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Research article

Inactivated COVID-19 vaccination and SARS-CoV-2 infection among Chinese adults in the “living with COVID” era

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ABSTRACT

The objective of this research was to examine the correlation between the status of inactivated COVID-19 vaccination and self-reported confirmed SARS-CoV-2 infection among adults after China entered the "living with COVID" era. A cross-sectional online survey was conducted among parents or guardians of students attending all 220 kindergartens and 105 primary or secondary schools in Longhua District of Shenzhen, China during March 1 to 9, 2023. The participating schools invited all parents or guardians of their students to complete the online survey. The study focused on a sub-sample of 68,584 participants who were either unvaccinated (n = 2152) or only receiving inactivated COVID-19 vaccination (n = 66,432). Logistic regression was employed for data analysis. Prior to the implementation of the "living with COVID" policy, 83.5% of the participants received three doses of inactivated COVID-19 vaccines; 63.0% reported being infected with the SARS-CoV-2 after the policy change. In a multivariate analysis, participants who had received a third dose within the past 6 months were less likely to be infected with SARS-CoV-2, as compared to those who had not completed the primary vaccination series (4–6 months: AOR: 0.84, 95%CI: 0.77, 0.92; ≤3 months: AOR: 0.82, 95%CI: 0.73, 0.92). Despite the high coverage, our results suggested that three doses of inactivated COVID-19 vaccines did not provide adequate protection against SARS-CoV-2 infection among Chinese adults.

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1. Introduction

Vaccination against coronavirus disease (COVID-19) is crucial in safeguarding individuals from SARS-CoV-2 infection and its severe consequences. In China, most people received inactivated COVID-19 vaccines [1]. A recently published meta-analysis demonstrated that two doses of inactivated COVID-19 vaccines were effective in reducing intensive care unit (ICU) admission and mortality associated with COVID-19 [2]. However, the waning efficacy of the primary vaccination series becomes evident over time [3–5]. Moreover, the primary vaccination series has shown inadequate protection against emerging variants of concern [2]. Previous studies support that administering a third dose of COVID-19 vaccination as a booster can greatly improve immunogenicity against both the wild-type and variants of concern among healthy people [4,5]. Adults in China were recommended to receive a third dose of COVID-19 vaccination as a booster, using the same vaccine as their primary series, since October 26, 2021 [6]. China has achieved high coverage of the COVID-19 booster dose (e.g., 70% of adults in July 2022) [7]. However, there was a dearth of studies investigating the effectiveness of the booster dose of inactivated COVID-19 vaccines at population level [1,8]. In the Hong Kong Special Administrative Region of China, one study observed significant protection against test positivity of Omicron BA.2 among people who had completed three doses of inactivated or mRNA vaccines (vaccine effectiveness: 52%; reference group: unvaccinated people) [8]. In mainland China, one study revealed that a vaccine efficacy of three doses of inactivated COVID-19 vaccination was 28.9% against Omicron BA.5 transmission [1].

The Chinese government made the decision to terminate its zero-COVID policy on December 7, 2022 [9], and no longer implement measures such as quarantine for both COVID-19 patients and their close contacts, universal regular COVID-19 testing, border control, and territory lockdown [10]. A surge in COVID-19 infections, predominantly attributable to the Omicron variant, was observed in China shortly after the country entered the "living with COVID" era. Previous studies estimated that up to 90% of the people in China had been infected with SARS-CoV-2 within one month after the policy change [11,12]. However, the actual situation regarding COVID-19 in China has not yet been fully understood due to the discontinuation of tracking or reporting asymptomatic SARS-CoV-2 cases since December 14, 2022, and the absence of daily updates on the COVID-19 situation since December 25, 2022 [13]. In light of these circumstances, population-based surveys might be viable alternatives to understand the situations.

The study utilized data from a population-based survey among adults during the massive COVID-19 outbreak in Shenzhen, China. The objective of this study is to investigate self-reported SARS-CoV-2 infection, which has been verified through nucleic acid amplification testing (NAAT) or rapid antigen testing (RAT) among adults before and after China entered the "living with COVID" era. Furthermore, this study examined whether participants' status of inactivated COVID-19 vaccination would be correlated with their self-reported SARS-CoV-2 infection.

2. Methods

2.1. Study design

This was a cross-sectional online survey among adults in Longhua District of Shenzhen, China, between March 1 and 9, 2023.

2.2. Participant recruitment and data collection

This online survey comprised of participants who met the following criteria: 1) individuals aged at least 18 years old, 2) parents or guardians of students enrolled in the kindergartens, primary schools, or secondary schools in Longhua District of Shenzhen at the time of the survey, and 3) possessing a smartphone with internet access. The Longhua District Center for Disease Control and Prevention (CDC) implemented the survey covering all kindergartens (n = 220) and primary and secondary schools (n = 105) in the Longhua District of Shenzhen. All schools in Shenzhen had WeChat groups connecting teachers with parents or guardians of all students to provide school information services. During the recruitment, the staff of all participating schools sent a letter inviting parents/guardians of the students to join the study in the WeChat groups. The letter explained the purposes and procedures of this study, participation was voluntary, and participants' right to refuse or quit the study without any consequences. Furthermore, participants were guaranteed that the survey would not collect personal identification, and all data would only be used for research purposes and kept confidential. We did not provide incentives to the participants. We invited one parent/guardian of each student to complete the survey. Prospective participants scanned a quick response (QR) code to access and complete an online informed consent form and then filled out the online questionnaire.

This online questionnaire, developed by using Questionnaire Star (Changsha Ranxing Information Technology Co, Changsha, China), was in simplified Chinese (Supplementary Material 1. Questionnaire in English and Chinese). To avoid duplicated entries, we only allow an individual WeChat account to access the online questionnaire once. The questionnaire consisted of 30 items, which were allocated in two pages with approximately 15 items per page and could be completed within 10 min. Prior to submission, the online survey platform conducted a completeness check to ensure that all required fields were filled out. All data were stored in the server of the Questionnaire Star with the password. Access to the database was restricted to the first authors and the corresponding author of the study. In January 2023, approximately 80,000 students enrolled in different levels of schools in Shenzhen. During the recruitment period, 77,645 participants completed the online questionnaire, representing 97% of the target population. We excluded 9061 participants who have received other types of COVID-19 vaccination (e.g., recombinant COVID-19 vaccines (CHO cell or adenovirus type 5 vector) and mRNA vaccines). This study focused on a sub-sample of 68,584 participants who were either unvaccinated (n = 2152) or only receiving inactivated COVID-19 vaccination (CoronaVac, Sinovac Biotech) (n = 66,432). Information on self-reported SARS-CoV-

2 infection and COVID-19 vaccination status of the entire sample (n = 77,645) was provided in Supplementary Material 2. The ethics committee of the Longhua District CDC approved this study (reference number: 2021006).

2.3. Sample size calculation

The Longhua district had approximately 80,000 students enrolled in kindergarten, primary, and secondary schools. This study aimed to cover at least the parents or guardians of 40,000 students (one for each student). The actual response rate was better than our expectation. Assuming 10–40% of the reference group (participants without a protective factor) reported a history of SARS-CoV-2 infection, the present sample size (n = 68,584) was able to detect the smallest odds ratio (OR) of 1.05 between people with and without such a protective factor. The statistical power was set as 0.80 and the alpha value was 0.05 for the sampling size calculation (PASS 11.0, NCSS LLC, Kaysville, the United States).

Table 1
Characteristics of the participants.

	All participants (n = 68,584)	Participants aged 18–44 years old (n = 61,113)	Participants aged ≥45 years old (n = 7471)	P values
	n (%)	n (%)	n (%)	
Background characteristics				
Age group, years				
18–44	61,113 (89.1)	–	–	–
≥45	7471 (10.9)	–	–	
Sex assigned at birth				
Male	14,580 (21.3)	11,513 (18.8)	3067 (41.1)	<.001
Female	54,004 (78.7)	49,600 (81.2)	4404 (58.9)	
Education level				
Junior high or below	11,831 (17.3)	10,097 (16.5)	1734 (23.2)	<.001
Senior high or equivalent	15,159 (22.1)	12,974 (21.2)	2185 (29.2)	
College or above	41,594 (60.6)	38,042 (62.3)	3552 (47.6)	
Full-time employment				
Yes	49,320 (71.9)	44,014 (72.0)	5306 (71.0)	.07
No	19,264 (28.1)	17,099 (28.0)	2165 (29.0)	
Number of other household members				
0	1147 (1.7)	1014 (1.7)	133 (1.8)	<.001
1	2341 (3.4)	1974 (3.2)	367 (4.9)	
2	10,621 (15.5)	9066 (14.8)	1555 (20.8)	
3–5	48,825 (71.2)	43,806 (71.7)	5019 (67.2)	
>5	5650 (8.2)	5253 (8.6)	397 (5.3)	
Presence of any chronic conditions				
No	64,446 (94.0)	58,078 (95.0)	6368 (85.2)	<.001
Yes	4138 (6.0)	3035 (5.0)	1103 (14.8)	
Perform physical activity regularly (≥3 days/week of physical activity of at least 30 min/day in the past six months)				
No	38,753 (56.5)	35,617 (58.3)	3136 (42.0)	<.001
Yes	29,831 (43.5)	25,496 (41.7)	4335 (58.0)	
History of SARS-CoV-2 infection				
Self-reported confirmed SARS-CoV-2 infection on or after December 7, 2022				
No	25,393 (37.0)	22,282 (36.5)	3111 (41.6)	<.001
Yes	43,191 (63.0)	38,831 (63.5)	4360 (58.4)	
Self-reported confirmed SARS-CoV-2 infection before December 7, 2022				
No	65,013 (94.8)	57,910 (94.8)	7103 (95.1)	.25
Yes	3571 (5.2)	3203 (5.2)	368 (4.9)	
COVID-19 vaccination status				
Number of doses of inactivated COVID-19 vaccine received by the adults (interval between the COVID-19 vaccine and December 7, 2022)				
0 dose	2152 (3.1)	1929 (3.2)	223 (3.0)	<.001
1 dose	769 (1.1)	724 (1.2)	45 (0.6)	
2 doses (>6 months)	6847 (10.0)	6276 (10.3)	571 (7.6)	
2 doses (4–6 months)	1137 (1.7)	1054 (1.7)	83 (1.1)	
2 doses (<3 month)	402 (0.6)	379 (0.6)	23 (0.3)	
3 doses (>6 months)	48,069 (70.1)	42,564 (69.6)	5505 (73.8)	
3 doses (4–6 months)	6746 (9.8)	5984 (9.8)	762 (10.1)	
3 doses (<3 months)	2462 (3.6)	2203 (3.6)	259 (3.5)	

N.A.: not applicable.
P values were obtained using Chi-square tests comparing the difference in study variables between children of different age groups.

3. Measurements

3.1. Development of the questionnaire

The questionnaire used in the present study was created by a panel of experts (e.g., epidemiologists, clinicians, and CDC workers). To access the readability and clarity of the questionnaire, we invited 10 adults to complete the questionnaire and collected their feedbacks. All participants in the pilot testing found the length of the questionnaire acceptable and the questions to be precise. Considering their feedback, the panel revised and finalized the questionnaire for the actual survey. We did not include these 10 adults in the actual survey.

3.2. Background characteristics

Information on sociodemographics such as age, gender, education level, employment status, and the number of other individuals residing in their households was collected. In addition, the chronic disease status and level of physical activity were collected.

3.3. Information about SARS-CoV-2 infection and COVID-19 vaccination

Information about a history of confirmed SARS-CoV-2 infection was collected. Among participants with such a history, methods to confirm the infection (RAT only, NAAT only, or both), date of the diagnosis, and COVID-19-related symptoms (measured by a validated checklist) were recorded [14]. The quantity of COVID-19 vaccination doses administered to the participants was recorded. Among the participants who had received a minimum of one dose of COVID-19 vaccination, the date on which they received the most recent dose was documented.

3.4. Statistical analysis

The chi-square test or independent sample *t*-test was used to compare the differences in SARS-CoV-2 infection, related symptoms, and vaccination status between two age groups (18–44 years versus ≥45 years). Self-reported SARS-CoV-2 infection after December 7, 2022, was the dependent variable. Bivariate logistic regression models were fit to assess the correlations between each independent variable of interest (COVID-19 vaccination history, confirmed SARS-CoV-2 before December 7, 2022, and background characteristics) and the dependent variable. Crude odds ratios (OR) and their corresponding 95% confidence interval (CI) were obtained. A multivariate logistic regression model was then performed including all variables with $p < .05$ in the bivariate analysis. Adjusted OR (AOR) and their 95% CI were obtained. Sub-group analyses were also conducted for two different age groups (18–44 years and ≥45 years). All

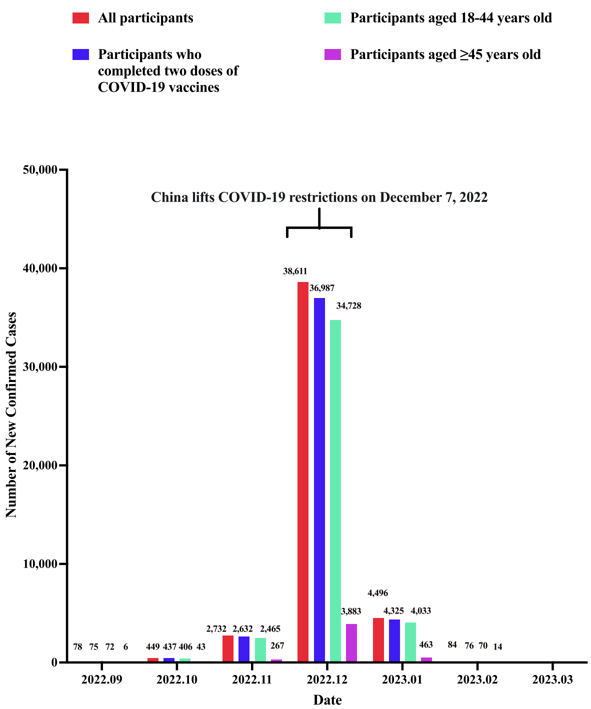

Fig. 1. The number of new confirmed cases among the participants.

statistical analyses were performed using SPSS Statistics for Windows version 26.0 (IBM Corp), with $p < .05$ considered statistically significant.

4. Results

4.1. Background characteristics

Most of the participants were under 45 years old (89.1%), female (78.7%), full-time employed (71.9%), and did not have any chronic conditions (94%). About half of them received tertiary education (60.6%), and 79.4% lived with at least three other household members. (Table 1).

4.2. SARS-CoV-2 infection

A total of 43,191 (63.0%) participants disclosed their personal record of a history of confirmed SARS-CoV-2 infection, which occurred either on or after December 7, 2022. Among these participants, 20,046 were confirmed by RAT, 12,610 were confirmed by NAAT, and the other 10,535 were diagnosed using both methods (Table 1). A significant difference in the SARS-CoV-2 infection was observed between participants aged 18–44 years and those aged 45 years or above (63.5% versus 58.4%; $p < .001$). Most of the infections were confirmed in December 2022, as depicted in Fig. 1. All adults with a history of confirmed SARS-CoV-2 infection on or after December 7, 2022, reported some COVID-19-related symptoms, such as fever (35,318/43,191, 81.8%), fatigue (25,691/43,191, 59.5%), headache (24,128/43,191, 55.9%), and dry cough (23,742/43,191, 55.0%) (Fig. 2). Among participants with a history of confirmed infection, those who were under 45 years were more likely to experience fever, headache, stuffy nose, and running nose, while they were less likely to have conjunctivitis, as compared to participants aged ≥45 years (Fig. 3). As compared to participants who did not complete the primary COVID-19 vaccine series, those who had received at least two doses of COVID-19 vaccines were more likely to experience dry cough, sore throat, stuffy nose, and runny nose, while they showed fewer symptoms such as a loss of smell, diarrhea, and pneumonia (Fig. 4). Compared to participants who received two doses, those who had received the booster doses were more likely to have a dry cough, sore throat, stuffy nose, and runny nose, while they were less likely to report a loss of smell, diarrhea, or pneumonia (Supplementary Material 3).

A small proportion of participants ($n = 3,571$, 5.2%) reported confirmed SARS-CoV-2 infection before December 7, 2022; 76.5% of these infections happened in November 2023. Among these participants ($n = 3571$), none of them had experienced a recurrence of SARS-CoV-2 infection after December 7, 2022.

4.3. Status of COVID-19 vaccination

The majority of adults completed two or more doses of inactivated COVID-19 vaccines (95.8%), and 83.5% received three doses of

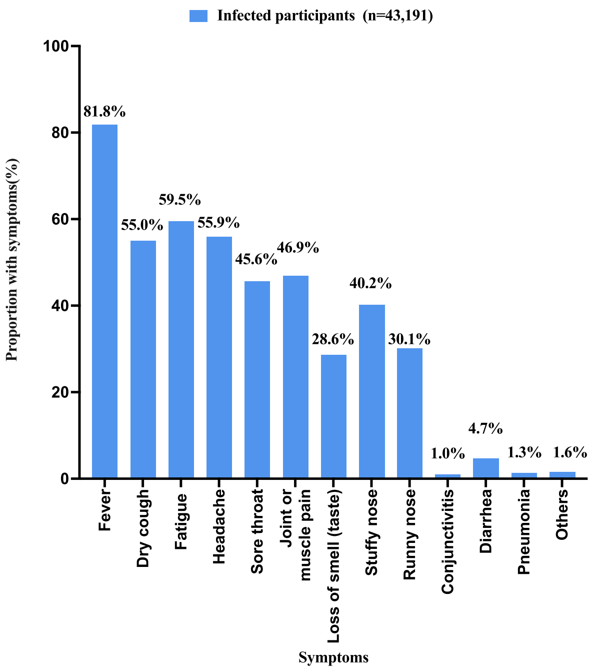

Fig. 2. The proportion of symptoms associated with COVID-19 among all participants.

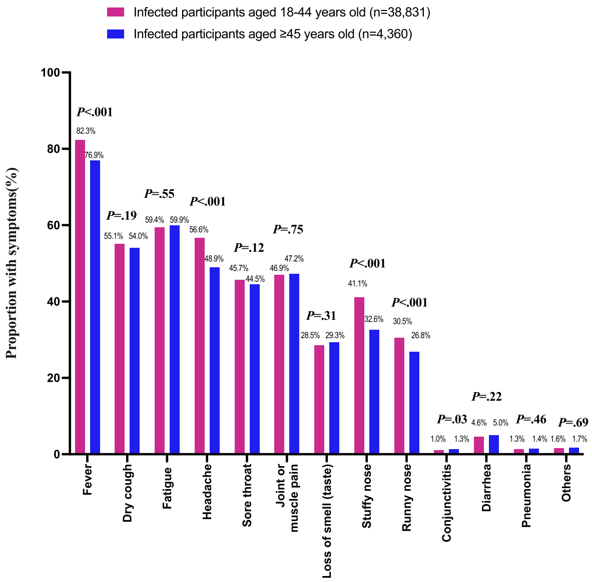

Fig. 3. The proportion of symptoms associated with COVID-19 among participants in different ages.

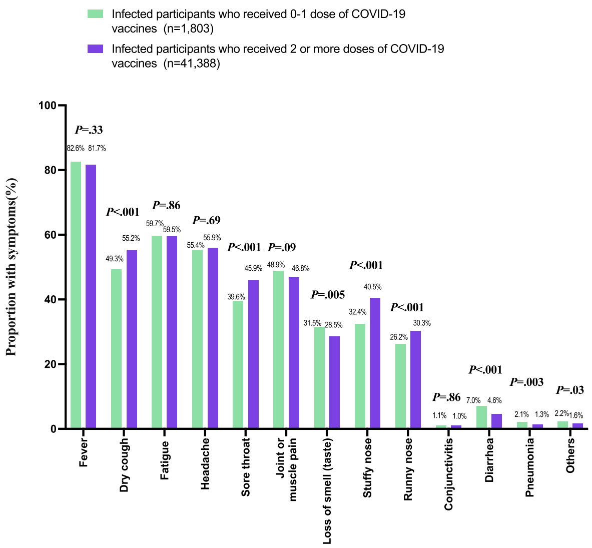

Fig. 4. The proportion of symptoms associated with COVID-19 among participants in different COVID-19 vaccination status.

inactivated vaccines. Participants aged 18–44 years had a lower primary vaccination series uptake rate (95.7% versus 96.4%, $p = .002$) and lower booster dose uptake rate (83.0% versus 87.4%, $p < .001$) compared to those aged 45 years or above. Among recipients of the booster doses ($n = 57,277$), 83.9% ($n = 48,069$) received it for more than six months (Table 1).

4.4. The correlation between COVID-19 vaccination status and SARS-CoV-2 infection

In the multivariate analysis, participants who had taken up their booster dose of inactivated COVID-19 vaccine within the past 6 months had a lower infection rate of SARS-CoV-2 (4–6 months: AOR: 0.84, 95%CI: 0.77, 0.92; ≤3 months: AOR: 0.82, 95%CI: 0.73, 0.92; reference group: received ≤1 dose). However, the SARS-CoV-2 infection rate among participants who received their booster dose for more than 6 months was similar to those who have not yet completed their primary vaccine series. In addition, participants who were female, having a higher education level, and having the presence of any chronic condition were more likely to report SARS-CoV-2 infection. Not having full-time employment and regular physical activity in the past six months were negatively correlated with SARS-CoV-2 infection (Table 2).

Table 2
Factors associated with self-reported confirmed SARS-CoV-2 infection on or after December 7, 2022.

	All participants (n = 68,584)		Participants aged 18–44 years old (n = 61,113)		Participants aged ≥45 years old (n = 7471)	
	AOR (95%CI)	P values	AOR (95%CI)	P values	AOR (95%CI)	P values
Background characteristics						
Age group, years						
18–44	Reference					
≥45	1.04 (0.99, 1.10)	.13	N.A.	N.A.	N.A.	N.A.
Sex assigned at birth						
Male	Reference		Reference		Reference	
Female	1.59 (1.53, 1.66)	<.001	1.58 (1.51, 1.65)	<.001	1.67 (1.51, 1.85)	<.001
Education level						
Junior high or below	Reference		Reference		Reference	
Senior high or equivalent	1.73 (1.64, 1.82)	<.001	1.72 (1.63, 1.81)	<.001	1.80 (1.58, 2.05)	<.001
College or above	3.36 (3.21, 3.51)	<.001	3.38 (3.23, 3.54)	<.001	3.13 (2.77, 3.54)	<.001
Full-time employment						
Yes	Reference		Reference		Reference	
No	0.88 (0.84, 0.91)	<.001	0.87 (0.84, 0.91)	<.001	0.93 (0.84, 1.04)	.21
Number of other household members						
0	Reference		Reference		–	
1	1.06 (0.91, 1.24)	.44	1.06 (0.90, 1.26)	.49	–	–
2	1.03 (0.90, 1.18)	.68	1.02 (0.89, 1.18)	.75	–	–
3–5	1.09 (0.96, 1.24)	.20	1.08 (0.94, 1.24)	.28	–	–
>5	1.01 (0.88, 1.16)	.92	0.98 (0.84, 1.14)	.79	–	–
Presence of any chronic conditions						
No	Reference		Reference		Reference	
Yes	1.72 (1.60, 1.85)	<.001	1.80 (1.64, 1.96)	<.001	1.57 (1.36, 1.80)	<.001
Perform physical activity regularly (≥3 days/week of physical activity of at least 30 min/day in the past six months)						
No	Reference		Reference		Reference	
Yes	0.58 (0.56, 0.60)	<.001	0.57 (0.55, 0.59)	<.001	0.69 (0.63, 0.76)	<.001
History of SARS-CoV-2 infection						
Self-reported confirmed SARS-CoV-2 infection before December 7, 2022						
No	–		–		–	
Yes	–	–	–	–	–	–
COVID-19 vaccination status						
Number of doses of COVID-19 vaccine received by the adults (interval between the second dose of COVID-19 vaccine and December 7, 2022)						
0-1 dose	Reference		Reference		Reference	
2 doses	1.05 (0.96, 1.15)	.29	1.03 (0.94, 1.13)	.54	1.29 (0.96, 1.73)	.10
3 doses (>6 months)	1.25 (1.15, 1.35)	<.001	1.22 (1.12 1.33)	<.001	1.54 (1.19, 2.00)	.001
3 doses (4–6 months)	0.84 (0.77, 0.92)	<.001	0.80 (0.73, 0.89)	<.001	1.24 (0.92, 1.66)	.16
3 doses (<3 months)	0.82 (0.73, 0.92)	.001	0.81 (0.72, 0.91)	.001	0.97 (0.68, 1.39)	.86

N.A.: not applicable.
—: P > .05 in univariate analysis and not considered by the multivariate logistic regression models.
AOR: adjusted odds ratios, odds ratios obtained from multivariate logistic regression models using all significant factors in the univariate analysis as candidates.
CI: confidence interval.

4.5. The correlation between COVID-19 vaccination status and SARS-CoV-2 infection in different age groups (18–44 years and ≥45 years)

Among those under 45 years old, receiving a booster dose of inactivated COVID-19 vaccination within the last 6 months was negatively correlated with SARS-CoV-2 infection. However, the correlation between receiving the booster dose and SARS-CoV-2 infection was not of statistically significant. (Table 2).

Compared to participants who only received two doses, those who had taken the booster dose of inactivated COVID-19 vaccination within the last 6 months had a lower SARS-CoV-2 infection rate (Supplementary Material 4).

Among participants without prior confirmed SARS-CoV-2 infection, the SARS-CoV-2 infection rate was lower among those who received three doses of inactivated COVID-19 vaccination than that of participants who only received two doses (Supplementary Material 5).

5. Discussion

In the absence of official data, this study provided a snapshot of the COVID-19 situation when China entered the “living with COVID” era. Our study also reported correlations between receiving the booster dose of inactivated COVID-19 vaccination and self-reported symptomatic SARS-CoV-2 infection, which contributed to the evidence on the effectiveness of such vaccination. The abovementioned findings could facilitate policymaking and COVID-19 vaccination booster dose service planning in China and other countries that mainly used inactivated COVID-19 vaccines.

Over 60% of our participants reported a history of confirmed SARS-CoV-2 infection after the country started to “live with COVID”.

Such infection rate was comparable to the figure predicted by the modeling studies [11,12]. However, the real situation might be even worse than our findings. One major reason for the underestimation was that most people with asymptomatic infection and a certain proportion of people with symptomatic infection might not receive a diagnosis due to the discontinuation of universal and regular COVID-19 screening and the limited NAAT and RAT capacity during the outbreak [10]. As a result, no participants in this study reported asymptomatic SARS-CoV-2 infection, which was quite different from the findings of a previous meta-analysis (32.4% of adults were asymptomatic following Omicron infection) [15].

Several reasons might explain why Chinese adults were vulnerable to SARS-CoV-2 when the country started to "live with COVID". First, China had been implementing strict measures for almost three years before the policy changed. Such measures put the COVID-19 situation under reasonable control and contributed to a meager SARS-CoV-2 infection rate among people in China prior to the policy changes (i.e., 5.2% in our sample). Therefore, the practical and long-term protection caused by natural transmission of SARS-CoV-2 was inadequate at the population level [16,17]. Second, despite the high coverage of booster doses, most people completed their booster dose for more than six months when the country started to "live with COVID". The protection conferred by the booster dose was waning over time and might be inadequate. Our results suggested that receiving the booster dose for more than six months was not associated with a lower likelihood of SARS-CoV-2 infection, which was similar to the findings of a previous [1]. To address the challenges of waning immunity to the first booster dose and the evolving contagious new variants of SARS-CoV-2, many countries implemented a second booster dose in many countries [18–20]. However, China did not introduce the second booster dose of the COVID-19 vaccination before policy changes [21].

The correlations between the COVID-19 vaccination booster dose uptake and self-reported confirmed SARS-CoV-2 infection were different between participants who were 18–44 years and those aged 45 years or above. Among younger participants, receiving the booster dose within the past six months was negatively correlated with SARS-CoV-2 infection. However, such a correlation was not statistically significant among older participants. One possible explanation was that older adults had lower immunogenicity to primary series and booster doses of COVID-19 vaccination due to lower vaccine-induced spike-specific $CD4^{+}$ T cells [22,23]. Therefore, older adults should be given more attention when implementing the second booster dose in China.

Although this study had strengths of a relatively large sample size and high response rate, it had several limitations. First, the SARS-CoV-2 infection rate might be underestimated, as China discontinued universal and regular COVID-19 screening after entering the "living with COVID" era. The service capacity of NAAT and RAT was inadequate during the outbreak. Self-reported data might also involve recall bias. Second, the self-reported COVID-19 vaccination status could lead to misclassification. Verifying the self-reported COVID-19 diagnosis and vaccination history was not feasible as this study was anonymous. Third, this study could only investigate factors correlated with symptomatic SARS-CoV-2 infection, as no participant reported asymptomatic infection. Fourth, this study only targeted a fraction of the adult population in China (i.e., parents or guardians of students), so the results might not be generalized to all adults in China. Fifth, we only recruited participants from one Chinese city. The results of this study may not be applicable to other areas in China. Shenzhen, being one of the largest and most advanced cities in the country, exhibited a greater extent of COVID-19 vaccination coverage and superior service capabilities in terms of testing during the outbreak. Moreover, we failed to include other personal COVID-19 preventive measures in our questionnaire. Facemask wearing, hand washing, and avoiding crowded places are still useful in preventing emerging variants of concerns such as Omicron [24]. Furthermore, a causal relationship could not be established due to the nature of the cross-sectional study. In addition, it was a limitation that we did not differentiate the symptoms of anosmia (loss of smell) and ageusia (loss of taste). Lastly, we were not able to determine the virus subtype in this study for the following reasons: 1) over half of our participants with SARS-CoV-2 infection were confirmed by RAT. The RAT results could not provide information about the virus subtype; 2) the healthcare system was overloaded during the massive COVID-19 outbreak in December 2022 and could not provide information on the virus subtype for participants who were confirmed by NAAT.

6. Conclusion

More than 60% of the participants reported SARS-CoV-2 infection after China changed its zero-COVID policy and entered the "living with COVID" era. Although the coverage was relatively high, the protection conferred by the booster dose of inactivated COVID-19 vaccination was inadequate.

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Ethical approval

This study was reviewed and approved by the committee of Longhua District Centre for Diseases Control and Prevention, with the approval number (reference: 2021006).

Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available as they contain sensitive personal behaviors (SARS-CoV-2 infection and COVID-19 vaccination uptake) but are available from the corresponding author on reasonable request.

CRediT authorship contribution statement

Hongbiao Chen: Writing – review & editing, Project administration, Methodology, Data curation, Conceptualization. **Siyu Chen:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Formal analysis, Conceptualization. **Lei Liu:** Writing – review & editing, Project administration, Methodology, Data curation, Conceptualization. **Yuan Fang:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Formal analysis. **Xue Liang:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Formal analysis. **Dongmei Liang:** Project administration, Methodology, Data curation. **Lixian Su:** Project administration, Methodology, Data curation. **Weijun Peng:** Project administration, Methodology, Data curation. **Xiaofeng Zhou:** Project administration, Methodology, Data curation. **Jingwei Luo:** Project administration, Methodology, Data curation. **Zixin Wang:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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NA.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e25803.

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