916~1.997)	0.129	0.945(0.645~1.384)	0.771	0.840(0.562~1.255)	0.394
40-49	1.162(0.779~1.733)	0.463	1.240(0.822~1.870)	0.305	0.693(0.455~1.056)	0.088	0.724(0.466~1.125)	0.151
50-59	1.018(0.663~1.564)	0.934	1.214(0.779~1.893)	0.392	0.790(0.542~1.151)	0.219	0.929(0.623~1.384)	0.716
≥60	0.690(0.443~1.074)	0.100	0.890(0.559~1.418)	0.625	0.537(0.358~0.806)	0.003	0.687(0.441~1.070)	0.097
Religion								
Atheist	1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)	
Others	0.816(0.391~1.702)	0.588	0.824(0.386~1.760)	0.617	0.968(0.620~1.512)	0.887	0.780(0.485~1.253)	0.304
Marriage								
Married	1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)	
Others	0.812(0.570~1.156)	0.247	0.629(0.385~1.027)	0.064	1.045(0.723~1.510)	0.816	0.873(0.531~1.435)	0.592
Educational level								
Below high school	1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)	

High school	1.164(0.880~1.540)	0.288	0.974(0.722~1.315)	0.865	1.183(0.897~1.562)	0.234	0.970(0.716~1.314)	0.846
University	1.011(0.778~1.315)	0.934	0.847(0.617~1.163)	0.304	0.852(0.627~1.158)	0.305	0.619(0.427~0.898)	0.011
Career								
Others	1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)	
Medical staff	1.275(0.795~1.047)	0.314	1.373(0.836~2.254)	0.210	1.379(0.817~2.326)	0.228	1.536(0.882~2.675)	0.129
Chronic condition								
Yes	1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)	
No	2.005(1.397~2.877)	□0.001	1.626(1.106~2.391)	0.013	1.732(1.228~2.442)	0.002	1.363(0.928~2.001)	0.114
Allergy history								
Yes	1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)	
No	1.364(0.882~2.108)	0.162	1.238(0.791~1.937)	0.350	0.878(0.536~1.437)	0.605	0.926(0.548~1.566)	0.774
Unclear	1.328(0.784~2.249)	0.291	1.333(0.773~2.299)	0.302	0.556(0.289~1.071)	0.079	0.578(0.290~1.152)	0.119
COVID-19 infection								

Table 2 Continued

Covariates	Urban				Rural			
	Model 1	*P*	Model 2	*P*	Model 1	*P*	Model 2	*P*
Yes	1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)	
No	1.948(1.562~2.428)	□0.001	1.976(1.576~2.477)	□0.001	1.104(0.879~1.388)	0.395	1.033(0.810~1.318)	0.794
Vaccine accessibility								
□15m	1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)	
15-30m	0.892(0.705~1.127)	0.338	0.939(0.736~1.197)	0.611	0.830(0.648~1.063)	0.140	0.963(0.742~1.250)	0.776

□30m	1.291(0.808~2.064)	0.286	1.362(0.836~2.219)	0.214	0.594(0.382~0.923)	0.021	0.924(0.575~1.484)	0.743
Unclear	1.059(0.682~1.643)	0.800	0.959(0.607~1.517)	0.859	1.713(1.049~2.796)	0.031	1.333(0.787~2.260)	0.285
Self-report health condition	1.004(0.997~1.010)	0.303	0.999(0.992~1.006)	0.766	1.010(1.002~1.019)	0.012	1.009(1.001~1.017)	0.036
Subjective social level	1.062(1.004~1.124)	0.036	0.931(0.803~1.078)	0.339	1.029(0.977~1.083)	0.282	0.985(0.929~1.043)	0.603
Subjective community level	1.075(1.016~1.138)	0.012	1.073(1.013~1.136)	0.016	1.041(0.988~1.096)	0.130	0.996(0.940~1.056)	0.905
Vaccine knowledge								
Level1	1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)	
Level2	1.128(0.850~1.496)	0.403	1.017(0.756~1.369)	0.907	0.635(0.479~0.842)	0.002	0.680(0.501~0.923)	0.013
Level3	1.444(1.064~1.960)	0.018	1.209(0.871~1.678)	0.256	0.531(0.384~0.735)	□0.001	0.704(0.491~1.007)	0.055
Level4	0.721(0.525~0.989)	0.043	0.666(0.475~0.933)	0.019	0.388(0.269~0.561)	□0.001	0.522(0.351~0.776)	0.001
Severity								
Level1	1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)	
Level2	1.011(0.693~1.477)	0.953	1.027(0.692~1.524)	0.895	1.056(0.692~1.613)	0.800	1.037(0.658~1.636)	0.875
Level3	0.892(0.688~1.156)	0.387	0.971(0.736~1.282)	0.837	0.949(0.725~1.242)	0.704	1.124(0.825~1.532)	0.458
Level4	1.159(0.814~1.651)	0.414	1.052(0.712~1.553)	0.800	0.679(0.484~0.954)	0.026	1.198(0.763~1.882)	0.433
Susceptibility								
Level1	1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)	
Level2	1.132(0.867~1.478)	0.363	1.284(0.956~1.724)	0.097	0.875(0.646~1.186)	0.389	0.591(0.416~0.840)	0.003

Table 2 Continued

Covariates	Urban				Rural			
	Model 1	*P*	Model 2	*P*	Model 1	*P*	Model 2	*P*
Level3	0.775(0.548~1.096)	0.150	0.918(0.636~1.325)	0.648	0.815(0.561~1.184)	0.284	0.713(0.476~1.068)	0.101
Level4	0.950(0.675~1.338)	0.770	1.060(0.733~1.531)	0.758	0.716(0.516~0.994)	0.046	0.870(0.601~1.259)	0.459
Benefits								
Level1	1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)	
Level2	0.927(0.726~1.183)	0.540	0.878(0.643~1.200)	0.416	0.573(0.445~0.738)	<0.001	0.537(0.376~0.765)	0.001
Level3	1.679(1.227~2.296)	0.001	1.410(0.899~2.211)	0.134	0.400(0.284~0.562)	<0.001	0.539(0.312~0.933)	0.027
Barriers								
Level1	1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)	
Level2	0.691(0.442~1.080)	0.105	0.753(0.468~1.211)	0.242	0.850(0.507~1.427)	0.540	0.585(0.337~1.015)	0.057
Level3	1.054(0.820~1.356)	0.681	1.110(0.760~1.621)	0.588	2.098(1.615~2.725)	<0.001	1.039(0.695~1.554)	0.851
Level4	1.130(0.822~1.554)	0.451	1.037(0.679~1.585)	0.866	2.364(1.684~3.320)	<0.001	1.165(0.734~1.850)	0.517
Self-efficacy								
Level1	1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)	
Level2	1.388(1.079~1.785)	0.011	2.162(1.551~3.015)	<0.001	1.120(0.859~1.461)	0.402	2.524(1.753~3.633)	<0.001
Level3	1.834(1.327~2.535)	<0.001	1.843(1.121~3.030)	0.016	0.710(0.510~0.989)	0.043	4.162(2.369~7.315)	<0.001
Trust in doctors								
Level1	1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)	

Level2	0.585(0.444~0.770)	<0.001	0.529(0.377~0.742)	<0.001	0.608(0.457~0.807)	0.001	0.665(0.456~0.969)	0.034
Level3	0.672(0.479~0.943)	0.021	0.670(0.435~1.030)	0.068	0.469(0.331~0.664)	<0.001	0.545(0.340~0.874)	0.012
Level4	0.990(0.733~1.336)	0.947	0.629(0.387~1.022)	0.061	0.256(0.182~0.361)	<0.001	0.364(0.200~0.661)	0.001
Trust in vaccine developers								
Level1	1.00(ref.)		1.00(ref.)		1.00(ref.)		1.00(ref.)	
Level2	0.826(0.612~1.115)	0.212	0.839(0.590~1.193)	0.329	1.074(0.781~1.476)	0.661	1.427(0.957~2.217)	0.081
Level3	0.599(0.441~0.813)	0.001	0.639(0.425~0.960)	0.031	0.551(0.410~0.741)	<0.001	0.993(0.612~1.612)	0.977
Level4	1.246(0.923~1.681)	0.151	1.032(0.633~1.683)	0.900	0.294(0.207~0.417)	<0.001	0.489(0.253~0.945)	0.033

Note:

COVID-19, Coronavirus disease 2019.

Model 1, unadjusted.

Model 2, adjusted age, chronic condition, COVID-19 infection, vaccine accessibility, self-report health condition, subjective community status, vaccine knowledge, benefits barriers, self-efficacy, trust in doctors and trust in vaccine developers.

We categorized the score of vaccine knowledge by quartiles as level 1 (1-2 points), level 2 (3-4 points), level 3 (5-6 points), and level 4 (7-9 points) , the score of severity by quartiles as level 1 (3-9 points), level 2 (10 points), level 3 (11-12 points), and level 4 (13-15 points), the score of susceptibility by quartiles as level 1 (3-7 points), level 2 (8-9 points), level 3 (10-11 points), and level 4 (12-15points), the score of benefits by quartiles as level 1 as (3-9 points), level 2 (10-12 points), and level 3 (13-15 points), the score of barriers by quartiles as level 1 as (4-8 points), level 2 (9-10 points), level 3 (11-12 points), and level 4 (13-20 points), the score of self-efficacy by quartiles as level 1 as (4-12 points), level 2 (13-16 points), and level 3 (17-20 points), the score of trust in doctors by quartiles as level 1(11-29 points), level 2 (30-34 points), level 3 (35-36 points), and level 4 (37-45 points) and the score of trust in vaccine developers by quartiles as level 1 (5-15 points), level 2 (16-19 points), level 3 (20 points), and level 4 (21-25 points).

Propensity scores matching analysis

In total, 3,912 samples were captured using PSM from the 5,780 participants. After PSM for sex, age, religion, career, self-report health condition, educational level, COVID-19 infection, vaccine accessibility, vaccine knowledge, susceptibility, barriers, trust in doctors and trust in vaccine developers, no statistically significant discrepancies were discerned between the urban and rural participants in all covariates (all P>0.05) (balance test and common support domain of PSM for urban and rural samples are shown in **Appendix file: Table S2 and Fig. S1**). Based on the balanced samples, the difference in COVID-19 vaccination among urban and rural participants was assessed. As shown in Figure.2, the prevalence of COVID-19 vaccination among rural participants (14.57%, 95% CI: 13.01–16.14) was still higher than urban participants (11.15%, 95% CI: 9.75–12.54) by 3.42% (P<0.05) after PSM (see **Figure 2**). In addition, the vaccination rate of COVID-19 in uninfected participants was higher than that of infected participants in most age groups (see **Figure 3**).

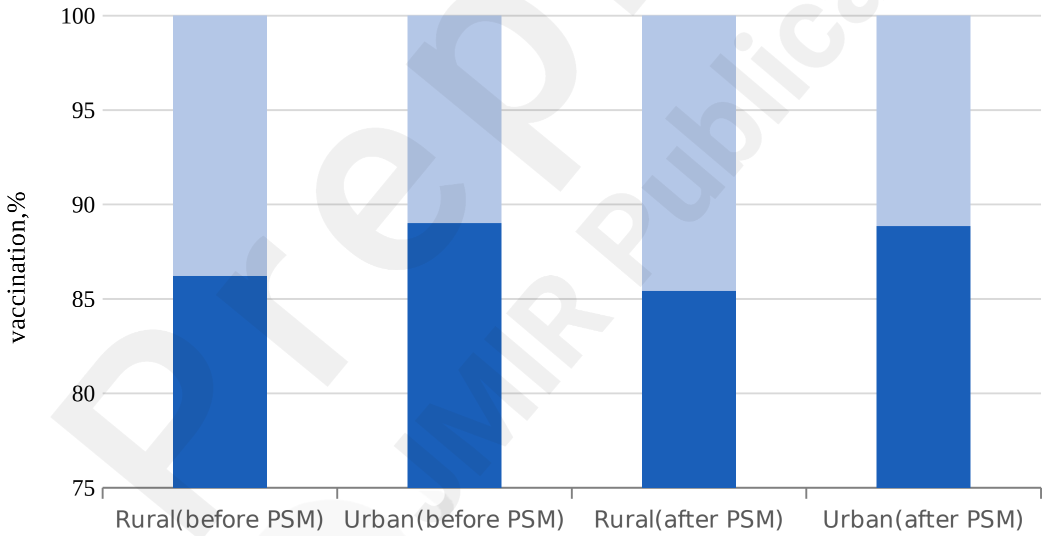

Figure 2 The prevalence of COVID-19 vaccination between urban and rural Chinese populations pre- and post-PSM.

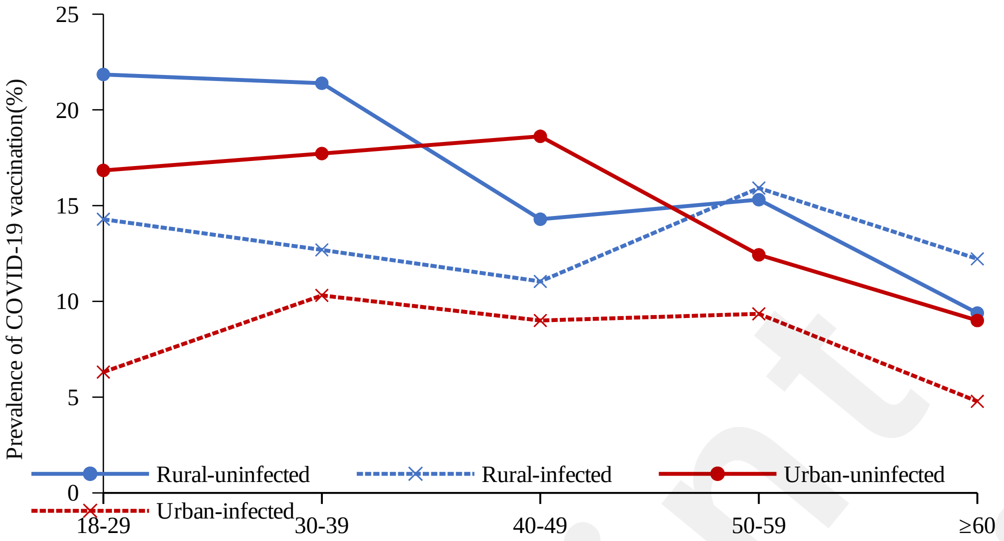

Figure 3 The prevalence of COVID-19 vaccination rate in all age groups by infection status of COVID-19 between urban and rural Chinese populations post-PSM

Discussion

Principal Findings

The present investigation showed that 12.18% participants completed the fourth COVID-19 (second booster) vaccination, with 10.99% urban participants and 13.76% rural participants completed the fourth COVID-19 (second booster) vaccination, respectively. Vaccine knowledge, self-efficacy, trust in healthcare system had an impact on the vaccination among the urban and rural residents. COVID-19 infection, chronic disease and subjective community level had an impact on the vaccination among urban residents. Educational level, self-report health condition, susceptibility and benefits had an impact on the vaccination among rural residents. According to PSM analysis, a disparity of 3.42% vaccine coverage rate was confirmed between urban and rural participants. In addition, the vaccination rate of COVID-19 in uninfected participants was higher than that of infected participants in most age groups.

Our research showed that there were differences in vaccination coverage rates between urban and rural residents, and rural residents had a higher COVID-19 vaccination rate than urban residents. Consistent with previous studies, not only for COVID-19, but also for other vaccines [35-37]. Some research results showed that the vaccination rate in rural areas is higher than that in urban areas[38, 39] . In a survey of the human papillomavirus (HPV) vaccination for men who have sex with men in England, the vaccination rate in rural areas was higher than that in urban areas[38]. A

COVID-19 vaccination coverage survey conducted in US veterans showed that the vaccination rate of rural veterans was higher than that of urban veterans[39]. Meanwhile, some research results showed that the vaccination rate in urban areas was higher than that in rural areas[40, 41]. In a survey of COVID-19 vaccination in the United States, the findings showed that the vaccination rate in urban areas was higher than that in rural areas[40]. In a survey of influenza vaccination among adults in the United States, the results showed that the vaccination rate in cities was higher than that in rural areas [36]. A survey conducted among adolescents in the United States assessing the utilization of vaccination services for vaccines such as MenACWY, Tdap, HPV, and influenza, revealed that urban adolescents had a higher rate of utilization compared to their rural counterparts [41].

The difference of vaccination between urban and rural areas was affected by many factors[42]. We believe that there are several reasons for the rural residents had a higher COVID-19 vaccination rate than urban residents. Firstly, due to the unbalanced allocation of medical resources, rural residents have a higher mortality rate of COVID-19 infection, and they are more willing to be vaccinated for their own safety[43, 44]. Secondly, with the development of urbanization in China, the rural population mobility and migrant workers lead to a small rural population base, so the vaccination rate is high[45]. Thirdly, the Chinese government has paid more attention to the health problems of the rural elderly population, and has taken relevant measures to ensure that every rural elderly person is vaccinated[46]. Finally, Vaccination is also easily affected by online information. Because rural residents have lower education levels, they have higher trust in online information than urban residents and have a strong intention to vaccinate[47-49].

The research results showed that factors, including vaccine knowledge level, self-efficacy, trust in medical staff, and trust in vaccine developers had an impact on the vaccination of urban and rural residents. Studies have shown that individual's comprehension of vaccine knowledge influenced their vaccination. [50, 51]. Those who lack sufficient vaccine knowledge may be hesitant about getting vaccinated [52]. The same applied to other types of vaccines, such as influenza vaccines, where individuals with higher levels of vaccine knowledge are more likely to receive influenza vaccines[53]. Similar to other researches, an individual's self-efficacy influenced their vaccination. Higher self-efficacy encouraged individuals to get vaccinated [54, 55]. And like other studies, trust in doctors and vaccine developers also affected individual's vaccination[56, 57]. A survey in the German showed that trust in the medical establishment had an impact on COVID-19 vaccination intention[58]. Confidence in public service delivery influenced favorable responses to mass immunization efforts[59]. In summary, when formulating a vaccination plan, we should pay attention to early promotion and publicity, such as the necessity, safety, effectiveness, and other related information of the vaccine. In addition, emphasis should be placed on improving residents' self-efficacy and on doctor-patient communication to increase vaccination rates [60].

Furthermore, our analysis revealed that in both urban and rural areas, the rate of fourth COVID-19 (second booster) vaccination was generally higher among residents without a history of infection compared to those who had been previously infected with COVID-19. The novel coronavirus (SARS-CoV-2) in environment constantly changes through mutations that generate variants[61]. A study has shown that the antibody response produced after vaccination better neutralize certain prevalent variants[62]. A statistically significant decreased risk for reinfection was found among individuals who were previously infected and then vaccinated versus those who were previously infected but remained unvaccinated[63]. In addition, there was a decreased risk for symptomatic disease among previously infected and vaccinated persons compared with those who were not vaccinated after infection[64]. Therefore, even if residents have a history of infection, they should be vaccinated again to avoid the next infection. Therefore, we suggest that in the process of promoting the booster vaccination, it should be emphasized that the booster vaccination should be given even if the person has been infected with SARS-CoV-2 and has acquired antibodies.

Strengths and Limitations

This study was the first nationwide survey on the vaccination of residents during the period of the fourth COVID-19 (second booster) vaccination. We reported the latest COVID-19 vaccination status of residents. Given the complexity of factors influencing COVID-19 vaccination, PSM analysis was used for the first time to exclude confounding variables and to quantify the disparities in COVID-19 vaccination rates by rural and urban further. The current study had several limitations that should be acknowledged. Firstly, due to the assessment of COVID-19 vaccination relied on self-reported questionnaires, subjectivity, self-bias, and response bias in the data (collection) was unavoidable. Secondly, while the study employed the PMT framework to collect COVID-19 vaccination covariates comprehensively, it seems possible to omit some unknown related factors.

In addition, PSM was used for 1:1 matching in this study, which indicated that the advantages of our study comprise two aspects. Firstly, PSM method was adopted to ensure that all indicators were collected from homogeneous respondents from both urban and rural areas. Secondly, 1:1 matching makes full use of the processing group information to ensure that the individuals in each group are found to be the closest and the robustness of the principal findings.

Conclusions

The fourth COVID-19 (second booster) vaccination coverage rate among the Chinese population was extremely low, and was significantly lower than the previous vaccine coverage rate. Given COVID-19 infection is still prevalent at a low level currently, efforts should be focused on enhancing self-efficacy and building trust in the healthcare system to expand vaccine coverage among the Chinese. For rural residents, building the confidence of vaccination benefits and improving the health status of the population are in priority. In urban areas, a larger proportion of people infected with COVID-19 and chronic patients should be vaccinated. In conclusion, the vaccination rate in rural areas is higher than that in urban areas. Therefore, we should pay attention to the differences between urban and rural areas and formulate targeted vaccination plans when implementing vaccination programs. In addition, the results of this study also provide reference for the future response to emerging major infectious diseases.

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Conflicts of Interest

None declared.

Data availability

All data can be acquired by contacting the corresponding author.

Abbreviations

COVID-19: Corona Virus Disease 2019

PSM: Propensity Score Matching

PMT: Protective Motivation Theory

CI: Confidence interval

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Supplementary Files

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