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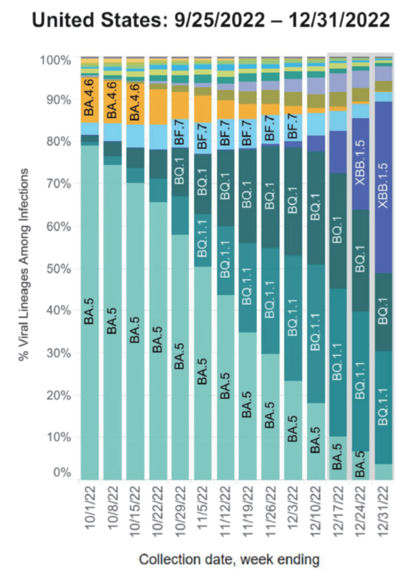

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Cover Image: adapted from the US Centers for Disease Control and Prevention, https://covid.cdc.gov/covid-data-tracker/#variant-proportions.

Preplanned Studies

Neglected Aspects of SARS-CoV-2 Aerosol Transmission in Bathrooms of Multistory and High-Rise Buildings — Beijing Municipality, China, October 2022

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Summary

What is already known about this topic?

There is a toilet flush-soil stack-floor drain pathway of aerosol transmission in multistory and high-rise buildings, but the influencing factors are not completely clear.

What is added by this report?

The poor airtightness of the connecting parts of the floor drain, as well as pressure fluctuations in the sewage pipe during toilet flushing caused by blockage of the soil stack vent, may lead to the cross-floor transmission of viral aerosols through the soil stack and floor drains.

What are the implications for public health practice?

In multistory and high-rise buildings, the bathroom floor drains should be kept sealed, and floor drain connecting parts should be airtight. Furthermore, the soil stack vent should not be blocked. In this way, the cross-floor transmission of viral aerosols can be effectively reduced.

The vertical transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) aerosols between building floors through the toilet flush-soil stack-floor drain route has been confirmed, but it is not fully understood (*1*–*3*). In a centralized quarantine apartment in Beijing, people with a positive SARS-CoV-2 nucleic acid test between September 29 and October 8, 2020 were quarantined in unit 02 and housed on multiple floors. The epidemiological investigation showed consistent genetic sequencing for all cases but ruled out the possibility of contact transmission during isolation and speculated that vertical transmission through the toilet flush-soil stack-floor drain route was possible. The field simulation experiment using fluorescent polystyrene microspheres as simulants found that the poor airtightness of the floor drain components, as well as the pressure fluctuation in the sewage pipe during toilet flushing caused by blockage of the soil stack vent, may have led to the cross-floor transmission of viral aerosols through the soil stack and floor drains in unit 02. During the coronavirus disease 2019 (COVID-19) pandemic, it is recommended that multistory and high-rise buildings maintain the water seals and ensure airtightness between the floor drain components. Furthermore, the soil stack vent should not be blocked. This will ensure pressure balance between the pipe and the atmosphere during toilet flushing and reduce pressure fluctuations in the pipe, in turn effectively eliminating cross-floor aerosol transmission.

The water traps were first removed from the floor drains to observe the pressure changed in the pipe. Experimental scenarios were set up to simulate viruses expelled in exhaled breath and in feces and urine. The bathroom fan was either turned on or off to simulate the situation of some individuals occasionally turning the exhaust fan off. Fluorescent polystyrene microspheres with aerodynamics similar to those of SARS-CoV-2 spike pseudoviruses were used to simulate the virus. Two scenarios, breathing and breathing with defecation with toilet flushing, were simulated in the bathroom of room 402. At the same time, monitoring and sample collection were conducted in bathrooms 502, 1002, 1902, and 2702, and experimenters were assigned to each bathroom to avoid personnel movement affecting the results. Both scenarios included two periods — when the bathroom exhaust fan was either on or off. Changes in the wind speed of the exhaust fan and floor drain, as well as the aerosol particle size spectrum (0.3–10 μm), were monitored in the bathrooms. PM_{10} filter membrane samples collected by medium flow PM_{10} samplers (100 L/min) and smear swab samples of the exhaust fan and floor drain were analyzed. The state of the exhaust fan and the arrangement of the toilet flushing in the two scenarios are shown in Supplementary Tables S1–S3 (available in http://weekly.chinacdc.cn/). The experimental method was previously published (*4–5*).

The bathroom exhaust fans were connected to the exhaust duct through the exhaust branch pipe, and the exhaust gas was discharged through a centrifugal fan on the roof. Therefore, the wind speed could be measured without turning on the exhaust fan. The wind speed in the bathroom floor drain was significantly affected by toilet flushing. Compared with scenario 1, it significantly increased after toilet flushing (scenario 2) and decreased with fewer simultaneously flushed toilets. Representative changes in wind speed are shown in Supplementary Figures S1 and S2 (available in http://weekly.chinacdc.cn/).

In all bathrooms, with the increase of simulated breathing time and the number of toilet flushes, the concentration of the different particle sizes increased (Supplementary Figure S3, available in http://weekly.chinacdc.cn/). The simulants were observed in the filter membrane samples collected from room 502 in scenario 1 period 2 and scenario 2 period 1 and from all rooms in scenario 2 period 2. No simulant was observed in the other filter membrane samples or in the exhaust fan or floor drain samples (Table 1 and Figure 1).

DISCUSSION

The onsite investigation found that bathroom floor drains were connected with the horizontal wastewater branch, and the sewage and branches led to the soil stack. The floor drains were equipped with removable water traps, but all connecting parts were metal-to-metal contacts with a poor sealing effect (Supplementary Figures S4 and S5, available in http://weekly.chinacdc.cn/). In addition, there was a cavity between the trap, the outside pipe, and the horizontal wastewater branch. Therefore, the water trap in the floor drain was removed during the experiment. The exhaust fan was turned on and off in scenario 1. However, regardless of the use of the exhaust fan, the bathroom exhaust pipe on the roof continued to discharge strongly through the centrifugal

TABLE 1. The observation results of fluorescent polystyrene microspheres of samples collected in different rooms in 2 scenarios.

Room number	Scenario 1		Scenario 2	
	Period 1	Period 2	Period 1	Period 2
502	Not observed	Observed (filter membrane samples)	Observed (filter membrane samples)	Observed (filter membrane samples)
1002	Not observed	Not observed	Not observed	Observed (filter membrane samples)
1902	Not observed	Not observed	Not observed	Observed (filter membrane samples)
2702	Not observed	Not observed	Not observed	Observed (filter membrane samples)

Note: Two scenarios, breathing (scenario 1) and breathing with defecation with toilet flushing (scenario 2), were simulated in the bathroom of room 402. Both scenarios included two periods, only turn off the exhaust fans in rooms 1002 and 1902 during period 1, and turn on all exhaust fans during period 2. PM_{10} filter membrane samples [collected by medium flow PM_{10} samplers (100 L/min)], smear swab samples of exhaust fan and floor drain were collected from each room in each period.

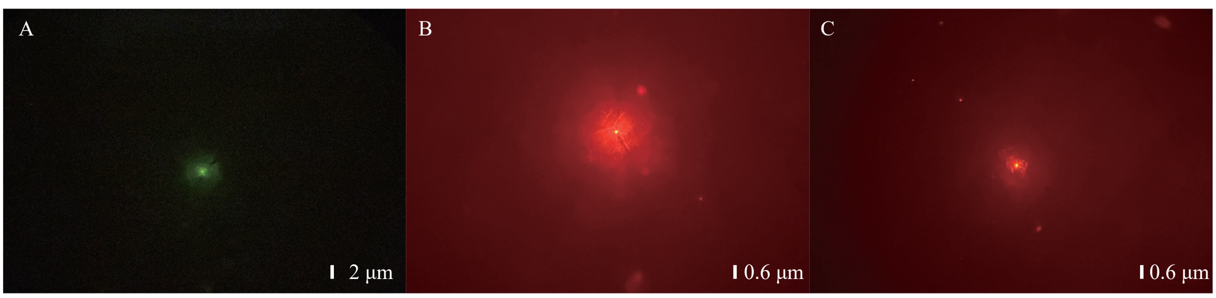

FIGURE 1. Representative photos of fluorescent microspheres collected by air samplers in different rooms in 2 scenarios. (A) room 502 during scenario 1-period 2, (B) room 502 during scenario 2-period 1, and (C) room 2702 during scenario 2-period 2.
Note: After simulating breath, defecation, and toilet flushing in room 402, fluorescent microspheres in filter membranes collected from experimental rooms were observed using fluorescent microscopy. Microspheres with different sizes are indicated in the photos.

fan. Even if the toilet was not flushed, aerosols could enter room 502, which was the closest to room 402, through the unsealed floor drain in the bathroom. However, owing to the increase in floor number and the relatively short experiment time (2 hours), the simulants were not able to enter bathrooms on higher floors.

The soil stack vent on the roof was equipped with filtration and disinfection devices and a centrifugal fan, making it impossible for air to move through the soil stack vent, which resulted in air pressure fluctuations when a toilet was flushed. When a toilet is flushed, there will be pressure fluctuations in the floor drains on all floors that are connected to the same soil stack (*3*,*6*). The use of a centrifugal fan to draw air upward increases the risk of damage to the floor drain water seal. When the toilet was flushed in room 402, simulants were observed in filter membrane samples collected in rooms 502, 1002, 1902, and 2702. This indicates that there is an aerosol transmission pathway from the toilet flush to soil stack to the floor drain.

Furthermore, even if the removable water trap is full in the unused floor drain that is reserved for the washing machine, pressure fluctuations that occur with the toilet flushing could make the viral aerosols turbulent within the soil stack, sewage pipe, and waste pipe. The aerosols could then accumulate in the cavity and spread to the bathroom through non-airtight floor drains. In the field experiment, simulants were found in all rooms that housed positive cases. This indicated that the poor sealing of the connecting parts of the floor drain and the pressure fluctuation in the sewage pipe during toilet flushing caused by blockage of the soil stack vent may have led to the cross-floor transmission of viral aerosols through the soil stack and floor drains, leading to cross-floor disease transmission.

In addition, although the centrifugal fan installed in the bathroom exhaust duct on the roof of the centralized quarantine apartment was kept on, it could only weakly discharge exhaust gas from bathrooms on the lower floors unless the exhaust fans were on. The weak discharge of exhaust gas was supported by the changes in the exhaust fan speeds and the aerosol particles still present in the air. The epidemiological investigation showed that some of the isolated individuals turned off the exhaust fan due to the noise. There was only one window close to the elevator in the corridor. When the window was not opened, the ventilation in the corridor was poor. The bathroom was close to the door of the room; if the exhaust fan was off, the viral aerosols in the bathroom could easily diffuse into the corridor and other rooms when the door was opened and closed for necessities such as nucleic acid testing, food delivery, and garbage removal, resulting in viral spread to adjacent rooms on the same floor. This possibility cannot be ruled out, and there have been previous reports of this phenomenon (*6*–*7*).

This field simulation study has some limitations. It was a qualitative study that only aimed to confirm the existence of an aerosol transmission pathway and did not investigate the risk of infection.

As more COVID-19 patients are quarantined at home, the following points are recommended for multistory and high-rise buildings: 1) In the bathroom, the floor drain reserved for the washing machine should be sealed with waterproof sealant. To ensure a water seal, a plastic bag filled with water needs to cover it, and another one should cover the floor drain of the shower area when not in use. 2) The soil stack vent should not be blocked; this will ensure pressure balance between the pipe and the atmosphere during toilet flushing, reduce pressure fluctuations in the pipe, and prevent damage to the floor drain water seal. If it is necessary to purify the exhaust gas, an electrostatic disinfection device can be installed at the exhaust port. 3) Ensure that the fresh air ventilation system of rooms without external windows is not blocked or closed, and do not block the bathroom exhaust duct or close the exhaust fan. 4) Strengthen health education for isolated individuals. They should open the windows regularly every day for proper ventilation and leave the bathroom exhaust fan on throughout their stay in quarantine. The toilet lid should be closed before flushing, and the water-filled plastic bag on the shower floor drain should be removed only when taking a shower. Management personnel should open the corridor windows regularly every day for ventilation.

Conflicts of interest: No conflicts of interest.

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SUPPLEMENTARY TABLE S1. The scenarios and time periods in the simulation experiment.

Scenario	Period	Time (min)
1	1	0–60
1	2	70–130
2	1	140–200
2	1	210–270

Note: Two scenarios, breathing (scenario 1) and breathing with defecation with toilet flushing (scenario 2), were simulated in the bathroom of room 402. Both scenarios included two periods, only turn off the exhaust fans in rooms 1002 and 1902 during period 1, and turn on all exhaust fans during period 2.

SUPPLEMENTARY TABLE S2. The arrangements of breathing simulation and defecation simulation with toilet flushing in two scenarios.

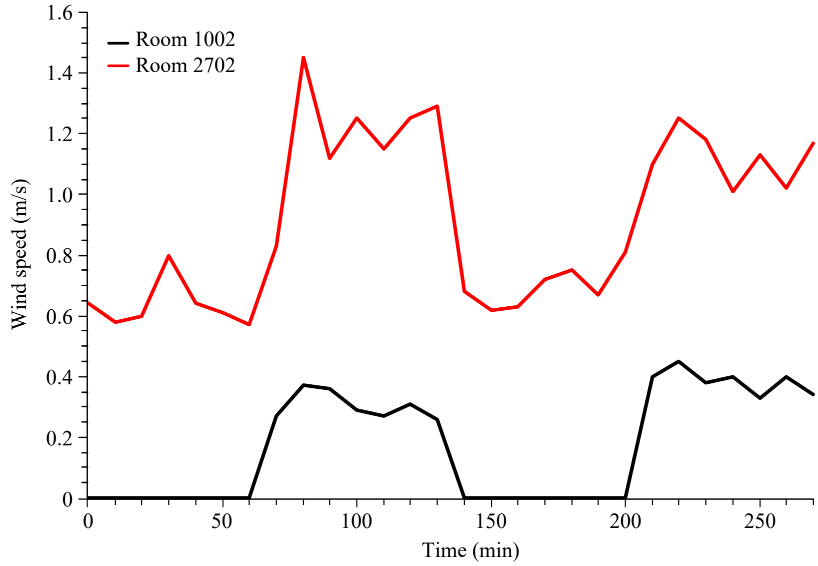
Time (min)	Room number				
	402	502	1002	1902	2702
0–60	B				
70–130	B				
140	B + D, F	F	F	F	F
150	B + D, F	F	F		F
160	B + D, F	F		F	F
170	B + D, F	F			F
180	B + D, F		F	F	
190	B + D, F		F		
200					
210	B + D, F	F	F	F	F
220	B + D, F	F	F		F
230	B + D, F	F		F	F
240	B + D, F	F			F
250	B + D, F		F	F	
260	B + D, F		F		
270					

Note: B means simulating breathing; D means simulating defecation; F means flushing the toilet.

SUPPLEMENTARY TABLE S3. The states of exhaust fans of different rooms in different time periods in two scenarios.

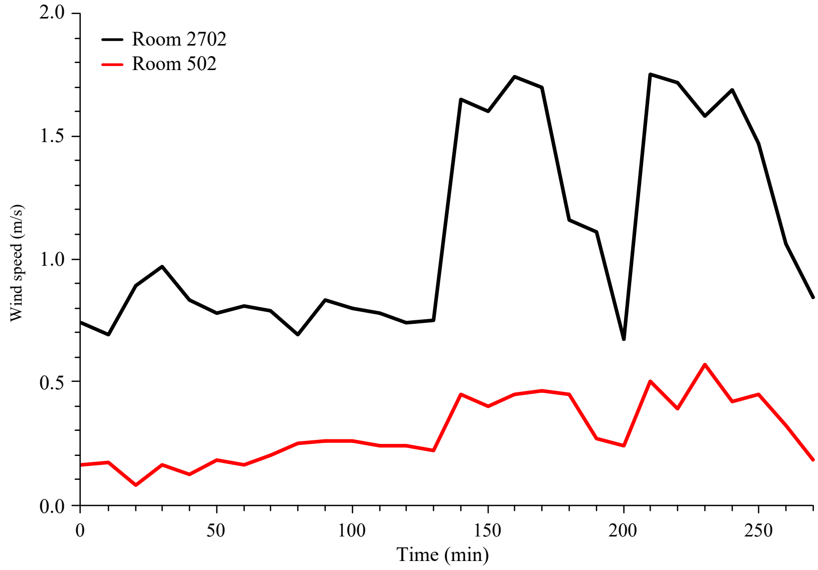
Room number	Scenario 1		Scenario 2	
	Period 1	Period 2	Period 1	Period 2
402	On	On	On	On
502	On	On	On	On
1002	Off	On	Off	On
1902	On	On	On	On
2702	Off	On	Off	On

Note: Two scenarios, breathing (scenario 1) and breathing with defecation with toilet flushing (scenario 2), were simulated in the bathroom of room 402. Both scenarios included two periods, only turn off the exhaust fans in rooms 1002 and 1902 during period 1, and turn on all exhaust fans during period 2. On/Off indicates turn on/off the exhaust fan during this period.



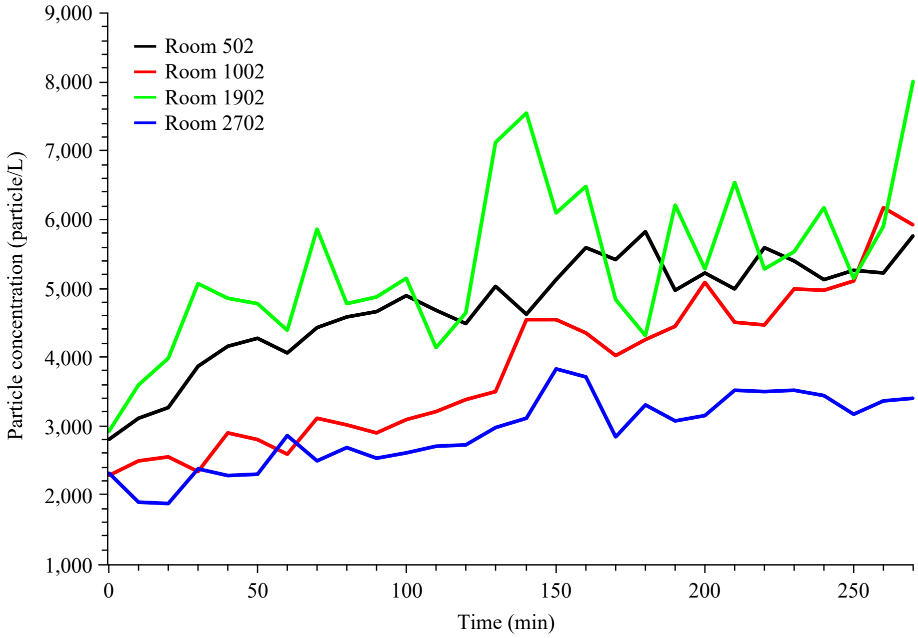
SUPPLEMENTARY FIGURE S1. Representative variations of the wind speed in the bathroom exhaust fans of rooms 1002 and 2702 during 2 scenarios.

Note: Two scenarios, breathing (scenario 1, 0-130 min) and breathing with defecation with toilet flushing (scenario 2, 140-270 min). In all the experimental rooms, the exhaust fans of bathrooms 1002 and 2702 were turned off only during 0–60 min and 140–200 min, and the exhaust fans were turned on in all bathrooms during the rest of the time.

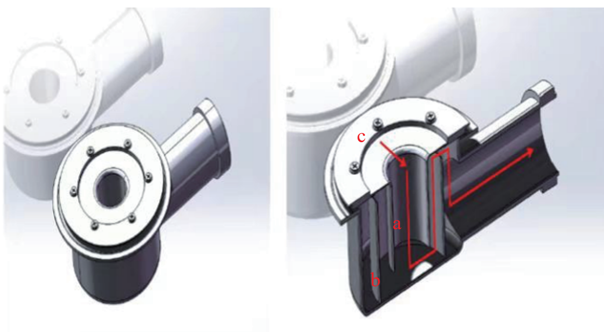


SUPPLEMENTARY FIGURE S2. Representative variations of the wind speed in the bathroom floor drain of rooms 502 and 2702 during 2 scenarios.

Note: Two scenarios, breathing (scenario 1, 0–130 min) and breathing with defecation with toilet flushing (scenario 2, 140–270 min), Only the toilet flushing in scenario 2 was simulated by changing the flushing bathroom arrangement every ten minutes, and the number of flushing bathrooms decreased over time.



SUPPLEMENTARY FIGURE S3. The changes of particle concentration over time at 1 μm in 2 scenarios in different rooms.
Note: Two scenarios, breathing (scenario 1, 0–130 min) and breathing with defecation with toilet flushing (scenario 2, 140–270 min), were simulated in bathroom 402. Changes in particle number concentrations were monitored in bathrooms 502, 1002, 1902, and 2702.



SUPPLEMENTARY FIGURE S4. Model diagram of a bathroom floor drain and schematic diagram of water flow direction of a centralized quarantine apartment in Beijing.
Note: a: The removable water trap in the floor drain; b: The cavity between the water trap, the outside pipe and the horizontal wastewater branch; c: The water flow direction.

SUPPLEMENTARY FIGURE S5. The figure of the floor drains and removable water trap in a centralized quarantine apartment in Beijing.

Preplanned Studies

Uptake of Heterologous or Homologous COVID-19 Booster Dose and Related Adverse Events Among Diabetic Patients: A Multicenter Cross-Sectional Study — China, 2022

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Summary

What is already known about this topic?

Although a third coronavirus disease 2019 (COVID-19) vaccination (booster) dose is highly recommended for diabetic patients, the vaccination behaviors and related adverse events are unclear among diabetic patients with a COVID-19 booster dose.

What is added by this report?

Diabetic patients with higher postprandial blood glucose, worrying about the safety of the booster dose were less likely to get the vaccine. While having positive attitudes towards COVID-19 booster vaccination, trusting the health professionals' advice on vaccination, diabetic patients were more likely to get the booster vaccine. Furthermore, the prevalence of adverse events was not significantly different between the homologous and heterologous boosting groups.

What are the implications for public health practice?

Effective measures should be taken to promote the COVID-19 booster dose uptake among diabetic patients. Health professionals should educate Chinese diabetic patients about the safety and efficacy of booster doses and continue to increase the COVID-19 booster dose vaccination coverage.

A third coronavirus disease 2019 (COVID-19) vaccination (booster) dose is highly recommended for both the healthy adult population and chronic patients, including diabetic patients. Previous studies have shown that diabetic patients are often hesitant to receive the vaccination due to the vaccination behaviors among diabetic patients to COVID-19 booster doses being unclear. This study aimed to explore the associated factors of COVID-19 booster dose and the prevalence of adverse events in homologous and heterologous boosting groups. A cross-sectional questionnaire survey was conducted among 457 diabetic inpatients in Shenzhen and Changzhi Cities from April to June 2022, of which 69.6% (318/457) respondents had received a COVID-19 booster dose. About 89.3% (284/318) and 10.7% (34/318) of the participants received homologous boosting and heterologous boosting, respectively. Diabetic patients with higher postprandial blood glucose [adjusted odds ratio (AOR): 0.54; 95% confidence interval (*CI*): 0.35–0.85], and those worried about the safety of the booster dose (AOR: 0.56; 95% *CI*: 0.34–0.92) were less likely to get the vaccine. Some factors were significantly and positively associated with COVID-19 booster dose vaccination, including positive attitudes towards COVID-19 booster dose vaccination (AOR: 2.46; 95% *CI*: 1.06–5.70), agreeing that diabetic patients can get COVID-19 booster dose (AOR: 2.19; 95% *CI*: 1.29–3.72), and agreeing that COVID-19 booster dose vaccination can effectively reduce the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) transmission risk (AOR: 1.97; 95% *CI*: 1.13–3.44). Moreover, diabetic patients who were influenced by clinical doctors (AOR: 1.77; 95% *CI*: 1.07–3.12) and family members (AOR: 1.61; 95% *CI*: 1.02–2.55) were more likely to get the booster vaccine. Furthermore, the prevalence of adverse events was not significantly different between people vaccinated with COVID-19 booster dose and those not vaccinated with booster [5.3% (17/318) *vs.* 9.4% (13/139), χ^2=2.53, *P*=0.11], and the prevalence of adverse events was not significantly different between the homologous and heterologous boosting groups [5.6% (16/284) *vs.* 2.9% (1/34), χ^2=0.44, *P*=0.51]. Health sectors should continue to encourage diabetic patients to receive the booster vaccination based on the study results and relevant guidelines to prevent their acquisition of SARS-CoV-2.

Diabetic patients are more vulnerable to serious illnesses, such as SARS-CoV-2 than people without diabetes (*1*), possibly due to systemic inflammatory responses and impaired immune system function. Vaccination can reduce morbidity and mortality caused by SARS-CoV-2. In addition, a third dose (booster) is highly recommended for patients with underlying medical conditions (*1*–*2*). Furthermore, China has promoted heterologous vaccines since February 2022 as a prime-boost immunization strategy. Interventions aimed at enhancing COVID-19 booster dose vaccination may reduce SARS-CoV-2 spread among diabetic patients since they are at high risk of severe disease course and mortality. However, previous studies showed that many diabetic patients in Italy (18.3%) and China (56.4%) are hesitant to receive COVID-19 primary vaccination (*3*–*4*). It has been noted that vaccination behaviors among diabetic patients to COVID-19 booster doses are unknown. This research aimed to explore COVID-19 booster dose vaccination behavior and its associated factors among diabetic patients, and the prevalence of adverse events between homologous and heterologous boosting groups. This study may facilitate the development of intervention measures for targeted booster vaccination among diabetic patients.

In this study, a cross-sectional survey was conducted among 502 diabetic inpatients from two hospitals in Shenzhen City, Guangdong Province (Shenzhen Hospital, Peking University, Shenzhen) and Changzhi City, Shanxi Province (Changzhi Heping Hospital). All hospitalized diabetes patients during the study period were continuously invited to attend this study. The participants anonymously filled out an online questionnaire survey between April and June 2022 after informed consent of the study objectives was collected. The questionnaire consisted of three components: 1) demographic and health-related information; 2) perception of booster dose vaccine; and 3) COVID-19 booster dose vaccination history (yes or no), which was a dependent variable. Heterologous boosting was defined as the injection of two doses of inactivated vaccine combined with one dose of adenovirus vaccine or one dose of recombinant protein vaccine. Homologous boosting was defined as the injection of three consecutive doses of inactivated vaccines. An adverse event was defined as an event occurred within 30 days after the last dose of COVID-19 vaccination.

The univariate and multivariable logistic regression model was used to evaluate the association between related variables and COVID-19 booster dose vaccination behaviors. All variables significant at the $P<0.05$ level in the univariate model were included in the multivariable logistic regression analysis. The entering procedure was used in the multivariable logistic regression model. The differences in the prevalence of adverse events between the two groups were assessed using Pearson's chi-squared test. $P<0.05$ was considered statistically significant. SPSS (version 25.0 software for Windows, SPSS, Inc., Chicago, IL, USA) was used for statistical analysis.

A total of 457 of 505 diabetes inpatients completed the survey (response rate; 90.5%), of which 267 were males (58.4%). About 30.2% of the participants had over 10 years of diabetes history, and 318 (69.6%) respondents had received the COVID-19 booster dose, of which 89.3% (284/318) and 10.7% (34/318) had received homologous boosting and heterologous boosting, respectively. Furthermore, two respondents received an adenovirus vaccine, and 32 received a recombinant protein vaccine. Only one health-related factor (baseline postprandial blood glucose) was significantly associated with COVID-19 booster dose vaccination uptake. The associations of demographic and health-related factors with COVID-19 booster dose vaccination behavior are shown in Supplementary Table S1, available in http://weekly.chinacdc.cn/.

About 92.8% of the respondents had a positive attitude toward the COVID-19 booster dose. However, only 63.2% of the respondents thought diabetic patients could get the booster dose. 57.3% of the respondents were worried about the side effects of a booster dose. About 80.1% of the participants agreed with the guidance and advice on the COVID-19 booster dose from the clinical doctors. The details of COVID-19 booster dose vaccine perception are shown in Table 1.

The results of the multivariable logistic regression analysis of factors associated with COVID-19 booster dose vaccination behaviors are shown in Table 2. Diabetic patients with higher baseline postprandial blood glucose (AOR: 0.54; 95% *CI*: 0.35–0.85) and those worried about the safety of booster dose vaccine (AOR: 0.56; 95% *CI*: 0.34–0.92) were less likely (negatively associated with booster vaccination) to get the booster vaccine. However, five factors were significantly and positively associated with COVID-19 booster vaccination: positive attitudes towards COVID-19 booster dose vaccination (AOR: 2.46; 95% *CI*: 1.06–5.70), agreeing that diabetic patients can get COVID-19 booster dose vaccine (AOR: 2.19;

TABLE 1. Univariate logistic regression analysis of COVID-19 booster dose vaccine perception with vaccination behavior among Chinese diabetic patients (*n*=457).

Factor	Total, *n* (%)	COVID-19 booster dose vaccination, *n* (%)		COR (95% *CI*)
		Yes (*n*=318)	No (*n*=139)	
Attitudes				
Q1. I support the vaccination of the COVID-19 booster dose.				
No (Strongly disagree or disagree or neutral)	33 (7.2)	13 (4.1)	20(14.4)	1
Yes (Agree or very agree)	424 (92.8)	305 (95.9)	119(85.6)	3.94 (1.90–8.18)*
Q2. Diabetic patients can get a COVID-19 booster dose vaccine.				
No (Strongly disagree or disagree or neutral)	168 (36.8)	93 (29.2)	75 (54.0)	1
Yes (Agree or strongly agree)	289 (63.2)	225 (70.8)	64 (46.0)	2.84 (1.88–4.28)*
Perceived efficacy				
Q3. COVID-19 booster dose vaccine can effectively prevent COVID-19.				
No (Strongly disagree or disagree or neutral)	193 (42.2)	119 (37.4)	74 (53.2)	1
Yes (Agree or strongly agree)	264 (57.8)	199 (62.6)	65 (46.8)	1.90 (1.27–2.85)*
Q4. COVID-19 booster dose vaccination can reduce the risk of COVID-19 transmission to other people.				
No (Strongly disagree or disagree or neutral)	92 (20.1)	43 (13.5)	49 (35.3)	1
Yes (Agree or very agree)	365 (79.9)	275 (86.5)	90 (64.7)	3.48 (2.17–5.59)*
Perceived safety				
Q5. COVID-19 booster dose vaccination has side effects.				
Yes (Neutral or agree or strongly agree)	262 (57.3)	166 (52.2)	96 (69.1)	1
No (Strongly disagree or disagree)	195 (42.7)	152 (47.8)	43 (30.9)	2.04 (1.34–3.12)*
Q6. I worry about the safety of the COVID-19 booster dose vaccine				
No (Strongly disagree or disagree or neutral)	334 (73.1)	250 (78.6)	84 (60.4)	1
Yes (Agree or strongly agree)	123 (26.9)	68 (21.4)	55 (39.6)	0.42 (0.27–0.64)*
Social impact				
Q7. I believe in the advice on COVID-19 booster dose vaccination from the doctors.				
No (Strongly disagree or disagree or neutral)	91 (19.9)	43 (13.5)	48 (34.5)	1
Yes (Agree or strongly agree)	366 (80.1)	275 (86.5)	91 (65.5)	3.37 (2.10–5.42)*
Q8. I believe in the advice on COVID-19 booster dose vaccination from the media.				
No (Strongly disagree or disagree or neutral)	179 (39.2)	118 (37.1)	61 (43.9)	1
Yes (Agree or strongly agree)	278 (60.8)	200 (62.9)	78 (56.1)	1.33 (0.88–1.99)
Q9. Family members' COVID-19 booster dose vaccination behavior will affect mine.				
No (Strongly disagree or disagree or neutral)	190 (41.6)	119 (37.4)	71 (51.1)	1
Yes (Agree or strongly agree)	267 (58.4)	199 (62.6)	68 (48.9)	1.75 (1.17–2.61)*

Abbreviation: COVID-19=coronavirus disease 2019; COR=crude odds ratio; *CI*=confidence interval.
* P<0.01.

95% *CI*: 1.29–3.72), and agreeing that COVID-19 booster dose vaccination can reduce SARS-CoV-2 transmission risk (AOR: 1.97; 95% *CI*: 1.13–3.44). Moreover, diabetic patients who could be influenced by doctors (AOR: 1.77; 95% *CI*: 1.07–3.12) and family members (AOR: 1.61; 95% *CI*: 1.02–2.55) were more likely to get the booster vaccine.

Adverse events, such as headache, fatigue, fever, and chills occurred in 17 (5.3%) of 318 respondents received booster dose. Furthermore, the prevalence of adverse events was not significantly different between people vaccinated with COVID-19 booster dose and those not vaccinated with booster 9.4% (13/139) (χ^2=2.53, P=0.11), and the prevalence of adverse

TABLE 2. Multivariable logistic regression analysis of factors associated with COVID-19 booster dose vaccination behavior among Chinese diabetic patients (*n*=457).

Factors	AOR (95% *CI*)
Attitudes	
Q1. I support the vaccination of the COVID-19 booster dose.	
No (Strongly disagree or disagree or neutral)	1
Yes (Agree or very agree)	2.46 (1.06–5.70)*
Q2. Diabetic patients can get a COVID-19 booster dose vaccine.	
No (Strongly disagree or disagree or neutral)	1
Yes (Agree or strongly agree)	2.19 (1.29–3.72)†
Perceived efficacy	
Q3. COVID-19 booster dose vaccine can effectively prevent COVID-19.	
No (Strongly disagree or disagree or neutral)	1
Yes (Agree or strongly agree)	0.87 (0.52–1.45)
Q4. COVID-19 booster dose vaccination can reduce the risk of COVID-19 transmission to other people effectively.	
No (Strongly disagree or disagree or neutral)	1
Yes (Agree or very agree)	1.97 (1.13–3.44)*
Perceived safety	
Q5. COVID-19 booster dose vaccination has side effects.	
Yes (Neutral or agree or strongly agree)	1
No (Strongly disagree or disagree)	1.42 (0.88–2.30)
Q6. I worry about the safety of the COVID-19 booster dose vaccine	
No (Strongly disagree or disagree or neutral)	1
Yes (Agree or strongly agree)	0.56 (0.34–0.92)*
Social impact	
Q7. I believe in the advice on COVID-19 booster dose vaccination from the doctors.	
No (Strongly disagree or disagree or neutral)	1
Yes (Agree or strongly agree)	1.77 (1.07–3.12)*
Q9. Family members' COVID-19 booster dose vaccination behavior will affect mine.	
No (Strongly disagree or disagree or neutral)	1
Yes (Agree or strongly agree)	1.61 (1.02–2.55)*
Health information	
Postprandial blood glucose	
<10.0 mmol/L	1
≥10.0 mmol/L	0.54 (0.35–0.85)†

Abbreviation: COVID-19=coronavirus disease 2019; AOR=adjusted odds ratio; *CI*=confidence interval.
* $P<0.05$.
† $P<0.01$.

events was not significantly different between the homologous and heterologous boosting groups [5.6% (16/284) *vs.* 2.9% (1/34), χ^2=0.44, P=0.51].

DISCUSSION

In this study, nearly a third of diabetic patients did not receive the booster dose vaccine. Although a booster dose is highly recommended for diabetic patients, many diabetic patients are still hesitant to receive a booster dose (*3–4*). The COVID-19 fatality risk is higher in diabetic patients than in healthy people by about 50% (*5*). Therefore, evidence-based vaccination strategies should be developed to enhance voluntary booster dose uptake among diabetic patients. Herein, results showed that the perceived safety of booster dose significantly influences vaccination behaviors. Previous studies conducted in the general adult population also showed that the awareness of vaccine safety is positively related to vaccination willingness (*6–7*). In addition, Kreps et al. found that a decrease in the incidence of major adverse effects is associated with a higher probability of choosing a vaccine (*8*). A study also showed that vaccine safety is the top concern for COVID-19 vaccination intentions among children with diabetes (*9*).

In this study, the perceived efficacy of the booster dose vaccine was positively related to vaccination behavior. Kreps et al. found that the more significant the efficacy of the vaccine, the longer the protection time and the greater the vaccination probability (*8*). Diabetic patients are susceptible to SARS-CoV-2, which may be more inclined to consider the effectiveness of the COVID-19 vaccine before vaccination. Therefore, the relevant departments should publicize the safety and effectiveness of the COVID-19 booster dose through data and authoritative statements to improve people's perceptions of the booster dose.

Furthermore, results also found that some social factors, such as vaccination suggestions by doctors and family members, were correlated with COVID-19 vaccination uptake, consistent with Duan L's research (*3*). Social factors have been highlighted in many health behavior theories, such as the Theory of Planned Behavior (TPB) since they change people's health behaviors. Nevertheless, Ai et al. showed that the heterologous booster dose produces higher SARS-CoV-2 neutralizing antibodies and similar adverse events than the homologous booster dose vaccination in healthy adults (*10*). In this study, heterologous booster dose and homologous booster dose produced similar adverse events in diabetic patients. Considering the safety and immunogenicity of inactivated COVID-19 vaccines (*11*), and their high effectiveness, especially when boosted (*12*). Moreover, there are some diabetes patients still cautious about receiving or not the heterologous booster doses, this firsthand real-world evidence may help provide more information to promote heterologous and homologous COVID-19 booster vaccination in China to prevent SARS-CoV-2 in diabetes patients.

These findings suggest that the perceived safety and efficacy of the COVID-19 booster dose vaccine can increase the vaccination rate among diabetic patients. Suggestions by health professionals and behaviors of family relatives can also promote booster dose uptake. Therefore, relevant institutions should promote immunization publicity by disseminating information about the safety and efficacy of booster vaccines through health science education by health professionals. Vaccinated diabetic patients can also be invited to conduct peer publicity, eliminating concerns among other patients, and improving their awareness to enhance their willingness to immunize. Furthermore, the results could be generalized to guide booster vaccination promotion in other major chronic comorbidities with COVID-19-like hypertension.

However, this study has some limitations. The enrolled participants were from two cities in China, and thus may limit the generalizability of the findings. In addition, this is a cross-sectional study and prevents the establishment of a causal relationship between vaccination behavior and the associated factors examined. Third, blood specimens were not collected to test COVID-19 immunological reaction items. Lastly, there is a recommendation guideline or consensus for the diabetic patients to get COVID-19 vaccinated, we should follow the instructions when making a recommendation to the patients with diabetes, not just from the result of this study.

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SUPPLEMENTARY TABLE S1. Univariate logistic regression analysis of demographic and health-related factors associated with COVID-19 booster dose vaccination behaviors among Chinese diabetic patients (*n*=457).

Factor	Total, *n* (%)	COVID-19 booster dose vaccination, *n* (%)		COR (95% *CI*)
		Yes (*n*=318)	No (*n*=139)	
Demographics				
Age (years)				
18–39	67 (14.7)	40 (12.6)	27 (19.4)	1
40–49	75 (16.4)	53 (16.7)	22 (15.9)	1.63 (0.81–3.26)
50–59	140 (30.6)	102 (32.0)	38 (27.5)	1.81 (0.98–3.35)
≥60	175 (38.3)	123 (38.7)	52 (37.4)	1.60 (0.89–2.87)
Gender				
Male	267 (58.4)	192 (60.4)	75 (54.0)	1
Female	190 (41.6)	126 (39.6)	64 (46.0)	0.77 (0.51–1.15)
Education level				
Below high school	217 (47.5)	143 (45.0)	74 (53.2)	1
High school	84 (18.4)	60 (18.9)	24 (17.3)	1.29 (0.75–2.24)
College	37 (8.1)	26 (8.2)	11 (7.9)	1.22 (0.57–2.61)
College above	119 (26.0)	89 (28.0)	30 (21.6)	1.54 (0.93–2.53)
Marital status				
Unmarried, divorced, or widowed	60(13.1)	40 (12.6)	20 (14.4)	1
Married	397(86.9)	278 (87.4)	119 (85.6)	1.17 (0.66–2.08)
Residence				
Urban	323(70.7)	224 (70.4)	99 (71.2)	1
Rural	134(29.3)	94 (29.6)	40 (28.8)	1.04 (0.67–1.61)
Monthly income (CNY)				
<2,000	144(31.5)	94 (29.6)	50 (36.0)	1
2,000–4,999	170(37.2)	120 (37.7)	50 (35.9)	1.28 (0.79–2.06)
≥5,000	143(31.3)	104 (32.7)	39 (28.1)	1.42 (0.86–2.35)
Health information				
BMI (kg/m^2)				
<18.5	11 (2.4)	6 (1.9)	5 (3.6)	1
18.5–23.9	209 (45.7)	154 (48.4)	55 (39.6)	2.33 (0.69–7.95)
24.0–27.9	164 (35.9)	112 (35.2)	52 (37.4)	1.80 (0.52–6.15)
≥28	73 (16.0)	46 (14.5)	27 (19.4)	1.42 (0.40–5.10)
Years of diabetes history				
≤10	319 (69.8)	224 (70.4)	95 (68.3)	1
>10	138 (30.2)	94 (29.6)	44 (31.7)	0.91 (0.59–1.39)
Fasting blood glucose (mmol/L)				
<7.0	234 (51.2)	172 (54.1)	62 (44.6)	1
7.0–13.9	203 (44.4)	134 (42.1)	69 (49.6)	0.70 (0.46–1.06)
≥13.9	20 (4.4)	12 (3.8)	8 (5.8)	0.54 (0.21–1.39)
Postprandial blood glucose (mmol/L)				
<10.0	223 (48.8)	165 (51.9)	58 (41.7)	1
≥10.0	234 (51.2)	153 (48.1)	81 (58.3)	0.66 (0.44–0.99)*

Abbreviation: BMI=body mass index, COR=crude odds ratio, CNY=China Yuan.
* *P*<0.05.

Preplanned Studies

Sleep Status Among Children and Adolescents Aged 6–17 Years — China, 2016–2017

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Summary

What is already known about this topic?

There has been little to no description of sleep status among children and adolescents nationwide in recent years.

What is added by this report?

This report assesses the sleep duration and sleep patterns of children and adolescents in China. Approximately half of the adolescents did not get the recommended amount of sleep on school days, and more than half overslept on weekends.

What are the implications for public health practice?

The importance of children and adolescents meeting recommended sleep durations needs greater emphasis, especially among older age groups and those in urban areas.

One of the most important age ranges for children to develop good sleeping habits, behaviors, and lifestyles is 6–17 years of age. During these years, sleep has significantly impacted many aspects of learning, daily life, and health status (*1*). Studies from 2010–2012 showed that the proportion of children and adolescents in China who do not get the recommended sufficient sleep was 69.8% (*2*). With only a few subsequent studies reporting on the sleep status of children and adolescents nationwide, knowledge of this field has been limited in recent years (*2*–*5*). This study used data from the China Nutrition and Health Surveillance of Children and Lactating Mothers in 2016–2017 to assess the average sleep duration, sleep patterns, and distribution of total sleep duration per 24 hours and naptime among children and adolescents aged 6–17 years in China. It is the latest data inferred from the surveillance program. The results show that approximately half of adolescents aged 13–17 years do not get the recommended amount of sleep on school days, and more than half oversleep on weekends. Targeted interventions are needed to make parents and children, especially older age groups and those in urban areas, aware of the importance of getting sufficient sleep and developing good sleeping habits.

The data in this study came from the China Nutrition and Health Surveillance of Children and Lactating Mothers in 2016–2017, which uses a multi-stage stratified cluster randomized sampling method. The method classifies all county-level administrative units in the mainland of China into four categories: big cities, medium and small cities, ordinary rural areas, and rural areas with lower economic development. These four areas were classified according to their economic and social development (*6*). First, a total of 275 county-level units were selected as surveillance points from the four categories. Second, two townships/subdistricts were selected from each surveillance point, with one primary school and one junior high school selected from each township/subdistrict. In addition, one high school was selected from each surveillance point, and one class was selected from each grade, with 28 students from each class being surveyed. The sample size was calculated using the 2013 overweight rate of 4.5% for children and adolescents aged 7–17 years as the calculation marker for determining sample size and taking into account a non-response rate of 10%. After data cleaning, a total of 74,246 valid samples of children aged 6–17 years were obtained. A total of 67,657 participants were included in this analysis, while 6,589 participants were excluded as a result of missing basic information variables or extreme values. The study was approved by the Ethical Committee of the Chinese Center for Disease Control and Prevention. All participants provided written informed consent signed by their parents.

The China Nutrition and Health Surveillance of Children and Lactating Mothers included questionnaires, medical examinations, dietary surveys, and laboratory tests. A self-designed questionnaire, with consultation and validation from experts, was used to collect basic information from respondents during face-to-face interviews with trained and qualified interviewers. The questionnaire collected information including demographic characteristics (i.e., gender, age, region, etc.) and sleep behaviors. Regions were divided based on physical geography and expert research, including North China (Beijing Municipality, Tianjin Municipality, Hebei Province, Shanxi Province, Inner Mongolia Autonomous Region), Northeast China (Heilongjiang Province, Jilin Province, Liaoning Province), East China (Shanghai Municipality, Jiangsu Province, Zhejiang Province, Shandong Province, Anhui Province, Jiangxi Province, Fujian Province, Taiwan, China), Central China (Hubei Province, Hunan Province, Henan Province), South China (Guangdong Province, Guangxi Zhuang Autonomous Region, Hainan Province, Hong Kong Special Administrative Region, Macao Special Administrative Region), Southwest China [Sichuan Province, Chongqing Municipality, Guizhou Province, Yunnan Province, Xizang (Tibet) Autonomous Region], and Northwest China (Shaanxi Province, Gansu Province, Xinjiang Uygur Autonomous Region, Qinghai Province, Ningxia Hui Autonomous Region). Left-behind children are defined as those with at least one parent currently working and living away from home for six or more months by the time of the survey, resulting in the child living alone without parental supervision. The wake-up time and bedtime were obtained by asking parents, "what time does your child usually get up in the morning and go to bed at night?" Naptime durations were obtained by asking parents, "how long does your child usually sleep during the day?" Sleep duration was calculated from the wake-up time and bedtime, while total sleep duration per 24 hours was calculated by the addition of sleep duration and naptime. According to a consensus statement by the American Academy of Sleep Medicine (*7*), the recommended amount of sleep is 9–12 hours for children aged 6–12 years and 8–10 hours for adolescents aged 13–18 years per 24 hours regularly. Insufficient sleep was defined as <9 hours for children and <8 hours for adolescents.

All statistical analyses were performed using the software SAS (version 9.4, SAS Institute Inc., Cary, USA), and $P<0.05$ was statistically significant. The data were adjusted for complex sample weights to ensure that the findings were nationally representative of children and adolescents; each observation was weighted by two components, namely sample weights, and ex-post weights, which were based on urban-rural, age- and sex-specific population data from the Sixth Population Census 2010 published by the National Bureau of Statistics. Means were calculated using the survey means process. *t*-tests and ANOVA were conducted to test for group differences in means, and Rao-Scott chi-squared tests were conducted for prevalence.

A total of 67,657 Chinese children and adolescents aged 6–17 years were included in the data analysis, including 33,652 males and 34,005 females. Table 1 describes the baseline characteristics of the participants and the total sleep duration per 24 hours for children and adolescents with different characteristics. Their average total sleep duration per 24 hours was 9.10 [standard deviation (SD): 1.30] hours on school days and 10.31 (SD: 1.42) hours on weekends. The total sleep duration per 24 hours decreased with age and was shortest in the Northeast and longest in the Southwest. Boys slept longer than girls on school days (9.15 hours versus 9.04 hours, $P<0.0001$), but the opposite occurred on weekends (10.23 hours versus 10.40 hours, $P<0.0001$). Children and adolescents in rural areas slept longer than those in urban areas, especially on school days (9.29 hours versus 8.87 hours, $P<0.0001$). The sleep duration composition of children and adolescents aged 6–12 years and 13–17 years is shown in Figure 1. The proportion of children aged 6–12 years meeting the recommended amount of sleep was 84.8% on school days and 80.7% on weekends. Among adolescents aged 13–17 years, the proportions were 54.7% and 37.0% on school days and weekends, respectively.

Overall, children and adolescents aged 6–17 years had an average wake-up time of 6:22 and 7:57, an average bedtime of 21:43 and 22:08, and an average nighttime sleep duration of 8.64 and 9.81 hours on school days and weekends, respectively. With increasing age, the wake-up time on school days is earlier from 6:06 to 6:40, bedtime is later from 20:56 to 22:56, and sleep duration at night is shorter from 9.73 to 7.16 hours. On weekends, the wake-up time is around 8:00, and bedtime is generally about half an hour later than on school days. Urban children slept later and less than rural children (Table 2). Figure 2 shows the distribution of naptime among Chinese children aged 6–17 years, classifying naptime into three categories: ≥1 hour, <1 hour, and no nap. The proportion of children taking naps increased with age, especially on school days.

TABLE 1. Total sleep duration per 24-hour for children and adolescents with different characteristics — China, 2016–2017.

Characteristics	Total (%)	School-days sleeptime, [hours (SD)]	*P* value	Weekends sleeptime, [hours (SD)]	*P* value
Total	67,657 (100)	9.10±1.30		10.31±1.42	
Age group (years)			<0.0001		<0.0001
6–	17,720 (26.19)	10.02±0.80		10.63±1.09	
9–	20,601 (30.45)	9.77±0.95		10.50±1.24	
12–	16,515 (24.41)	8.95±1.10		10.29±1.44	
15–17	12,821 (18.95)	7.89±0.98		9.90±1.67	
Sex			<0.0001		<0.0001
Male	33,652 (49.74)	9.15±1.27		10.23±1.42	
Female	34,005 (50.26)	9.04±1.33		10.40±1.43	
Area			<0.0001		<0.0001
Urban	31,896 (47.14)	8.87±1.26		10.25±1.46	
Rural	35,761 (52.86)	9.29±1.30		10.35±1.39	
Region*			<0.0001		<0.0001
North China	10,114 (14.95)	8.89±1.25		10.12±1.38	
Northeast China	5,367 (7.93)	8.77±1.29		10.04±1.50	
East China	17,203 (25.43)	9.07±1.27		10.28±1.42	
Central China	9,063 (13.40)	9.28±1.34		10.36±1.35	
South China	7,041 (10.41)	8.93±1.23		10.13±1.50	
Southwest China	10,883 (16.09)	9.36±1.30		10.51±1.40	
Northwest China	7,986 (11.80)	8.94±1.32		10.46±1.41	
Primary caregiver			<0.0001		<0.0001
Father/mother	53,744 (79.44)	9.02±1.30		10.29±1.44	
Grandparents	12,416 (18.35)	9.44±1.23		10.39±1.33	
Others	1,497 (2.21)	8.92±1.23		10.27±1.61	
Living in the school			<0.0001		<0.0001
Yes	18,532 (27.39)	8.61±1.35		10.08±1.59	
No	49,125 (72.61)	9.31±1.21		10.41±1.33	
Left-behind children			<0.0001		<0.0001
Yes	13,547 (20.02)	9.32±1.27		10.39±1.39	
No	54,110 (79.98)	9.03±1.30		10.28±1.43	

Abbreviation: SD=standard deviation.

* Regions were divided based on physical geography and expert research, including North China (Beijing Municipality, Tianjin Municipality, Hebei Province, Shanxi Province, Inner Mongolia Autonomous Region), Northeast China (Heilongjiang Province, Jilin Province, Liaoning Province), East China (Shanghai Municipality, Jiangsu Province, Zhejiang Province, Shandong Province, Anhui Province, Jiangxi Province, Fujian Province, Taiwan, China), Central China (Hubei Province, Hunan Province, Henan Province), South China (Guangdong Province, Guangxi Zhuang Autonomous Region, Hainan Province, Hong Kong Special Administrative Region, Macao Special Administrative Region), Southwest China [Sichuan Province, Chongqing Municipality, Guizhou Province, Yunnan Province, Xizang (Tibet) Autonomous Region], and Northwest China (Shaanxi Province, Gansu Province, Xinjiang Uygur Autonomous Region, Qinghai Province, Ningxia Hui Autonomous Region).

DISCUSSION

This study showed the total sleep duration per 24 hours and sleep patterns for children and adolescents aged 6–17 in China during 2016–2017. The proportion of insufficient sleep was 13.3% on school days and 4.6% on weekends for children aged 6–12 years, and 36.9% and 6.0% for adolescents aged 13–17 years. The proportion of insufficient sleep in the United States of America is 37.4% for children aged 6–12 years and 31.2% for adolescents aged 13–17 years (*8*). Comparatively, the situation of short sleep durations on school days is slightly more serious for Chinese adolescents aged 13–17 years. Older and

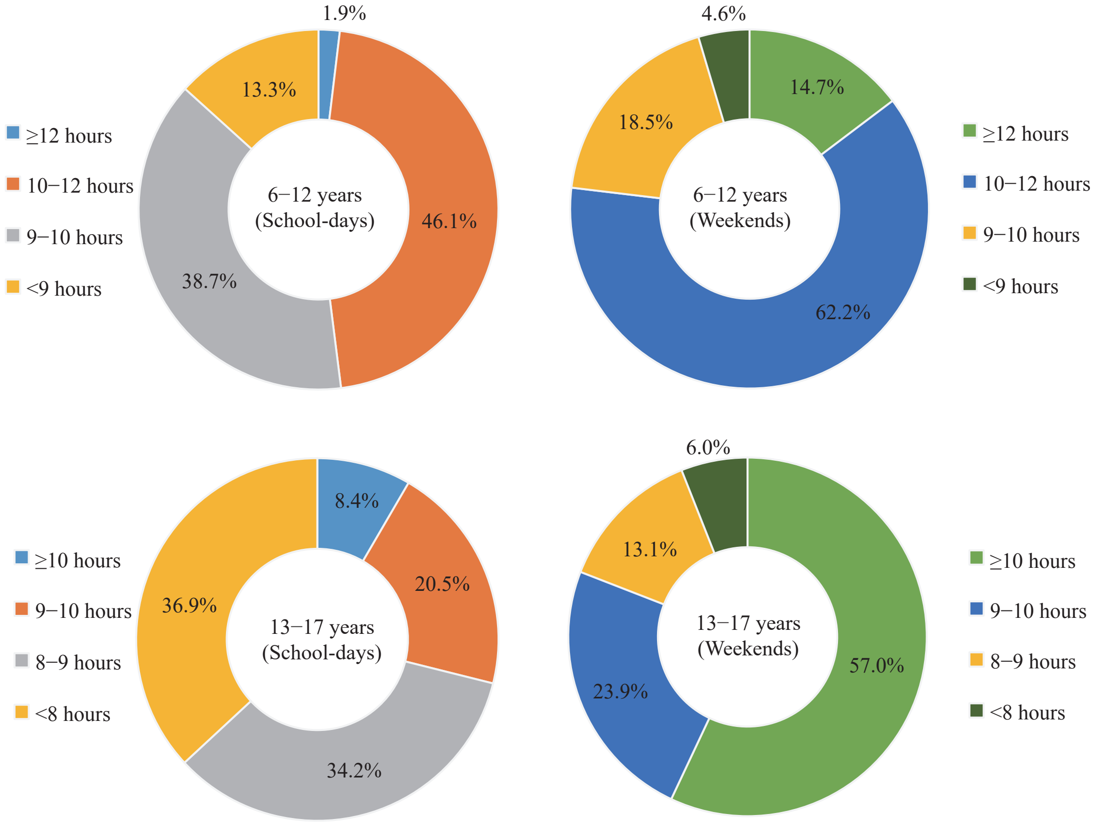

FIGURE 1. Sleep duration composition of children and adolescents aged 6–17 years — China, 2016–2017.

TABLE 2. Sleep patterns of children and adolescents aged 6–17 years — China, 2016–2017.

Sleep patterns	Total	Age group (years)				*P*-value	Area		*P* value
		6–	9–	12–	15–17		Urban	Rural	
School-days									
Wake-up time	6:22±0:32	6:40±0:26	6:31±0:28	6:14±0:31	6:06±0:29	<0.0001	6:23±0:32	6:21±0:32	<0.0001
Bedtime	21:43±1:09	20:56±0:41	21:03±0:46	21:43±0:54	22:56±0:48	<0.0001	22:00±1:06	21:29±1:09	<0.0001
Sleep duration at night (h)	8.64±1.34	9.73±0.69	9.46±0.81	8.52±1.00	7.16±0.84	<0.0001	8.39±1.27	8.86±1.36	<0.0001
Weekends									
Wake-up time	7:57±1:04	7:52±0:52	7:53±0:57	8:00±1:06	8:03±1:15	<0.0001	8:01±1:05	7:53±1:03	<0.0001
Bedtime	22:08±1:06	21:33±0:49	21:43±0:54	22:11±1:01	22:57±1:01	<0.0001	22:22±1:03	21:56±1:06	<0.0001
Sleep duration at night (h)	9.81±1.25	10.32±0.82	10.17±1.05	9.81±1.18	9.10±1.34	<0.0001	9.65±1.21	9.95±1.27	<0.0001

urban participants were particularly at risk of short sleep durations and tended to sleep late. As their age increased, Chinese adolescents aged 13–17 years got up earlier and took a higher proportion of napping on school days. This may be the result of senior students in cities having heavier academic loads, especially on school days, and needing longer naps to catch up on sleep. Children who are left behind have a longer sleep duration, likely because they are largely located in rural areas. Children whose primary caregivers are not parents or grandparents and children who live in school have even shorter sleep durations. Public health practitioners, educators, and clinicians should advise primary caregivers about the importance of meeting recommended sleep durations in children and adolescents and support parents in developing good sleep habits for their children.

An analysis conducted in eight Chinese provinces in 2010 showed that the average sleep duration for children aged 6–12 years was 9.11 hours and 9.80 hours on school days and weekends, respectively. The proportion of sleeping <9 hours and 9–10 hours was

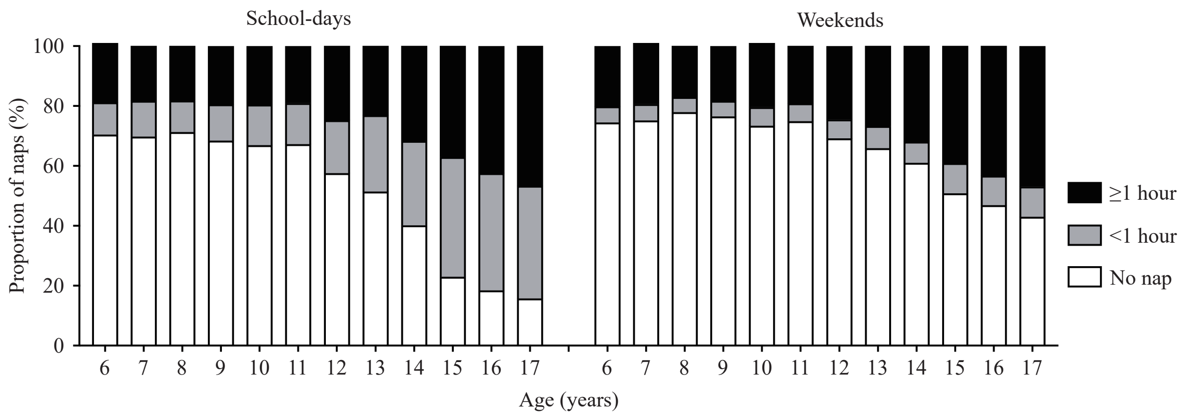

FIGURE 2. Distribution of naptime among children aged 6–17 years — China, 2016–2017.

32.8% and 39.7% on school days, and 13.6% and 27.3% on weekends (*3*). This study showed that this population has a longer average sleep duration, with 13.3% and 38.7% sleeping <9 hours and 9–10 hours on school days and 4.6% and 18.5% on weekends. Another study in 2010 showed that 68.7% of students aged 13–15 years and 91.1% of students aged 16–18 years slept <8 hours, which was comparable to 74.1% and 93.8% reported in a 2014 study (*4*–*5*). Although the two results showed an upward trend in the proportion of adolescents in China with short sleep duration, the proportion of adolescents aged 13–17 years in this study who slept <8 hours was 36.9% on school days and 6.0% on weekends. Previous estimates of the proportion were significantly higher, which may be explained by different methods used to obtain sleep duration data between studies. The data in this study was calculated from parent-reported wake-up times, bedtimes, and added nap times. The results of previous studies were derived from parents' or students' self-reported sleep durations, which may contribute to an underestimation of total sleep duration. Additionally, the ages of the study populations in the 10- and 14-year studies were not the same as the ages in this study.

Comparing these results shows that sleep status among children and adolescents in China improved in 2016–2017 compared to previous years. Short sleep duration was improved on weekends. Oversleeping was more serious than school days, with 57% of adolescents aged 13–17 years sleeping more than the recommended amount of sleep (i.e., 10 hours). It is important to note that weekend oversleeping does not alleviate the usual lack of sleep and may lead to several negative consequences. A nationally representative cross-sectional study in the United States of America showed that both later weeknight bedtimes and weekend oversleeping were associated with increased odds of mental disorders and even suicidality (*9*). A large sample study in the Republic of Korea also found that long weekend oversleeping among adolescents independently predicted higher suicidality (*10*). Therefore, this phenomenon should not be encouraged.

The findings in this study are subject to several limitations. First, responses might be affected by recall bias, interpretation of items, or social desirability. Second, the study results were derived from a cross-sectional survey, which is not specific to the sleep of children. Therefore, the results were not adequate and comprehensive. Most current studies in the field of child sleep in China are based on cross-sectional surveys, with few longitudinal studies designed. The lack of uniform questionnaires or scales between different studies as well as the often incomplete agreement in defining relevant concepts, leads to a lack of comparability between studies. Methods for sleep duration surveillance among children need to be improved, and it is hoped that more detailed and reliable survey data will be available in the future to analyze child sleep status.

Insufficient sleep is a serious risk factor for poor physical and mental health in children and adolescents (*1*). Primary caregivers can help children get an ideal amount of sleep by supporting good sleep habits. If possible, children should choose a parent or grandparent as their primary caregiver and try not to stay in school accommodations. Clinicians and educators can guide parents about the importance of sleep at all ages as well as discuss sleep routines and sleep problems with parents, children, and adolescents. Teachers should teach students about sleep health and support them in developing good sleep habits as part of their educational work. Students themselves should also be conscious of the need to develop a regular routine. Public health practitioners should call on society, schools, and families to cultivate good home and living environments, reduce student academic loads, and encourage active exercise habits. Doing so will help improve the sleep status of children and adolescents.

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Vital Surveillances

Epidemic Characteristics, High-Risk Areas and Space-Time Clusters of Human Brucellosis — China, 2020–2021

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ABSTRACT

Introduction: Analyze the recent epidemiological and temporal-spatial characteristics of human brucellosis in China and provide information for adjusting strategies for brucellosis control.

Methods: Human brucellosis data were obtained from the National Notifiable Disease Reporting System (NNDRS). A geographical information system (GIS) was used to visualize high-risk areas with annual incidence based on county (district) polygons. The space-time scan statistic (STSS) was applied to detect the space-time clusters of human brucellosis.

Results: A total of 69,767 cases were reported from 2,083 counties in the mainland of China in 2021, a 47.7% increase from 2020 (47,425). About 95.5% of the total cases were centralized in northern China and 31.8% in Inner Mongolia (IM). The number of counties with an incidence exceeding 100 per 100,000 was 34 in 2020 and 65 in 2021. From 2020 to 2021, 24 space-time clusters were detected. The two primary clusters were located northeast of IM, including 109 counties. The secondary clusters affected 208 counties in 2020 and spread to 297 counties in 2021, the majority of which were located in the middle of IM, exhibiting a trend spreading west from IM to neighboring provincial-level administrative divisions (PLADs).

Conclusions: From 2020 to 2021, the incidence of human brucellosis nationwide was exponential, demonstrating distinct spatiotemporal characteristics. Space-time clusters were located in IM and neighboring areas. Therefore, considerable efforts are required to curb this momentum.

Human brucellosis is one of the most important zoonotic diseases caused by bacteria of genus *Brucella* (*1*). Human brucellosis is primarily acquired through contact with infected animals or their products and the consumption of contaminated animal food. Human brucellosis reemerged in the mainland of China during the mid-1990s, reaching a historically high record of 57,222 cases reported in 2014, slowly decreasing to 37,947 in 2016, and rebounding to 44,036 in 2019 (*2–3*). It is important to explore the recent epidemic pattern and hotspot areas using temporal-spatial analysis to precisely provide policy recommendations for brucellosis control on the county (district) level. At present, the spatiotemporal analysis of brucellosis in China is mainly based on provincial or prefecture polygons (*2–3*), or only focused on certain northern China (*3–5*), especially Inner Mongolia (IM). There is a gap in the literature examining spatial-temporal patterns of county polygons in human brucellosis. Therefore, this study aimed to explore the epidemiological characteristics, spatial-temporal distribution patterns, and detect high-risk areas for human brucellosis from 2020 to 2021 nationwide at the county level in China.

METHODS

The human brucellosis data were extracted from the Chinese National Notifiable Disease Reporting System (NNDRS). Descriptive epidemiology was used to analyze the epidemiological characteristics. The research described the annual incidence (AI) and seasonality by stratifying the country into southern and northern regions using the same definition as in previous studies (*5*). SAS (version 9.4, SAS Institute Inc., Cary, USA) and Excel 2010 (Microsoft Corp., Redmond, WA., USA) were used to analyze and draw statistical figures. Disease maps of human brucellosis from 2020 to 2021 in China were visualized with annual incidence using ArcGIS Desktop software (version 10.6; Esri; Redlands, California, USA), based on county boundaries.

The space-time scan statistic (STSS) based on spatial dynamic window scanning statistics was used to explore the spatial-temporal clustering of human brucellosis. Monte Carlo simulations were performed to access *P*-values using a Poisson model. The log-likelihood ratio (LLR) and relative risk (RR) were calculated to test the hypotheses for each scanning window. The cluster with the maximum LLR is the primary cluster, and the other clusters are secondary (*6*). This research explored the space-time clusters for each year and used 10% of the studied population as the maximum cluster size, setting the time interval as half a year.

RESULTS

Temporal Trend and Seasonality

From 2020 to 2021, a total of 117,012 human brucellosis cases were reported from 31 provincial-level administrative divisions (PLADs). The annual number of cases reported nationwide was 47,245 (3.4/100,000) in 2020 and increased to 69,767 (5.0/100,000) in 2021. The number of cases in 2021 increased by 47.7% compared to that in 2020; the incidence increased by 46.9% from 2020 to 2021. The peak season for human infections is from March to August, accounting for 66.0% of the total cases nationwide. The northern and southern regions had similar seasonal distributions (Figure 1).

Social-Demographical Characteristics

Among all the human brucellosis cases nationwide, males accounted for 70.9% and 72.0% in 2020 and 2021, respectively, with a sex ratio of 2.4:1 and 2.6:1 in 2020 and 2021 (χ^2=17.432, *P*<0.001). In 2020, the percentage of persons aged between 25 and 64 years was 81.5%, which was 81.7% in 2021 (χ^2=191.058, *P*<0.001). In 2020, farmers and herders accounted for 84.5% of the total patients, and the proportion in 2021 was 85.5% (χ^2=195.219, *P*<0.001).

Geographical Distribution Stratified by Northern and Southern China

From 2020 to 2021, 95.5% of the total cases were centralized nationwide in Northern China. IM reported the most cases (37,257 cases; 31.8% of the total nationwide) and had an average annual incidence (AAI) of 75.7/100,000. The other 10 PLADs with the highest number of cases were located in northern China (Liaoning, Shanxi, Henan, Ningxia, Xinjiang, Hebei, Gansu, Heilongjiang, Shandong, and Jilin), with AAI ranging from 2.8/100,000 to 55.4/100,000, and the increasing amplitude in AI ranging from 24.4% to 194.7% (Table 1). In Southern China, the AAI ranged from 0.2/100,000 to 1.1/100,000, and the increasing amplitude in AI ranged from 16.1% to 109.1% in the 10 PLADs with the highest number of cases. In Yunnan, the incidence exceeded 1.0/100,000 (Table 1).

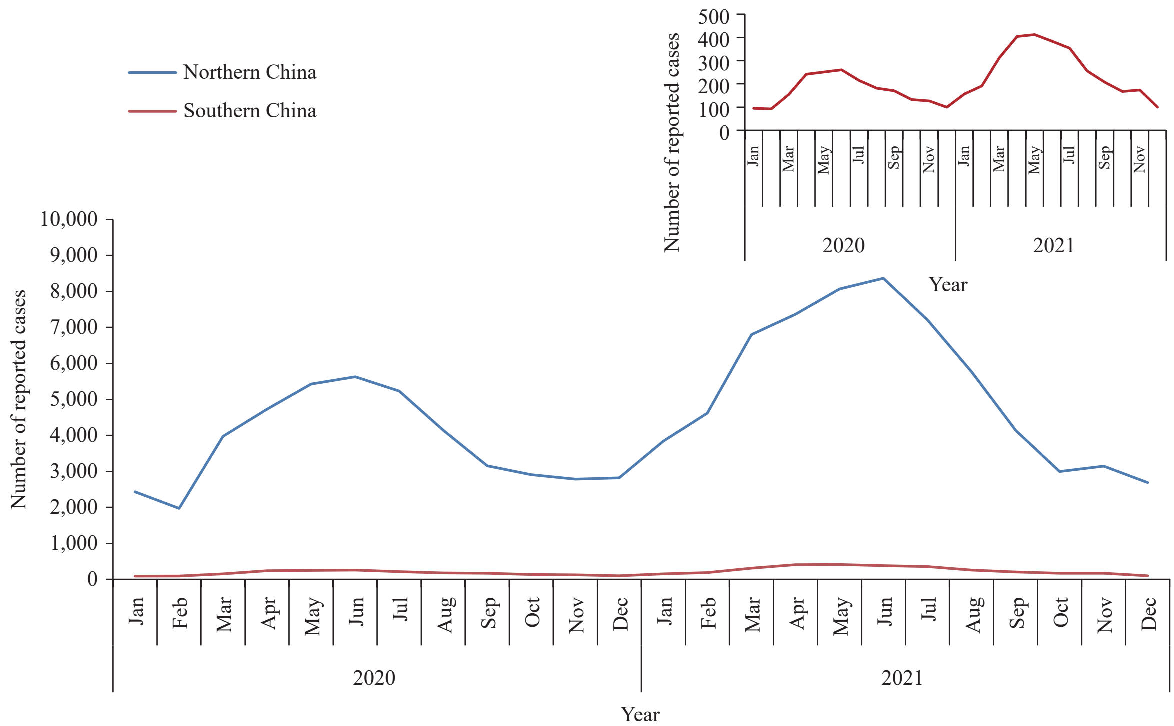

FIGURE 1. Monthly distribution of human brucellosis in Northern and Southern China, 2020–2021.

TABLE 1. Human brucellosis reported cases and incidence in the PLADs of Northern and Southern China from 2020 to 2021.

PLADs	2020		2021		Increasing amplitude in incidence (%)
	Case (*n*)	Incidence (per 100,000)	Case (*n*)	Incidence (per 100,000)	
Northern China					
Inner Mongolia	15,944	62.8	21,313	88.6	41.2
Liaoning	2,965	6.8	5,449	12.8	87.8
Shanxi	3,365	9.0	4,823	13.8	53.1
Henan	3,110	3.2	4,888	4.9	52.3
Ningxia	2,934	42.2	4,943	68.6	62.5
Xinjiang	3,010	11.9	4,780	18.5	55.0
Hebei	2,968	3.9	4,664	6.3	59.8
Gansu	2,956	11.2	4,562	18.2	63.2
Heilongjiang	2,884	7.7	4,048	12.7	65.3
Shandong	2,372	2.4	3,323	3.3	38.6
Jilin	1,136	4.2	1,265	5.3	24.4
Qinghai	263	4.3	756	12.8	194.7
Southern China					
Yunnan	381	0.78	699	1.48	89.7
Guangdong	355	0.31	455	0.36	16.1
Anhui	231	0.36	340	0.56	55.6
Jiangsu	166	0.21	285	0.34	61.9
Hunan	161	0.23	239	0.36	56.5
Sichuan	129	0.15	199	0.24	60.0
Zhejiang	123	0.21	178	0.28	33.3
Guangxi	120	0.24	224	0.45	87.5
Fujian	110	0.28	182	0.44	57.1
Jiangxi	49	0.11	103	0.23	109.1

Abbreviation: PLADs=provincial-level administrative divisions.

High-Risk Areas Based on Counties (Districts) Polygon

The number of districts and counties with reported cases increased from 1,888 in 2020 to 2,083 in 2021, an increase of 10.4%. The number of counties with an incidence above 100.00 per 100,000 was 34 in 2020 and 65 in 2021, the majority of which were located in IM (31, 88.6% in 2020, and 46, 70.8% in 2021). In 2021, Ningxia, Xinjiang, and Gansu had the number of counties with an incidence above 100.00 per 100,000 was 6, 5, 5, respectively. In 2020, the number of counties with an incidence exceeding 10.00 per 100,000 was 344; 83 were located in IM, and the others were located in Xinjiang (53), Shanxi (49), Heilongjiang (34), Gansu (29), and Ningxia (20) (Figure 2A). In 2021, the number of counties with an incidence of more than 10.00 per 100,000 was 517; these counties were located in IM (95), Shanxi (79), Xinjiang (67), Heilongjiang (56), Hebei (38), Gansu (37) (Figure 2B). Counties affected by human brucellosis spread from IM to neighboring PLADs (Figure 2A, 2B).

Space-Time Cluster Based on Counties (Districts) Polygon

In a total of 24 space-time clusters of human brucellosis were detected over the past two years, including two primary clustering areas and twenty-two secondary clustering areas. The coverage center of the primary clustering area was located in the Ulgai management (45.7N, 118.8E), Xilin Gol League, northeast part of the IM. The primary cluster covers 109 counties in 2020 and 2021. The total number of counties covered by the secondary clustering area

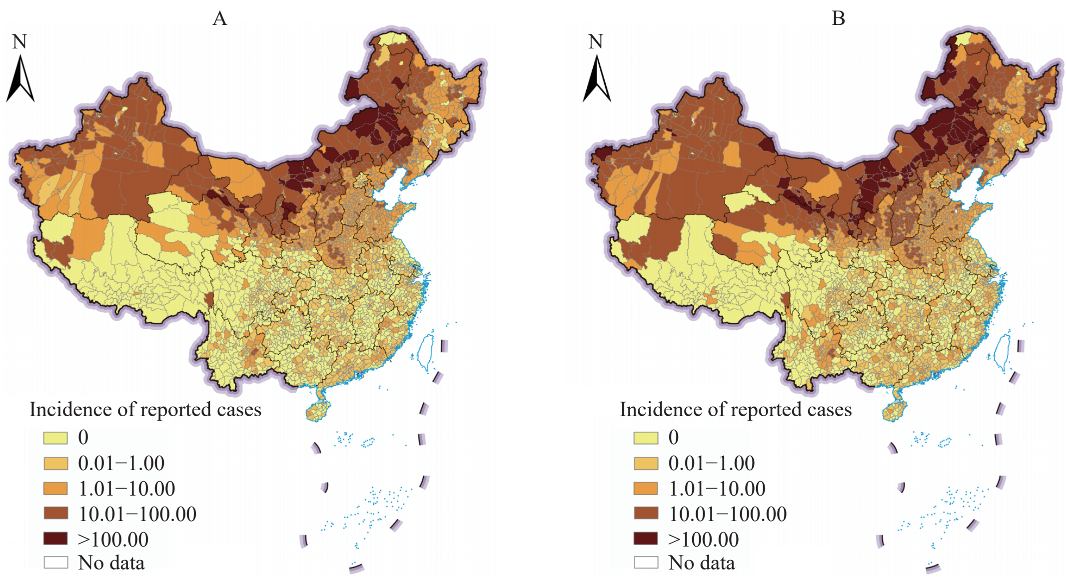

FIGURE 2. Geographical distribution of the reported human brucellosis in 31 PLADs of China, 2020–2021. (A) Incidence of reported cases in 2020. (B) Incidence of reported cases in 2021.
Abbreviation: PLADs=provincial-level administrative divisions.

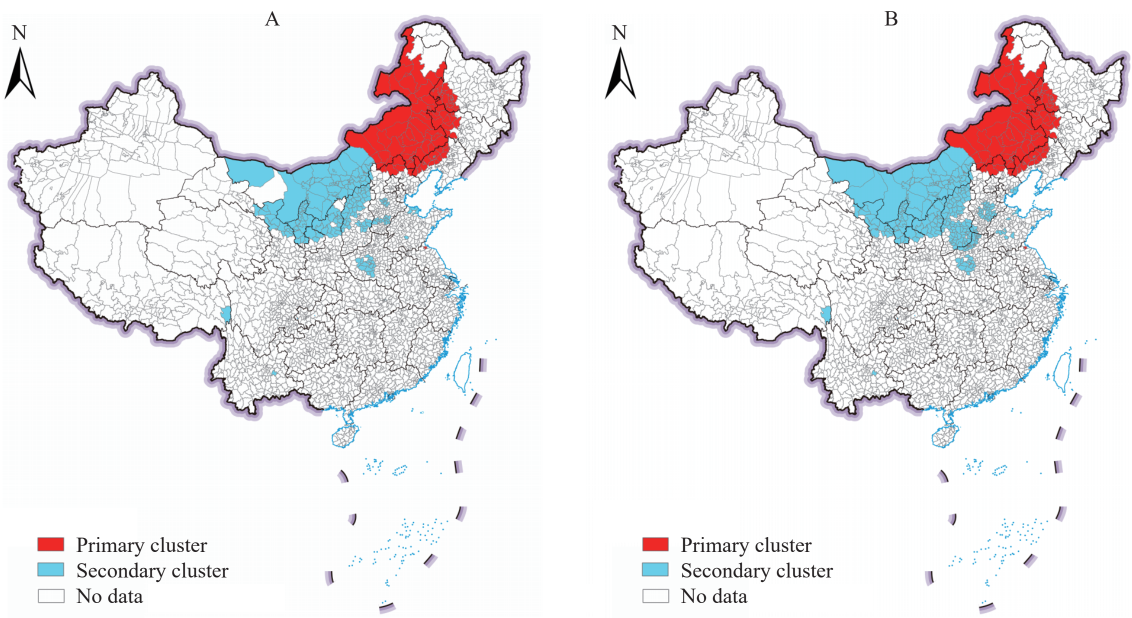

FIGURE 3. Spatial clustering of the reported brucellosis cases in 31 PLADs of China from 2020 to 2021. (A) Spatial clustering in 2020; (B) Spatial clustering in 2021.

increased from 208 in 2020 to 297 in 2021. In 2020, the counties covered by secondary clusters were mainly located in IM (54), Shanxi (49), Hebei (24), Henan (21), Ningxia (20), and Shaanxi (20). In 2021, these mainly involved Shanxi (81), Henan (57), IM (55), Hebei (41), Ningxia (20), and Shaanxi (20) (Figure 3). Among the 24 space-time clusters, 18 clusters occurred from February to August, and five clusters occurred from March to September (Table 2).

CONCLUSIONS

The epidemic of human brucellosis in China from 2020 to 2021 has been on the rise, with a rapidly increasing incidence, and an increase in the number of districts and counties experiencing infection. The incidence of brucellosis is characterized by spatiotemporal aggregation. The majority of space-time

TABLE 2. Space-time clusters of human brucellosis in China, 2020–2021.

Scan time frame (year)	Cluster time (mm/dd–mm/dd)	Centroid (latitude, longitude)/ radius (km)	Cluster counties (*n*)	LLR	RR	*P*-value
2020	2/20–8/20	(45.7N, 118.8E)/530.6	109	14503.2	13.5	<0.001
2020	3/1–8/28	(45.7N, 118.8E)/584.3	149	9001.7	9.0	<0.001
2020	4/1–9/5	(33.7N, 112.9E)/87.7	20	294.9	3.0	<0.001
2020	2/8–8/25	(37.0N, 113.0E)/72.0	9	248.2	5.5	<0.001
2020	4/12–10/1	(24.8N, 103.3E)/0	1	66.8	8.8	<0.001
2020	4/23–8/17	(37.4N, 115.4 E)/44.5	8	35.4	2.5	<0.001
2020	5/18–8/12	(37.9N, 118.5E)/42.8	3	33.5	4.5	<0.001
2020	4/7–8/10	(35.7N, 117.2 E)/0	1	31.5	4.6	<0.001
2020	5/8–11/2	(32.7N, 113.3E)/0	1	29.5	3.5	<0.001
2020	3/1–8/1	(29.7N, 98.6 E)/0	1	23.2	9.6	<0.001
2020	5/1–7/4	(38.8N, 115.5E)/34.3	10	23.1	2.3	<0.001
2020	4/22–8/20	(37.3N, 114.5E)/323.9	5	19.6	2.4	<0.01
2021	2/1–8/1	(45.7N, 118.8E)/530.6	109	18918.0	14.1	<0.001
2021	2/20–8/20	(41.1N, 107.1E)/586.39	153	17357.7	11.6	<0.001
2021	2/10–8/5	(33.7N, 112.9E)/87.7	22	714.0	3.7	<0.001
2021	2/25–8/15	(36.1N, 112.9E)/150.2	78	424.4	2.2	<0.001
2021	2/24–8/21	(24.8N, 103.3E)/0	1	233.6	16.9	<0.001
2021	3/20–9/15	(38.0N, 115.5E)/85.4	33	155.8	2.0	<0.001
2021	3/28–9/1	(35.7N, 117.3E)/0	1	101.0	6.6	<0.001
2021	2/23–8/23	(35.7N, 117.9 E)/0	1	57.2	4.8	<0.001
2021	3/17–7/23	(39.4N, 118.9E)/38.4	3	54.8	3.3	<0.001
2021	3/24–9/14	(36.2N, 116.8 E)/30.4	3	21.9	1.9	<0.05
2021	5/1–8/29	(29.7N, 8.6E)/0	1	19.9	9.2	<0.05
2021	4/5–8/8	(37.2N, 117.8E)/0	1	18.6	4.2	<0.05

Abbreviation: LLR=log likelihood ratio; RR=relative risk.

clusters occurred from February to August. The high-risk areas for brucellosis spread from IM to neighboring PLADs, and even presented in Xinjang, thereby involving more areas.

There may be several reasons for the rising momentum of human brucellosis in China. First, human brucellosis is mainly transmitted by infected livestock, especially in sheep or goats, and human-to-human transmission is rare. The prevalence of brucellosis in ovine and caprine flocks in China had increased from 1.0% in the 2000–2009 period to 3.2% in the 2010–2018 period (*7*). However, it seemed that the control measures on animal brucellosis such as vaccination had been relaxed and insufficient. For example, as a PLAD with a developed animal husbandry industry, IM's annual stock is dominated by ewe with a proportion of 65%, none of the ewes are vaccinated (*8*). In addition, Chinese demand for livestock products has increased in recent years even in southern China and the price of beef and lamb has been increasing, which contributed to the growth in the number of sheep raised and persons engaged in husbandry. The number of sheep rose from 31010.5 (×10,000 head) in 2018 to 31941.3 (×10,000 head) in 2020 nationwide (*9*). Frequent trade activity accelerated the flow of livestock products, which may lead to the spread of the disease (*10*). The inadequate implementation of quarantine measures for trans-regional livestock transport could also act as the driver of the expanding trend (*11–12*).

Spatiotemporal aggregation was mainly detected in the eastern and central parts of IM and neighboring PLADs, which is consistent with previous reports (*5*). However, compared in 2010–2018 period to previous studies, the center of the primary space-time clusters shifted to the east and the number of counties involved in the cluster increased. This study suggests that the epidemic is on the rise and spreading east. Other studies also have shown that the brucellosis positivity rate in sheep in the eastern part of China is 7%, which is higher than in other parts of the country (*7*). IM is an important livestock husbandry center with a suitable climate and high vegetation cover creating optimal conditions for the survival of *Bacteria* spp (*8*). Furthermore, farmers and herdsmen primarily conduct production activities at their residences or surrounding areas, which could have caused a high incidence, especially in IM and the adjacent areas in the neighboring provinces (*5*,*12*).

The epidemic period of temporal-spatial clusters in the past two years exhibited distinct seasonal characteristics, with peaks in late spring and summer, which was consistent with the incidence of brucellosis. This peak coincided with the lambing season (*2*). The demographic characteristics of human brucellosis cases from 2020 to 2021 were predominantly young and middle-aged farmers or herdsmen (*11*–*12*), which are consistent with those of previous studies. These occupations involve breeding, slaughtering, grazing, fur processing, and trading livestock, and therefore this group was subject to higher exposure and infection opportunities.

This study has several limitations. First, data quality may be affected by the quality of reporting in different regions. Owing to its atypical symptoms and signs, human brucellosis is underreported and misdiagnosed. However, we were able to utilize the most up-to-date and comprehensive dataset. Furthermore, less than one-tenth codes for counties in the case data set could not be matched to those in the map data set, however, given that the proportion is small, the data is still representative.

In general, more resources need to be allocated to high-risk areas, such as IM and its surrounding provinces and Xinjiang, to strengthen the prevention and control of animal brucellosis to mitigate the situation. The animal husbandry department needs to secure more resources and effort control measures on animal brucellosis such as the Quarantine-Slaughter-Immunization. Given that the factors affecting the livestock epidemic are difficult to eliminate in the short term, the Department of Health should continue to promote health education campaigns to reduce the exposure of high-risk populations as well as promoting early diagnosis and prompt treatment.

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Notifiable Infectious Diseases Reports

Reported Cases and Deaths of National Notifiable Infectious Diseases — China, November 2022

Diseases	Cases	Deaths
Plague	0	0
Cholera	0	0
SARS-CoV	0	0
Acquired immune deficiency syndrome*	4,299	1,458
Hepatitis	104,438	53
Hepatitis A	749	0
Hepatitis B	86,371	32
Hepatitis C	15,057	20
Hepatitis D	10	0
Hepatitis E	1,732	1
Other hepatitis	519	0
Poliomyelitis	0	0
Human infection with H5N1 virus	0	0
Measles	82	0
Epidemic hemorrhagic fever	895	5
Rabies	16	8
Japanese encephalitis	1	1
Dengue	174	0
Anthrax	23	0
Dysentery	1,975	1
Tuberculosis	48,352	333
Typhoid fever and paratyphoid fever	419	0
Meningococcal meningitis	4	1
Pertussis	2,160	0
Diphtheria	0	0
Neonatal tetanus	1	0
Scarlet fever	1,896	0
Brucellosis	2,569	0
Gonorrhea	7,630	0
Syphilis	35,152	3
Leptospirosis	10	0
Schistosomiasis	8	0
Malaria	74	0
Human infection with H7N9 virus	0	0
COVID-19[†]	62,723	7
Influenza	82,663	0
Mumps	8,702	0

Continued

Diseases	Cases	Deaths
Rubella	120	0
Acute hemorrhagic conjunctivitis	1,738	0
Leprosy	20	0
Typhus	116	0
Kala azar	11	0
Echinococcosis	97	0
Filariasis	0	0
Infectious diarrhea[§]	50,972	0
Hand, foot and mouth disease	50,633	0
Total	467,973	1,870

* The number of deaths of acquired immune deficiency syndrome (AIDS) is the number of all-cause deaths reported in the month by cumulative reported AIDS patients.

[†] According to the data from website of the National Health Commission of the People's Republic of China, the number of COVID-19 cases in the whole country in October was 63,180 cases, which included 267 cases from Hong Kong Special Administrative Regions, Macao Special Administrative Regions, and Taiwan, and 190 imported foreign cases. 7 deaths were reported.

[§] Infectious diarrhea excludes cholera, dysentery, typhoid fever and paratyphoid fever.

The number of cases and cause-specific deaths refer to data recorded in National Notifiable Disease Reporting System in China, which includes both clinically-diagnosed cases and laboratory-confirmed cases. Only reported cases of the 31 provincial-level administrative divisions in the mainland of China are included in the table, whereas data of Hong Kong Special Administrative Region, Macau Special Administrative Region, and Taiwan, China are not included. Monthly statistics are calculated without annual verification, which were usually conducted in February of the next year for de-duplication and verification of reported cases in annual statistics. Therefore, 12-month cases could not be added together directly to calculate the cumulative cases because the individual information might be verified via National Notifiable Disease Reporting System according to information verification or field investigations by local CDCs.

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