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Mental health, health-related quality of life, and lung function after hospital discharge in healthcare workers with severe COVID-19: a cohort study from China

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Coronavirus disease 2019 (COVID-19) is an acute respiratory infectious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection. It is highly contagious and can cause death in severe cases. As reported by the World Health Organization (WHO), as of 6:36 pm Central European Summer Time (CEST), 12 August 2022, there had been 585 950 285 confirmed cases of COVID-19, including 6 425 422 deaths (WHO, 2022).

According to previous studies, healthcare workers (HCWs) have a higher risk of developing COVID-19 compared with the general community, and the severity of COVID-19 is closely related to the health-related effects after discharge (Huang et al., 2021). Therefore, the health consequences of COVID-19, especially in critically ill HCWs, have been in the focus of research worldwide. Hubei Province has the highest proportion of severe COVID-19 among Chinese HCWs. As reported in February 2020, 64% (1088/1688) of the HCWs with severe COVID-19 were from Hubei Province, especially Wuhan (Epidemiology Working Group for NCIP Epidemic Response, Chinese Center for Disease Control and Prevention, 2020). Therefore, studying the health impacts of these critically ill HCWs after hospital discharge is of great significance to the improvement of global public health.

A number of studies have focused on the health consequences in convalescent phase in patients with COVID-19 (Chew et al., 2020; Huang et al., 2020, 2021; Xiang et al., 2020; Wu et al., 2021). However, no study has yet reported both the psychological and physical consequences of severe COVID-19 in frontline HCWs after discharge. In this study, we aimed to investigate the mental health, health-related quality of life, and lung function of HCWs with severe COVID-19 after discharge from the hospital based on the "Rehabilitation Care Project for Medical Staff Infected with COVID-19" (Xiong et al., 2021a, 2021b, 2022) in China.

The 656 enrolled HCWs with COVID-19, who were discharged from the hospital from 22 January 2020 to 25 May 2020, completed several questionnaires, lung function tests, and 6-min walking tests in follow-up visits from July 2020 to January 2021. In this study, HCWs with missing admission information (n=116), no information on comorbidities (n=15), or those with mild or moderate COVID-19 (n=192) were

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excluded. Of the remaining 333 HCWs with severe COVID-19, 164 HCWs completed a mental health questionnaire on Day 139.4 (127.3, 150.5) after discharge, 197 HCWs completed the short form 36 health survey questionnaire (SF-36) on Day 158.0 (146.0, 184.0) after discharge, 170 HCWs completed a lung function test, and 148 completed a 6-min walking test on Day 205.0 (186.0, 225.8) after discharge (Fig. 1).

The demographic and clinical characteristics of 333 HCWs with severe COVID-19 have been described in detail in our prior study (Xiong et al., 2021a). The results showed that HCWs' median age was 36.0 (31.0, 43.0) years, 77% of the HCWs were female (n=257), and 57% of the HCWs were nurses (n=191).

On Day 139.4 (127.3, 150.5) after discharge, 164 participants completed the Essen Trauma Inventory questionnaire. According to the criteria of Diagnostic and Statistical Manual-Fourth Edition, Text Revision (DSM-IV-TR), 23% (37/164) of the HCWs with severe COVID-19 were diagnosed with post-traumatic stress disorder (PTSD). There was no statistically significant difference in the prevalence of PTSD between male (7/33, 21%) and female (30/131, 23%) HCWs. Using multivariable adjusted logistic regression to analyze the potential risk factors (age, education, roles in work, sex, body mass index (BMI), smoking habit, comorbidities, residual symptom of headache, residual symptom of dizziness, residual symptom of palpitation, residual symptom of difficult breathing, intensive care unit (ICU) admission, physical harm, life in danger, physical harm of others, life in danger of someone else, and other trauma in addition to COVID-19) that were associated with the risk of PTSD, we found that age of >36 years (odds ratio (OR) 4.02, 95% confidence interval (CI) (1.08, 14.92)), ICU admission (OR 25.49, 95% CI (3.70, 175.69)), residual symptom of dizziness (OR 3.58, 95% CI (1.24, 10.28)), and life in danger (OR 21.51, 95% CI (1.72, 269.32)) were related to the risk of PTSD (Table 1).

In the present study, 197 HCWs with severe COVID-19 completed the SF-36 questionnaire on Day 158.0 (146.0, 184.0) after discharge. After adjusting for age, sex, education, roles in work, BMI, smoking habit, days of admission, and days of completing the questionnaire, it was revealed by the multivariable adjusted linear regression model that HCWs with comorbidities

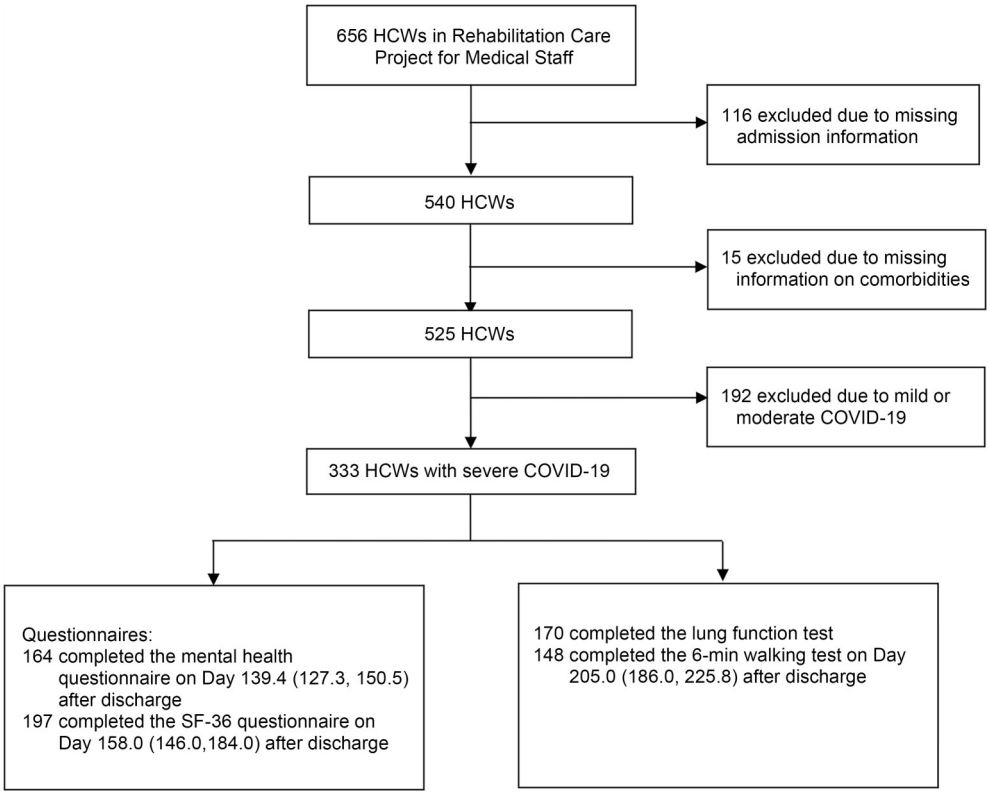

Fig. 1 Flow diagram of this study. HCWs: healthcare workers; SF-36: short form 36 health survey questionnaire; COVID-19: coronavirus disease 2019.

Table 1 Factors associated with the risk of PTSD in HCWs with severe COVID-19 (*n*=164)

Category	OR (95% CI)	*P* value
Age (years)		0.04
⩽36	1	
>36	4.02 (1.08, 14.92)	
ICU admission		0.001
No	1	
Yes	25.49 (3.70, 175.69)	
Residual symptom of dizziness		0.02
No	1	
Yes	3.58 (1.24, 10.28)	
Life in danger		0.02
No	1	
Yes	21.51 (1.72, 269.32)	

HCWs: healthcare workers; ICU: intensive care unit; PTSD: post-traumatic stress disorder; OR: odds ratio; CI: confidence interval; COVID-19: coronavirus disease 2019.

had lower scores for bodily pain than those without (β −4.30, 95% CI (−7.92, −0.68)) (Table 2). No differences were found in the remaining seven aspects of health-related quality of life after discharge among medical staff with or without complications. In addition, no gender differences in health-related quality of life after discharge were found.

On Day 205.0 (186.0, 225.8) after discharge, 170 HCWs with severe COVID-19 completed the total lung capacity test, 163 completed the measurement of diffusion capacity, and 148 completed the 6-min walking test. We found that the most affected parameter was the lung perfusion capacity (mainly diffusion capacity for carbon monoxide (DLCO) and DLCO/alveolar ventilation (VA)) in HCWs with severe COVID-19. In this study, 36% (59/163) and 21% (35/163) of the HCWs with severe COVID-19 presented DLCO of <80% and DLCO/VA of <80%, respectively (Table 3). Obstruction (forced expiratory volume in one second (FEV_1)/forced vital capacity (FVC)<70%) and restriction (total lung capacity (TLC)<80%) were found in 11% and 2% of patients, respectively. No differences were found between the genders in the lung function of HCWs and between those with or without comorbidities (all *P* values>0.05). The results of the 6-min walking test showed that male HCWs walked longer than females (β 45.97, 95% CI (14.97, 76.97)), whereas male HCWs were more likely to walk less than the lower limit of the normal range than females (OR 7.20, 95% CI (1.03, 50.23)) (Table 3).

In the Chinese cohort of HCWs with COVID-19, the results showed that on Day 139.4 (127.3, 150.5) after discharge, 23% of the HCWs with severe COVID-19 were diagnosed with PTSD, and the factors associated with the risk of PTSD were age of >36 years, ICU admission, residual symptoms of dizziness, and

Table 2 Health-related quality of life at follow-up according to sex and comorbidities from SF-36 questionnaire

Category	Total (*n*=197)	Sex		β (95% CI)		Comorbidities		β (95% CI)	
		Female (*n*=163)	Male (*n*=34)	Female	Male	No (*n*=134)	Yes (*n*=63)	No	Yes
Physical functioning	85.0 (70.0, 90.0)	85.0 (70.0, 90.0)	85.0 (71.3, 90.0)	0	−2.64 (−9.97, 4.69)	85.0 (70.0, 90.0)	80.0 (65.0, 87.5)	0	−0.69 (−5.60, 4.22)
Role-physical	25.0 (0.0, 75.0)	25.0 (0.0, 75.0)	37.5 (0.0, 75.0)	0	−0.32 (−18.68, 18.03)	25.0 (0.0, 75.0)	0.0 (0.0, 75.0)	0	−1.91 (−14.20, 10.38)
Bodily pain	60.0 (60.0, 70.0)	60.0 (60.0, 70.0)	60.0 (60.0, 60.0)	0	0.54 (−4.87, 5.94)	60.0 (60.0, 70.0)	60.0 (60.0, 60.0)	0	−4.30 (−7.92, −0.68)*
General health	45.0 (30.0, 60.0)	45.0 (30.0, 57.5)	52.5 (41.3, 60.0)	0	−1.23 (−9.61, 7.13)	50.0 (35.0, 60.0)	45.0 (30.0, 55.0)	0	0.24 (−5.36, 5.84)
Energy/vitality	60.0 (45.0, 75.0)	60.0 (45.0, 75.0)	60.0 (46.3, 75.0)	0	−3.03 (−12.57, 6.51)	65.0 (50.0, 75.0)	60.0 (45.0, 75.0)	0	−3.18 (−9.57, 3.21)
Social functioning	77.8 (55.6, 88.9)	77.8 (55.6, 88.9)	72.2 (55.6, 88.9)	0	0.97 (−9.27, 11.19)	77.8 (55.6, 88.9)	66.7 (55.6, 77.8)	0	−4.01 (−10.87, 2.84)
Role-emotional	33.3 (0.0, 100.0)	33.3 (0.0, 100.0)	33.3 (0.0, 91.7)	0	−3.38 (−22.98, 16.21)	33.3 (0.0, 100.0)	33.3 (0.0, 83.3)	0	−3.05 (−16.18, 10.07)
Mental health	64.0 (48.0, 76.0)	68.0 (48.0, 80.0)	60.0 (48.0, 67.0)	0	−8.85 (−18.66, 0.96)	66.0 (48.0, 79.0)	64.0 (48.0, 74.0)	0	0.13 (−6.43, 6.70)

All data are expressed as median (interquartile range) unless otherwise specified. * *P*<0.05. For associations of sex and comorbidities with outcome measurement, the variables including age, sex, education, roles in work, body mass index (BMI), smoking habit, comorbidities, days of admission, and time of completing the questionnaires were all included in the models. SF-36: short form 36 health survey questionnaire; CI: confidence interval.

Table 3 Lung function and 6-min walking tests at follow-up according to sex and comorbidities

Category	Total	Sex		OR or β (95% CI)		Comorbidities		OR or β (95% CI)	
		Female	Male	Female	Male	No	Yes	No	Yes
Lung function test									
Number of HCWs	170	134	36			119	51		
FEV_1<80% (percentage of predicted)	7 (4%)	6 (4%)	1 (3%)			6 (5%)	1 (2%)		
FVC<80% (percentage of predicted)	0	0	0			0	0		
FEV_1/FVC<70%	18 (11%)	16 (12%)	2 (6%)			13 (11%)	5 (10%)	1	OR 0.78 (0.23, 2.64)
RV<80% (percentage of predicted)	21/163 (13%)	17/129 (13%)	4/34 (12%)	1	OR 0.93 (0.16, 5.25)	14/112 (13%)	7/51 (14%)	1	OR 0.81 (0.25, 2.65)
TLC<80% (percentage of predicted)	3/163 (2%)	2/129 (2%)	1/34 (3%)			3/112 (3%)	0		
FRC<80% (percentage of predicted)	25/163 (15%)	18/129 (14%)	7/34 (21%)	1	OR 1.71 (0.39, 7.49)	13/112 (12%)	12/51 (24%)	1	OR 2.50 (0.90, 6.94)
DLCO<80% (percentage of predicted)[†]	59/163 (36%)	57/129 (44%)	2/34 (6%)			39/112 (35%)	20/51 (39%)	1	OR 1.10 (0.49, 2.44)
DLCO/VA<80%	35/163 (21%)	35/129 (27%)	0			22/112 (20%)	13/51 (25%)	1	OR 1.92 (0.77, 4.82)
6-min walking test									
Number of HCWs	148	116	32			101	47		
Distance walked in 6 min (m)	577.4 (551.8, 618.0)	569.5 (542.0, 602.3)	623.5 (585.8, 645.8)	0	β 45.97 (14.97, 76.97)[*]	575.0 (549.0, 615.0)	583.4 (553.3, 638.9)	0	β 0.10 (−22.18, 22.39)
Percentage of predicted value (%)[‡]	87.0 (81.0, 93.0)	87.5 (81.0, 93.3)	85.0 (81.5, 90.0)	0	β −4.65 (−9.58, 0.29)	87.0 (80.0, 93.0)	87.0 (83.5, 93.0)	0	β −0.26 (−3.29, 3.81)
Less than lower limit of the normal range[§]	27/148 (18%)	20/116 (17%)	7/32 (22%)	1	OR 7.20 (1.03, 50.23)[*]	20/101 (20%)	7/47 (15%)	1	OR 0.65 (0.21, 2.07)

[*] P<0.05. [†] The carbon monoxide diffusion capacity was not corrected for hemoglobin. [‡] The predicted values were calculated according to the method of Enright and Sherrill (1998). [§] The lower limit of the normal range was calculated by subtracting 153 m from the predicted value for men or by subtracting 139 m for women. For associations of sex and comorbidities with outcome measurement, the variables including age, sex, education, roles in work, body mass index (BMI), smoking habit, comorbidities, days of admission, and time of completing the tests were all included in the models. Data are expressed as number (percentage), number/total number (percentage), or median (interquartile range), unless otherwise specified. The differing denominators used indicate missing data. HCWs: healthcare workers; DLCO: diffusion capacity for carbon monoxide; FEV_1: forced expiratory volume in one second; FRC: functional residual capacity; FVC: forced vital capacity; OR: odds ratio; RV: residual volume; TLC: total lung capacity; VA: alveolar ventilation; CI: confidence interval.

life in danger due to COVID-19. On Day 158.0 (146.0, 184.0) after discharge, HCWs with severe COVID-19 with comorbidities had lower scores in the assessment of bodily pain.

We found that the prevalence of PTSD in HCWs with severe COVID-19 was 21.2%, which may be related to the fact that they experienced "double exposure" (they were infected and also witnessed the infection and death of others) (Xiao et al., 2020). The risk of PTSD in Chinese HCWs who were free from COVID-19 was 4.8% (Xiong et al., 2021b). Thus, the risk of PTSD in Chinese HCWs with severe COVID-19 was 4–5 times of that in normal control HCWs. The prevalence of PTSD in HCWs with severe COVID-19 in this study (21.2%) was higher than that of PTSD in HCWs in Singapore and India (7.4%) (Chew et al., 2020), but was lower than that of PTSD in HCWs who worked in ICUs in the UK during COVID-19 (40%) (Greenberg et al., 2021). On Day 139.4 (127.3, 150.5) of discharge, the high risk of PTSD suggested that alertness was needed regarding the risk of PTSD and the chronic course of PTSD. Herein, we found that ICU admission was related to the risk of PTSD, which may be linked to the use of invasive medical procedures including mechanical ventilation in the ICU. Relationship between life in danger due to COVID-19 and PTSD may partly be explained by trauma factors. In the future, more studies should be conducted

to effectively explore early psychosocial interventions strategies for high-risk populations of PTSD.

Regarding the health-related quality of life, on Day 158.0 (146.0, 184.0) after discharge, this study found that HCWs with severe COVID-19 with comorbidities had lower scores in bodily pain than those without. This was consistent with findings of Huynh et al. (2022) where the scores of quality of life in COVID-19 patients with comorbidities were higher than those without. We did not observe significant associations between sex and scores of SF-36. A follow-up study in China reported that female patients with COVID-19 had lower scores for bodily pain and role-emotional than males (Chen et al., 2020). In comparison, the scores for bodily pain (our median value: 60.0; their mean value: 89.8) and role-emotional (our median value: 33.3; their mean value: 91.1) in our study were much lower than the scores reported in population with normal health (Chen et al., 2020). Guo et al. (2020) found that male patients with COVID-19 had decreased score in the role-emotional domain. Due to the above inconsistencies, the associations of sex and health-related quality of life in different populations with COVID-19 deserve further investigation.

We found that up to 36% of the HCWs with severe COVID-19 had diffusion impairment on Day 205.0 (186.0, 225.8) after discharge, which was similar to that reported by Jin Yin-tan Hospital in China (Huang et al., 2021). They reported that 22%–56% of patients with COVID-19 of various severity scales had pulmonary diffusion abnormality at six months after symptom onset. In our study, the results of male HCWs in the 6-min walking test were worse than those of female HCWs. We did not complete the HCWs' lung function test or the 6-min walking test at baseline. It is still unclear to what extent the observed results in our study were related to SARS-CoV-2 infection, though we found that very few HCWs had reported lung and/or heart disease at baseline. Thus, the recovery of lung function over a longer period of time, especially in male HCWs, deserves further attention.

This research has several limitations. Firstly, the questionnaires used were all completed online, and we could not rule out that the participants misunderstood some of them, even though the questions were explained in detail and we would verify the answers with the HCWs if conflicts existed. Secondly, we did not evaluate the participants' lung function and 6-min walking test level at baseline. Therefore, the abnormalities of lung function and 6-min walking test observed in our study may not be directly related to SARS-CoV-2 infection. Nonetheless, the proportions of HCWs suffering from chronic lung disease and heart disease at baseline were not high (self-reported at enrollment). Thirdly, regarding the mental health of the HCWs, only PTSD was diagnosed, and future studies should also focus on other mental disorders besides PTSD. Lastly, the sample size of our study may be limited despite that we had included 333 HCWs with severe COVID-19 in Hubei Province, which is to date the highest proportion of enrolled HCWs with severe COVID-19 in China. Our results need to be confirmed by larger cohort studies in the future.

In summary, this is the first study considering both the psychological and the physical consequences of severe COVID-19 in HCWs after hospital discharge. The findings suggest that psychological and physical recovery support and active interventions must be given to HCWs with severe COVID-19 after discharge, especially among male HCWs and those with comorbidities.

Data sharing

Restrictions apply to the availability of these data, and hence they are not available publicly but can be obtained from the corresponding author on reasonable request. A proposal with a detailed description of study objectives and statistical analysis plan will be needed for the evaluation of the reasonability of such request. The corresponding author and the institution will make a decision based on these materials; those data are available upon reasonable request and with the permission of the corresponding author and institution. Additional materials may also be required during the process.

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Author contributions

Yu HU, Jiahong XIA, Yang JIN, Lijuan XIONG, Xiongjing CAO, and Qian LI contributed to the study design and methods. Lijuan XIONG and Qian LI drafted the manuscript. Qian LI, Huangguo XIONG, Daquan MENG, Yanzhao ZHANG, and Liang TANG conducted the statistical analyses. Lijuan XIONG, Xiongjing CAO, Daquan MENG, Mei ZHOU, Yanzhao ZHANG, Xinliang HE, and Yupeng ZHANG were responsible for the implementation of the project. Yu HU, Jiahong XIA, Yang JIN,

and Lijuan XIONG managed the project and provided guidance. Yu HU took responsibility for the integrity of the data and the accuracy of the data analysis. All authors had full access to all the data in the study. All authors revised the manuscript and gave final approval for the version to be published.

Compliance with ethics guidelines

Lijuan XIONG, Qian LI, Xiongjing CAO, Huangguo XIONG, Daquan MENG, Mei ZHOU, Yanzhao ZHANG, Xinliang HE, Yupeng ZHANG, Liang TANG, Yang JIN, Jiahong XIA, and Yu HU declare that they have no conflict of interest.

According to the principles of the Declaration of Helsinki, this research was approved by the Ethics Committee of Union Hospital, Tongji Medical College, Huazhong University of Science and Technology (No. 2020-0506). Informed consent was obtained from all healthcare workers for being included in the study.

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