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ORIGINAL RESEARCH

Assessment of the Risk and Symptoms of SARS-CoV-2 Infection Among Healthcare Workers During the Omicron Transmission Period: A Multicentric Study from Four Hospitals of Mainland China

Shuaishuai Chen[1,2,*], Mengyuan Chen[1,2,*], Qiaoming Chen[3], Tongtong Zhang[4], Bing Xu[5], Tao Hsin Tung[6], Bo Shen[1,2], Xiaomai Wu[7]

[1]Department of Clinical Laboratory, Taizhou Hospital of Zhejiang Province Affiliated to Wenzhou Medical University, Linhai, People's Republic of China; [2]Key Laboratory of System Medicine and Precision Diagnosis and Treatment of Taizhou, Taizhou, People's Republic of China; [3]Department of Prevention and Health Care, Taizhou Enze Medical Center (Group) Enze Hospital, Taizhou, People's Republic of China; [4]Department of Prevention and Health Care, Taizhou Hospital of Zhejiang Province Affiliated to Wenzhou Medical University, Linhai, People's Republic of China; [5]Department of Human Resources, Taizhou Hospital of Zhejiang Province Affiliated to Wenzhou Medical University, Linhai, People's Republic of China; [6]Evidence-Based Medicine Center, Taizhou Hospital of Zhejiang Province Affiliated to Wenzhou Medical University, Linhai, People's Republic of China; [7]Department of Respiratory and Critical Medicine, Taizhou Enze Medical Center (Group) Enze Hospital, Taizhou, People's Republic of China

*These authors contributed equally to this work

Correspondence: Bo Shen, Taizhou Hospital of Zhejiang Province affiliated to Wenzhou Medical University, 150 Ximen Street of Linhai City, Linhai, 317000, People's Republic of China, Email shenb@enzemed.com; Xiaomai Wu, Taizhou Enze Medical Center (Group) Enze Hospital, 1 East Tongyang Road of Luqiao, Taizhou, 318000, People's Republic of China, Email wuxm@enzemed.com

Purpose: The SARS-CoV-2 omicron variant emerged and spread rapidly among the population in the early stage of China's normalized prevention and control in December 2022. Healthcare workers (HCWs) are particularly exposed to SARS-CoV-2, it is important to evaluate the impact of the omicron pandemic on HCWs in China.

Methods: A self-administered online survey was conducted on infected HCWs from four hospitals of Taizhou. A total of 748 HCWs received the survey via DingTalk, and 328 responded to the questionnaire. The risk factors were investigated using univariate and multivariate logistic regression analysis.

Results: By December 20, 2022, 748 HCWs tested positive by PCR, and the infection rate was 11.4% (748/6581). Among 328 respondents, the most common symptoms were cough (88.4%), fever (83.5%), runny nose (77.1%), sore throat (73.2%), headache (70.1%), muscle aches (67.1%), and fatigue (53.4%). 69.8% (229/328) of the participants had five or more major onset symptoms, while no severe case was observed. The multivariate analysis indicated that the poor sleep quality (OR = 2.29, 95% CI: 1.31–4.02, P = 0.004) was an independent risk factor for more major onset symptoms, while wore gloves ≥95% times in working (OR = 0.49, 95% CI: 0.28–0.85, P = 0.011) was significantly related to fewer symptoms. In addition, 239 (72.9%) recipients reported high fever (temperature ≥38.5°C), less common cold (≤3 vs >3 times/year, OR = 2.20, 95% CI: 1.05–4.65, P = 0.038) was significantly associated with high fever.

Conclusion: Our findings imply rapid transmissibility of omicron and multiple-onset symptoms among HCWs. Improved auto-immunity and self-protection measures for HCWs may be helpful in controlling infection and clinical symptoms. Our results provide empirical reference values for improved countermeasures and protective measures for major public health emergencies.

Keywords: SARS-CoV-2 omicron, healthcare workers, multiple onset symptoms, poor sleep quality, China

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Introduction

SARS-CoV-2 have caused global pandemics in the recent 3 years, contributing to 657.98 million infections and 6.68 million deaths by January 7, 2023.[1] Devastating epidemics pose great threats to human health, especially the older adult population.[2] As China has a huge population of over 1.4 billion,[3] it faces much more serious situations regarding COVID-19 prevention and control than the majority of other countries and regions in the world. Since SARS-CoV-2 WA1 wave started in China in late December 2019, the Chinese government has promulgated and implemented a series of laws and regulations, scheduled a series of policies, and built shelter hospitals and urban nucleic acid bases to prevent and control epidemics. Different SARS-CoV-2 variants show different virulence, transmissibility, and immune escape abilities, leading to different prevalence outcomes.[4,5] Based on the SARS-CoV-2 genotype or sub-genotype circulation and epidemic scale, COVID-19 prevention and control policies in China have been adjusted scientifically and precisely.

Vaccines are considered effective and safe for the prevention and control of SARS-CoV-2.[6,7] The mass vaccination against SARS-CoV-2 was advanced from December 2020 in China. Participants in vaccination campaigns for COVID-19 in China provided informed consent and were voluntary. Currently, several types of vaccines against SARS-CoV-2 have been approved in China, including inactivated, adenovirus vector, and recombinant protein vaccines. Inactivated vaccines, including Sinovac's CoronaVac and Sinopharm's CoronaVac, are the most extensively used vaccines in China and included in the WHO emergency use listing.[8] Until early 2023, the total coverage rates of the first-dose and full-course vaccination for the entire population of China have reached 93.0% and 90.6%, respectively.

The SARS-CoV-2 omicron variant, which has spread worldwide since December 2021, has become the main pathogen in the general population,[9,10] and also became the predominant pathogen in China since January 2022. The main epidemic strains are BA.5.2 and BF.7 and their subbranches, since the adjustment of prevention and control policies in China. As omicron variants have relatively low virulence but higher transmissibility, China unveiled optimized policies one after another in late 2022 to guide the Easing Covid Policy step-by-step. In combination with the low pathogenicity, low morbidity and mortality, high vaccination coverage, and accumulated experience in prevention and control, China has adjusted COVID-19 from "Class B infectious disease and managed as Class A infectious disease" to "Class B Infectious Disease and managed as Class B Infectious Disease" in early January 2023[11] (Figure 1).

Optimized Easing COVID Policies on Omicron Variants may lead to larger omicron waves. Although omicron waves have been reported in several countries and regions,[12,13] the epidemiological situation and disease-associated symptoms and factors in China remain unclear. Furthermore, the majority of Chinese were not previously infected with SARS-CoV-2,

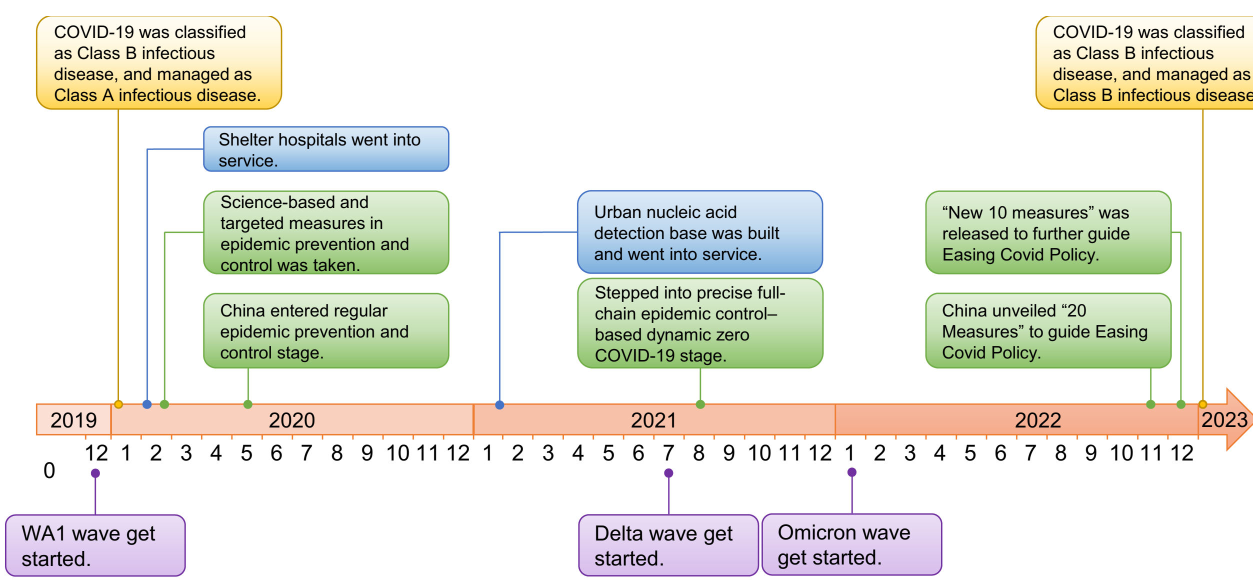

Figure 1 China government implemented science-based, precise, and flexible policies and laws, to prevent and control SARS-CoV-2 infections.

the situations were totally different from any other countries and regions in the world, and studies on omicron waves in Chinese populations are urgently needed. As health-care workers (HCWs) are regularly screened for omicron infections and are exposed to high biological risks, studying the impact of omicron variants among HCWs can provide more professional and scientific data. HCWs were routinely screened for SARS-CoV-2 infection via real-time PCR analysis. HCWs underwent a twice-a-week testing schedule for SARS-CoV-2, while those operating in high-risk clinical areas such as fever clinics and designated medical institutions that centrally manage COVID-19 patients were screened daily for SARS-CoV-2. Upon entering the peak period of the omicron variant infection, medical demands will increase sharply, bringing extraordinary pressure on medical systems as well as high risks of infection for HCWs. However, the epidemiological characteristics of the SARS-CoV-2 Omicron variants among HCWs under such emergency status in China remain unclear.

In this first multicenter study of omicron infections in HCWs in mainland China under the normalization of prevention and control policy, we aimed to characterize the epidemiological and clinical features of omicron-infected HCWs and explore the risk factors associated with increased clinical symptoms and high fever from late November 2022 to December 20, 2022. Our findings contribute to provide scientific data for hospital policymakers in well-organized management and arrangement and present the impact of the omicron wave on populations from HCWs' professional insights under emergency situations.

Materials and Methods

Study Design and Participants

This multicenter study included four hospitals in Taizhou: Taizhou Hospital, Enze Hospital, Taizhou Rehabilitation Hospital, and Enze Maternity Hospital. The inclusion criteria were HCWs who tested positive using the real-time reverse-transcription-polymerase chain reaction (RT-PCR) assay for SARS-CoV-2, consented to participate in the study and were able to complete the questionnaire online (Figure 2). The participants included clinicians (physicians, surgeons, physical/respiratory therapists, and those who had direct contact with patients), nurses, medical technicians, and administrative services, such as security staff and logistic services. The study was approved by the local ethics committee of each hospital, and all procedures were performed in accordance with the tenets of the Declaration of Helsinki.

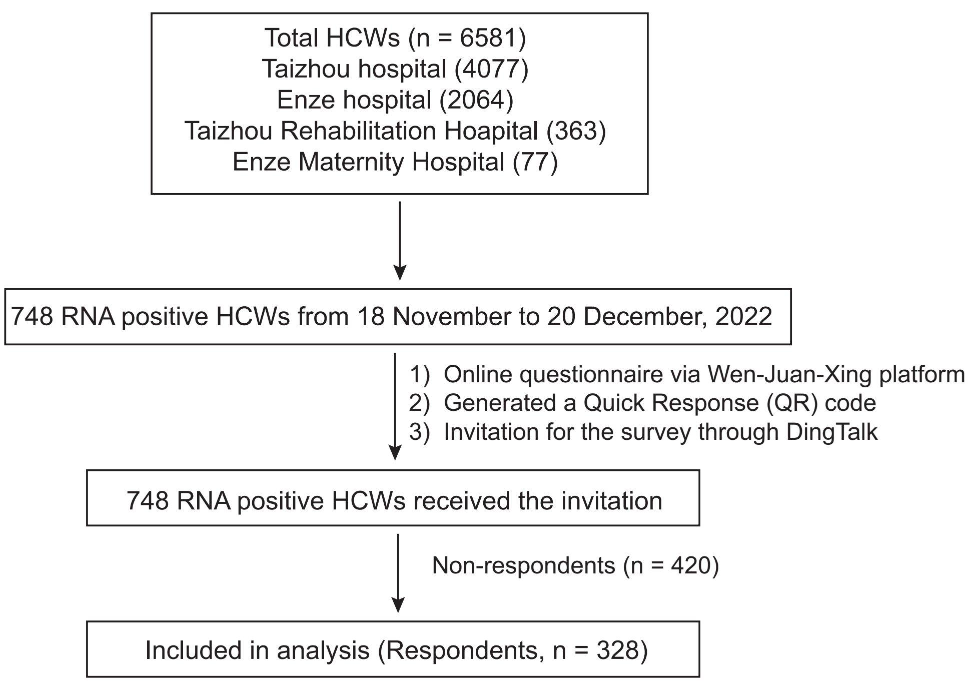

Figure 2 Flowchart of enrolled healthcare workers with omicron infection.

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The main epidemic variants of SARS-COV-2 virus were BA.5.2 and BF.7 in Taizhou, which was sampled for genomic sequencing by the Taizhou Centers for Disease Control and Prevention. In this study, the two-dose primary immunization and first booster dose of HCWs were Sinovac's CoronaVac inactivated vaccine. Two doses of basic immunity with an interval of 2–4 weeks, and the third dose (first booster dose) was given 6 months after the second dose. A portion of HCWs received the fourth dose (second booster) of a recombinant protein vaccine or adenovirus vector vaccine against COVID-19. Occupational infections were defined as those in close contact with confirmed COVID-19 cases of colleagues or patients at work, in absence of a positive household member. Non-occupational infections were defined as those that had not contacted with confirmed patients or colleagues.

Questionnaires

A self-administered online questionnaire, referred to the WHO/2019-nCoV/HCW Surveillance Protocol/2020.1, modified according to the actual situation, was designed using the Wen-Juan-Xing platform (Changsha Ranxing Information Technology Co., Ltd., Hunan, China), and a Quick Response (QR) code was generated. A total of 748 HCWs with omicron infections in hospitals from November 18 to December 20, 2022, were invited to participate in the survey through DingTalk, one of the most commonly used chat tools in China. The respondents answered the questionnaire through scanning the Quick Response (QR) code between December 22 and 24, 2022. Age, sex, height, weight, education level, job tasks, preexisting basic diseases, physical condition, ventilation in the working environment, personal and protective equipment (PPE), vaccine dose, and symptoms were assessed. Physical exercise habits were defined as regular exercise at least three times a week for more than 30 min.

Statistical Analysis

All data were analyzed using SPSS Statistics software (version 23.0; IBM Corp., Armonk, N.Y., USA). Categorical variables were analyzed using the chi-square test and displayed as frequencies and percentages. The seven major onset symptoms include cough, fever, runny nose, sore throat, headache, muscle aches, and fatigue. The participants were separated into ≥5 major onset symptoms group and <5 major onset symptoms group, according to the symptoms, and divided into two groups based on high fever or not (≥38.5°C vs <38.5°C). The population size was calculated by Power Analysis and Sample Size Software (PASS) version 11, the minimum sample size achieved a power of 80%, and under 5% significance level, using a 2-sided hypothesis test. Potential factors associated with the multiplicity of symptom onset or high fever were assessed using univariate analyses. Variables with $P < 0.2$ in the univariate analysis were included in the logistic regression model and analyzed using the stepwise regression method. A P value < 0.05 was considered statistically significant.

Results

The Transmissibility of Omicron Among Healthcare Workers

The epidemiological characteristics of HCWs infected with the SARS-CoV-2 omicron variant are shown in Figure 3A. A total of 748 HCWs were infected between November 8 and December 20, 2022, in the centers. Thirteen cases were infected in November, and five cases were infected from December 1 to 8, 2022. Since December 9, the number of infections among HCWs increased daily.

Daily infection rates in the four hospitals are shown in Figure 3B. The cumulative incidence rate was 12.0% (488/4077), 10.6% (218/2064), 8.5% (31/363), and 14.3% (11/77) at Taizhou Hospital, Enze Hospital, Taizhou Rehabilitation Hospital, and Enze Maternity Hospital, respectively. In addition, we analyzed the omicron infections for HCWs in different job tasks, as shown in Figure 3C, the infection rates of nurses, clinicians, medical technicians and other job tasks were 13.9%, 11.8%, 7.6%, and 5.5%, respectively. Our results demonstrate that the risk of infection varies by job tasks; nurses and clinicians have an increased risk of infection compared with medical technicians and other position roles, as they have a higher frequency and duration of direct contact with patients.

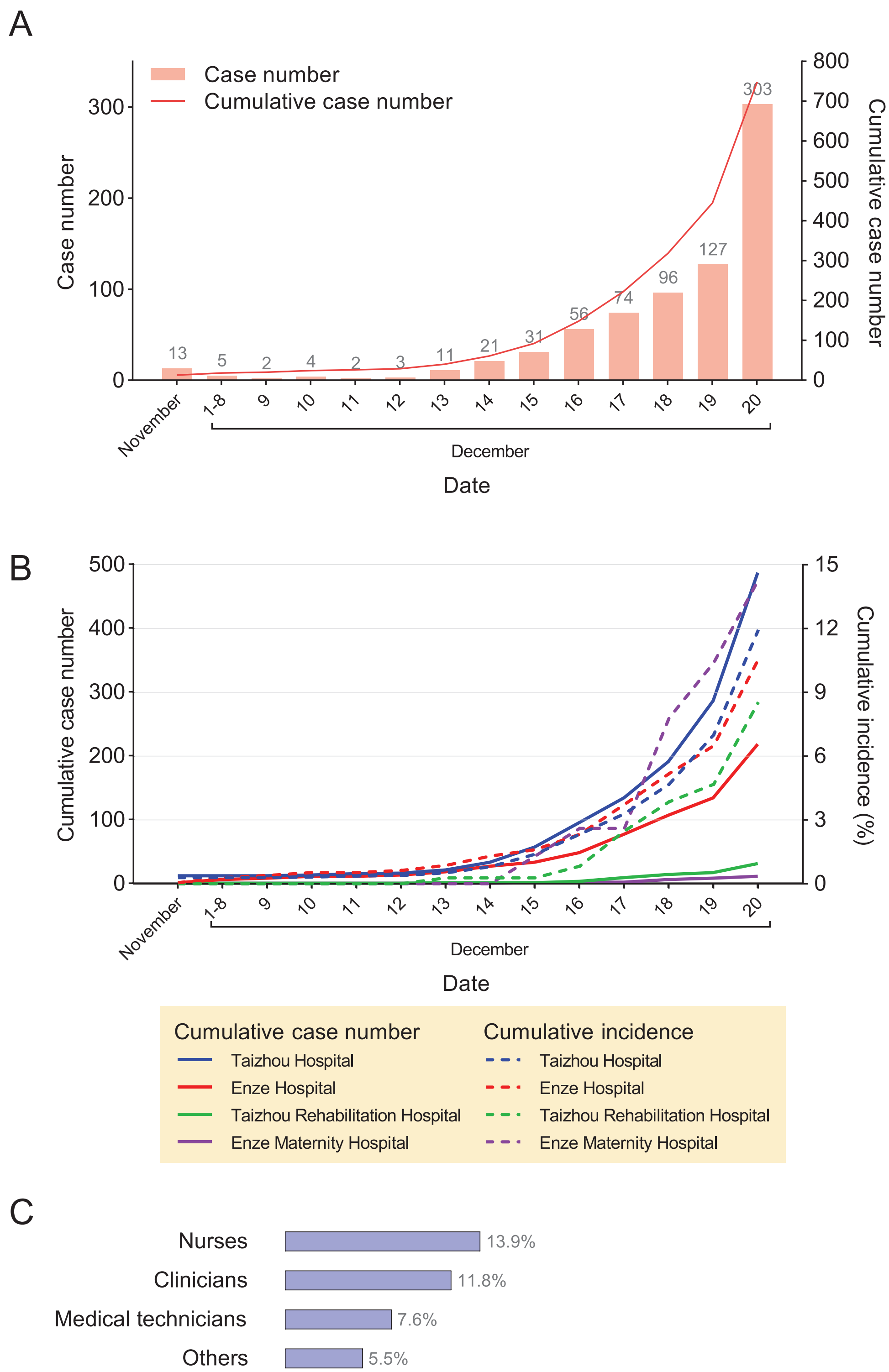

Figure 3 Epidemiological characteristics of healthcare workers infected with SARS-CoV-2 omicron variant in this study. (**A**) Time distribution of cases. (**B**) Incidence of omicron infections in four hospitals. (**C**) Incidence of omicron infections in different positions.

Characteristics of the Study Population

A total of 328 of the 748 eligible HCWs participated in the survey and completed the questionnaire; the overall response rate was 43.9%. As shown in Table 1, female had a high response rate than male (45.9% vs 35.0%), <40 years aged group had high response rate than ≥40 years aged group (45.6% vs 38.7%). The proportions of clinicians, nurses, medical technicians, and HCWs

Table 1 The Response Rate of the Omicron Infection Survey Among Healthcare Workers

Variable	Eligible Population (n=748)	Attendant Population (n=328)	Response Rate (%)
Sex			
Male	143	50	35.0
Female	606	278	45.9
Age (year)			
<40	550	251	45.6
≥40	199	77	38.7
Education			
College degree or below	238	108	45.4
Bachelor's degree	408	181	44.4
Master's degree or above	103	39	37.9
Job tasks			
Clinician	166	62	37.3
Nurse	360	149	41.4
Medical Technician	73	55	75.3
Others	149	62	41.6
Total	748	328	43.9

with other infections were 22.2% (166/748), 48.1% (360/748), 9.7% (73/748), and 20.0% (149/748), respectively. We then compared the demographic characteristics of respondents and non-respondents among HCWs with omicron infection (Table 2). Demographic characteristics, such as age and level of education in respondents, were similar to those in non-respondents, whereas gender and job tasks between the two groups were significantly different ($P < 0.05$).

The baseline characteristics of participants are displayed in Table 3. The participants consisted of 278 female (84.8%) and 50 male (15.2%), their mean age was 32.9±8.7 years, and mean BMI was 22.2±3.0 kg/m^2. A total of 37 (11.3%) participants had preexisting basic diseases, including hypertension, diabetes, and autoimmune diseases. A total of 97 (29.6%) participants received four vaccine doses, and all were vaccinated within 14 days. Moreover, the results showed that the percentage of HCWs immunized with either 1, 2, or 3 doses was 0.9% (3/328), 7.9% (26/328), and 60.1% (197/328), respectively. More than half of the participants (183, 55.8%) experienced fatigue before infection, and 32.3% had

Table 2 Comparisons of Demographic Characteristics Between Respondents and Non-Respondents of the Survey Among Healthcare Workers Infected with Omicron

Variable	Respondents (n=328)		Non-Respondents (n=420)		*P* value for χ^2-test
	No.	%	No.	%	
Sex					
Male	50	15.2	92	21.9	0.021
Female	278	84.8	328	78.1	
Age (year)					
<40	251	76.5	299	71.2	0.101
≥40	77	23.5	121	28.8	
Education					
College degree or below	108	32.9	129	30.7	0.401
Bachelor's degree	181	55.2	227	54.1	
Master's degree or above	39	11.9	64	15.2	
Job tasks					
Clinician	62	18.9	104	24.8	<0.001
Nurse	149	45.4	211	50.2	
Medical Technician	55	16.8	18	4.3	
Others	62	18.9	87	20.7	

Table 3 The Baseline Characteristics of the Participants

Variable	Participants (n = 328) n (%)
Female	278 (84.8)
Age (year)	32.9±8.7
BMI (kg/m^2)	22.2±3.0
Education	
College degree or below	108 (45.4)
Bachelor's degree	181 (55.2)
Master's degree or above	39 (11.9)
Job tasks	
Clinician	62 (18.9)
Nurse	149 (45.4)
Medical Technician	55 (16.8)
Others	62 (18.9)
Preexisting basic diseases	37 (11.3)
Vaccines	
1 dose	3 (0.9)
2 doses	26 (7.9)
3 doses	197 (60.1)
4 doses	97 (29.6)
Fatigue before infection	183 (55.8)
Poor sleep before infection	106 (32.3)
Sleep duration per day	
< 7 hours	103 (31.4)
≥ 7 hours	225 (68.6)
Exercise habit (≥3 times/week)	46 (14.0)
Symptom	
<5 major symptoms	99 (30.2)
≥5 major symptoms	229 (69.8)
Body temperature (≥38.5°C)	239 (72.9)
Fever days (≥ 2 days)	244 (74.4)
Ventilation at working environment	
Yes	139 (42.4)
No	189 (57.6)
Type of masks	
Surgical masks	234 (71.3)
Medical protective masks	92 (28.0)
Other	2 (0.6)
Wore masks in working (≥95% times)	294 (89.6)
Wore masks out working (≥95% times)	91 (27.7)
Wore gloves (≥95% times)	78 (23.8)
Wore face shield (≥95% times)	39 (11.9)

poor sleep. Moreover, 103 (31.4%) of participants sleep less than 7 h per day, and 14.0% keep exercise habit (≥3 times/week) in their daily life. After infection, 229 (69.8%) participants appeared to have five or more major onset symptoms. A total of 239 (72.9%) participants had temperatures higher than 38.5°C body temperature, and 244 (74.4%) of the participants experienced fever for ≥2 days. Only 139 participants (42.4%) worked in a ventilated environment. A questionnaire on personal and protective equipment (PPE) showed that 234 (71.3%) wore surgical masks, and 92 (28.0%) wore medical protective masks. A total of 294 (89.6%) participants wore masks in the work environment ≥95% of the time, whereas only 91 (27.7%) participants wore masks outside the work environment for ≥95% of the time. Moreover, 78 (23.8%) participants wore gloves, and 39 (11.9%) wore face shields in their work environment ≥95% of the time.

Factors Associated with Major Onset Symptoms

The most common symptoms were cough (290, 88.4%), fever (274, 83.5%), runny nose (253, 77.1%), sore throat (240, 73.2%), headache (230, 70.1%), muscle aches (220, 67.1%), and fatigue (175, 53.4%) (Figure 4A). Only 6 (1.8%) participants reported no symptoms. We found that 25.3% (83/328) overlapped with seven major onset symptoms and 24.7% (81/328) overlapped with six major onset symptoms (Figure 4B); however, no severe infection was observed among HCWs in this study.

In our survey, 229 participants reported five or more major onset symptoms and 99 participants reported <5 major onset symptoms; univariate analysis showed that fatigue, poor sleep quality before infection, and wore gloves ≥95% times were factors affecting multiple-onset symptoms after infection ($P < 0.05$). We included the index of $P < 0.2$ in the univariate analysis into the regression analysis and analyzed using stepwise multiple logistic regression. As shown in Table 4, poor sleep quality (yes vs no, OR = 2.29, 95% CI: 1.31–4.02, $P = 0.004$) was significantly related to multiple major onset symptoms of omicron infection, and wore gloves ≥95% times when working (yes vs no, OR = 0.49, 95% CI: 0.28–0.85, $P = 0.011$) was significantly related to less major onset symptoms. In addition, we separated the participants into two groups according to high fever (≥38.5°C) or not (<38.5°), multivariate analysis showed that those who had less common cold were more likely to have high fever (≤3 vs >3 times/year, OR = 2.20, 95% CI: 1.05–4.65, $P = 0.038$), as shown in Table 5.

Occupational versus Non-Occupational Acquired by HCWs

The distribution of occupational and non-occupational infections acquired by HCWs were estimated by *t*-test or chi-square test and the results are shown in Table 6. The mean age of HCWs between occupational and non-occupational infections has no difference (32.8 ± 8.0 vs 32.9 ± 9.0, $P = 0.896$). The rate of occupational infections (107/328) was particularly lower than non-occupational infections (221/328). Considering job tasks, nurses had the highest proportion of both occupational and non-occupational SARS-CoV-2 infection. Other job task such as administrative services, those not contacted with patients, has lower rate of occupational infections than non-occupational infections.

Recommendation of Healthcare Workers

We also collected suggestions from HCWs on individual protection and personal life against omicron infection, and the results are shown in Figure S1. They provide advice on individual protection and personal life habits, with most suggestions including wearing masks correctly, strengthening self-protection consciousness, maintaining good hand hygiene, and social distancing. A total of 40.3% of clinicians, 34.9% of nurses, 47.3% of medical technicians, and 21.4% of administrative staff correctly recommended wearing masks. In total, 24.2% of clinicians, 20.1% of nurses, 25.5% of medical technicians, and 21.4% of administration staff recommended strengthening self-protection consciousness. Interestingly, administration staff may provide more consideration to personal lifestyle habits than clinical workers.

Discussion

This study was a multicenter investigation of SARS-CoV-2 omicron infection among HCWs during its emergence in China. Our study aimed to describe the symptoms and epidemic characteristics of the acute outbreak of omicron among HCWs in Taizhou, to provide a reference for the public and HCWs, and also provide an evidence-based basis for the prevention and control of epidemics. The main epidemic variants of the SARS-COV-2 virus were BA.5.2 and BF.7 in this study, which were sampled for genomic sequencing by the Taizhou Centers for Disease Control and Prevention. In this study, we observed the rapid transmissibility of omicrons and multiple onsets of symptoms after infection among HCWs. Clinical frontline HCWs had an increased risk of infection compared with those in other job tasks. Poor sleep quality and wearing gloves <95% times in working were associated with multiple major onset symptoms of omicron infection. Fever is a common symptom of SARS-COV-2 infection, and those with ≤3 times of common cold episodes per year are more likely to have high fever after omicron infection.

The SARS-CoV-2 omicron variant has spread rapidly worldwide and become the dominant variant globally.[14] Omicron in Europe had a negligible impact on human health in terms of morbidity and mortality in general,[9,15] and so in China. In China, the proportion of asymptomatic infections and mild cases of infected individuals exceeds 90%,

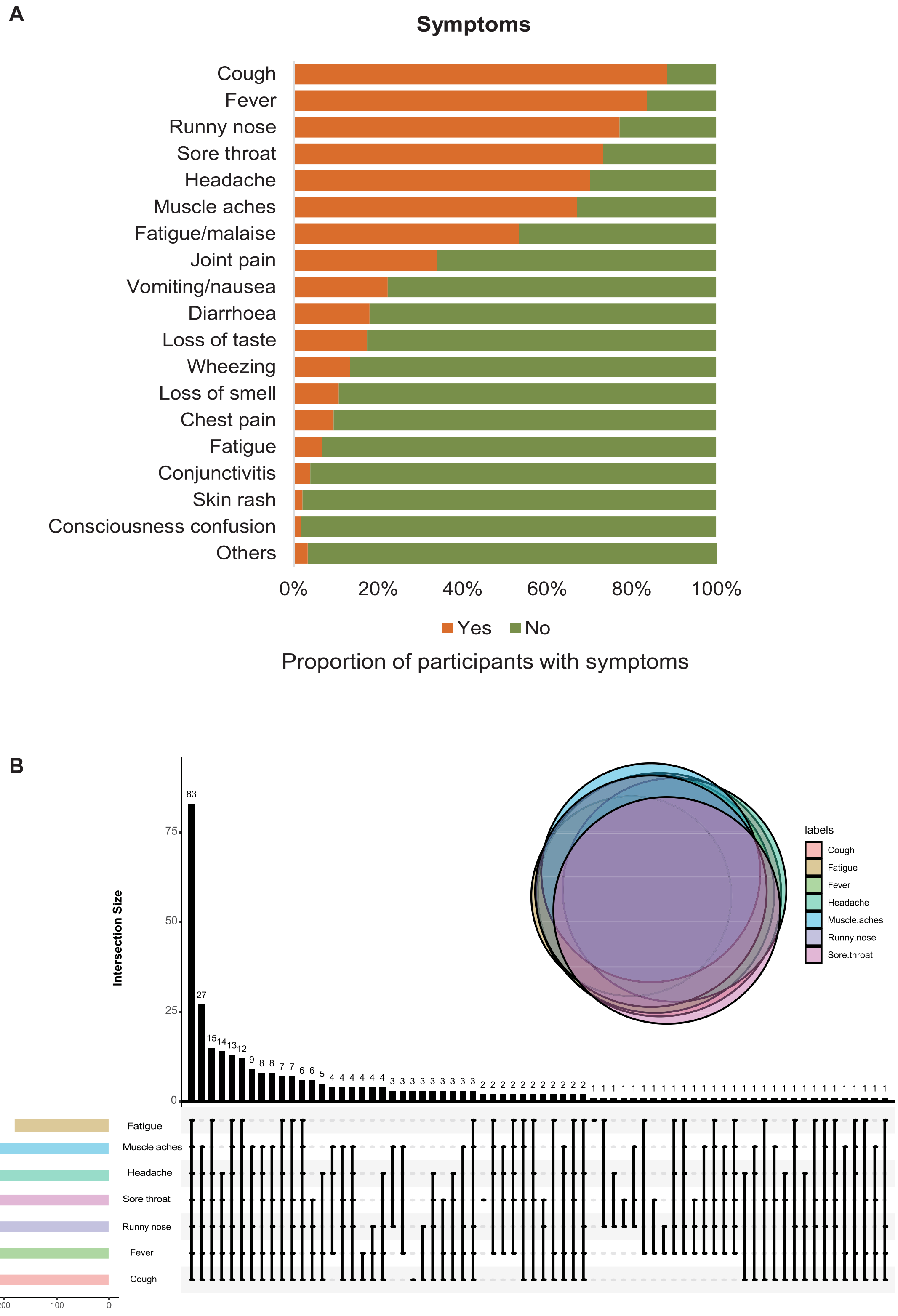

Figure 4 Presenting symptoms in healthcare workers infected with SARS-CoV-2 omicron variant. (**A**) Symptoms by frequency of presentation. (**B**) Venn diagrams and Up-Set plots showing the overlap of the most common symptoms.

Table 4 Factors Associated with Major Symptoms by Univariate and Stepwise Multiple Logistic Regression

Variable	≥5 Major Symptoms (n = 229)	<5 Major Symptoms (n = 99)	Univariate Analysis		Multivariate Analysis	
	n(%)	n(%)	Crude OR (95% CI)	*P* value	Adjusted OR (95% CI)	*P* value
Sex						
Male	31 (62.0)	19 (38.0)	0.66 (0.35–1.23)	0.193	/	0.225
Female	198 (71.2)	80 (28.8)				
Age (year)						
≥40	50 (64.9)	27 (35.1)	0.75 (0.43–1.28)	0.287	–	–
<40	179 (71.3)	72 (28.7)				
BMI (kg/m^2)						
>24	51 (65.4)	27 (34.6)	0.76 (0.44–1.31)	0.325	–	–
≤24	176 (71.3)	71 (28.7)				
Preexisting basic diseases						
Yes	27 (73.0)	10 (27.0)	1.20 (0.55–2.56)	0.657	–	–
No	202 (69.4)	89 (30.6)				
Vaccines						
4 doses	62 (63.9)	35 (36.1)	0.68 (0.41–1.13)	0.133	/	0.174
0–3 doses	167 (72.3)	64 (27.7)				
Common cold						
≤3 times/year	203 (68.8)	92 (31.2)	0.60 (0.25–1.42)	0.241	–	–
>3 times/year	26 (78.8)	7 (21.2)				
Fatigue before infection						
Yes	136 (74.3)	47 (25.7)	1.62 (1.01–2.60)	0.047	/	0.347
No	93 (64.1))	52 (35.9)				
Poor sleep before infection						
Yes	84 (79.2)	22 (20.8)	2.03 (1.18–3.50)	0.011	2.29 (1.31–4.02)	0.004
No	145 (65.3)	77 (34.7)				
Sleep duration						
< 7 hours/day	79 (76.7)	24 (23.3)	1.65 (0.97–2.81)	0.068	/	0.231
≥ 7 hours/day	150 (66.7)	75 (33.3)				
Exercise habit						
≥ 3 times/week	30 (65.2)	16 (34.8)	0.78 (0.41–1.51)	0.464	–	–
< 3 times/week	199 (70.6)	83 (29.4)				
Wore masks in working						
≥95% times	208 (90.8)	86 (86.9)	1.50 (0.72–3.13)	0.282	–	–
<95% times	21 (9.2)	13 (13.1)				
Wore masks out working						
≥95% times	62 (27.1)	29 (29.3)	0.90 (0.53–1.51)	0.680	–	–
<95% times	167 (72.9)	70 (70.7)				
Wore gloves						
≥95% times	47 (20.5)	31 (31.3)	0.57 (0.33–0.97)	0.036	0.49 (0.28–0.85)	0.011
<95% times	182 (79.5)	68 (68.7)				
Wore face shield						
≥95% times	29 (12.7)	10 (10.1)	1.29 (0.60–2.76)	0.511	–	–
<95% times	200 (87.3)	89 (89.9)				

Notes: Adjustment for gender, vaccines, fatigue before infection and sleep duration per day.

with extremely low severity and mortality rates, may be due to the low pathogenicity, high vaccination coverage, and accumulated experience in prevention and control. The high transmissibility of the omicron variants is associated with several factors. The genome of the omicron variant showed more than 30 mutations in the spike protein compared with the original sequence, which may increase transmissibility by affecting binding affinity and evading the immune response.[16] The present study showed that the transmissibility of omicron among HCWs was rapid, and the number of infections increased daily, which was consistent with previous findings.

Since the beginning of the pandemic, HCWs begun to pay attention to personal protective measures. Our results showed that the rate of occupational infections was particularly lower than non-occupational infections, consistent with a recent study on HCWs in Italy, during the omicron transmission period, the proportion of occupational infections was

Table 5 Factors Associated with High Fever by Univariate and Stepwise Multiple Logistic Regression

Variable	≥ 38.5°C (n=239)	< 38.5°C (n=86)	Univariate Analysis		Multivariate Analysis	
	n (%)	n (%)	Crude OR (95% CI)	*P* value	Adjusted OR (95% CI)	*P* value
Sex						
Male	39 (78.0)	11 (22.0)	1.17 (0.58–2.35)	0.668	–	–
Female	200 (72.7)	75 (27.3)				
Age (year)						
≥40	53 (69.7)	23 (30.3)	0.78 (0.44–1.38)	0.391	–	–
<40	186 (74.7)	63 (25.3)				
BMI (kg/m^2)						
>24	56 (72.7)	21 (27.3)	0.94 (0.53–1.68)	0.842	–	–
≤24	180 (73.5)	65 (26.5)				
Preexisting basic diseases						
Yes	22 (59.5)	15 (40.5)	0.48 (0.24–0.98)	0.042	0.49 (0.24–1.00)	0.051
No	217 (75.3)	71 (24.7)				
Vaccines						
4 doses	65 (68.4)	30 (31.6)	0.75 (0.44–1.27)	0.287	–	–
0–3 doses	174 (75.7)	56 (24.4)				
Common cold						
≤3 times/year	220 (75.3)	72 (24.7)	2.25 (1.07–4.72)	0.032	2.20 (1.05–4.65)	0.038
>3 times/year	19 (57.6)	14 (42.4)				
Fatigue before infection						
Yes	133 (73.5)	48 (26.5)	1.06 (0.65–1.74)	0.821	–	–
No	106 (73.6)	38 (26.4)				
Poor sleep before infection						
Yes	84 (79.2)	22 (20.8)	1.58 (0.91–2.74)	0.106	/	0.062
No	155 (70.8)	64 (29.2)				
Sleep duration						
< 7 hours/day	77 (74.8)	26 (25.2)	1.02 (0.60–1.73)	0.945	–	–
≥ 7 hours/day	162 (73.0)	60 (27.0)				
Exercise habit						
≥ 3 times/week	30 (65.2)	16 (34.8)	0.63 (0.32–1.22)	0.170	/	0.183
< 3 times/week	209 (74.9)	70 (25.1)				
Wore masks in working						
≥95% times	215 (90.0)	76 (88.4)	1.18 (0.54–2.58)	0.681	–	–
<95% times	24 (10.0)	10 (11.6)				
Wore masks out working						
≥95% times	63 (26.4)	27 (31.4)	0.78 (0.46–1.34)	0.371	–	–
<95% times	176 (73.6)	59 (68.6)				
Wore gloves						
≥95% times	53 (22.2)	24 (27.9)	0.74 (0.42–1.29)	0.285	–	–
<95% times	186 (77.8)	62 (72.1)				
Wore face shield						
≥95% times	29 (12.1)	10 (11.6)	1.05 (0.49–2.26)	0.901	–	–
<95% times	210 (87.9)	76 (88.4)				

Notes: Adjustment for comorbidity, vaccines, poor sleep before infection and exercise habit.

relatively low as compared to infections acquired by same HCWs outside hospital.[10] Several previous studies have shown that the infection risk of clinical tasks involving direct or close contact with COVID-19 patients is higher than administrative services.[9,10,15] Our results demonstrated that frontline HCWs are at a high risk of omicron infection, nurses and clinicians have an increased risk of infection compared with medical technicians and other job tasks, as they have a higher frequency and duration of direct contact with patients, consistent with previous research. The proportion of infections among HCWs reported in this survey was consistent with previous reports.[17]

In addition to the respiratory tract, SARS-CoV-2 affects various organs, causing myocardial dysfunction, gastrointestinal symptoms, dermatological complications, and liver and kidney impairment.[18] Hui et al reported that omicron replicates faster in the bronchus but has a lower replication efficiency in the lung parenchyma than other SARS-CoV-2

Table 6 Comparisons of SARS-CoV-2 Infections of Healthcare Workers Between Occupational and Non-Occupational Infections

Variable	Occupational Infections (n=107)	Non-Occupational Infections (n=221)	*P* value
Age (year)	32.8±8.0	32.9±9.0	0.896
Sex			
Male	16 (15.0)	34 (15.4)	0.919
Female	91 (85.0)	187 (84.6)	
Job tasks			
Clinician	21 (19.6)	41 (18.6)	0.183
Nurse	54 (50.5)	95 (43.0)	
Medical Technician	19 (17.8)	36 (16.3)	
Others	13 (12.1)	49 (22.2)	

variants.[19] Our results showed that the most common symptoms of omicron infection were cough, fever, runny nose, sore throat, headache, muscle aches, and fatigue, mainly expressed as upper respiratory tract infection. No severe pulmonary infection was observed among HCWs at the deadline of our study, mainly because of the high vaccination rate of HCWs. More than two-thirds of the participants had an overlap of five or more onset symptoms. A study of UK participants with positive symptomatic PCR or antigen test results for SARS-CoV-2 showed that the most frequently reported symptoms among omicron infections were runny nose, headache, sore throat, sneezing, and persistent cough, which are similar to our results.[20]

Interestingly, poor sleep quality led to increased symptoms after infection. Several studies have shown that sleep is important in maintaining the stability of the immune system and health of the population.[21] Sleep deprivation has been shown to alter the immune system and impair the immune response, possibly causing immune dysregulation, inflammation, and facilitating viral infection.[22,23] Previous studies have shown that sleep deprivation, poor sleep quality, and high fatigue are possible risk factors for SARS-CoV-2 infection and are related to negative outcomes.[24,25] Sleep disorders are common among clinical frontline staff because of their extended and/or night shift work, which may facilitate SARS-CoV-2 infection and aggravate symptoms during infection.[26,27] In this study, approximately one-third of the participants slept for less than 7 h per day or had poor sleep quality, and long-term sleep deficiency may lead to immune dysregulation. Alleviating long-term fatigue and sleep deficiency is important through adjustment of the shift arrangements and working states to maintain optimal immune function and prevent repeated infections and severe symptoms.

Moreover, our results have an interesting finding that those who had common cold ≤3 times per year were more likely to have a high fever after omicron infection. Although the common cold is a relatively mild, self-limiting illness, immunocompromised individuals are more susceptible to infections caused by common cold viruses.[28] As fever is the predominant thermoregulatory response to infection and inflammatory diseases, high body temperatures enhance the effectiveness of systemic immune responses during infection via stimulating both innate and adaptive immunity.[29]

Interestingly, the vaccination status was unrelated to symptom diversity. The neutralizing antibody titer of the vaccine immunization gradually decreased after 6 months. Several studies have demonstrated that the omicron variant escapes most monoclonal antibodies and is neutralized by antibodies generated by a stronger vaccine dose.[4,30] As three doses of vaccine are enough to be protected against symptomatic disease, and the fourth-dose vaccination of the participants was within 14 days in this study, which may be the reason the vaccination dose was not related to multiple onset symptoms.

However, this study had several limitations. First, the sample included a larger proportion of female and less of male, which may have resulted in sampling bias. Second, the response rate was low, and the structure of gender and positions was inconsistent, which may have resulted in a bias in sample representativeness. Finally, as we included infected HCWs at the initial stage of the epidemic, the sample size was small, and the short duration of the survey may have resulted in a bias in some onset symptoms. However, these results require further large-scale external verification.

Conclusion

The SARS-CoV-2 epidemic is ongoing globally and remains a challenge for the public. This study analyzed the infections and symptoms in HCWs during the first wave of the epidemic after the normalization of prevention and control measures in China. The present findings imply rapid transmissibility of omicron and multiple-onset symptoms after omicron infection among HCWs in mainland China. Clinical frontline workers have an increased risk of infection compared with other job tasks such as administrative services. Sleep disorders are common among HCWs, poor sleep quality is a risk factor associated with more onset symptoms, and the common cold ≤3 times/year is a risk factor for high fever after infection. Protective measures, such as ensuring an adequate supply of personal protective measures, adequate rest and sleep time, improving sleep quality, and alleviating fatigue, are of great significance in protecting HCWs from infection and alleviating symptoms, thus helping maintain the hospital's treatment capacity. Improved autoimmunity and self-protection measures for HCWs at high biological risk may be helpful in controlling COVID-19 infection and clinical symptoms. This study also provided empirical reference values for countermeasures and improved protective measures for the public during major public health emergencies.

Ethics Approval

The study was approved by the ethics committee of Taizhou Hospital of Zhejiang province.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Disclosure

The authors report no conflicts of interest in this work.

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