https://doi.org/10.1016/j.ijdrr.2021.102658

Long-term effects of disaster exposure on health care workers' resilience: A comparison of the Wenchuan earthquake-exposed and unexposed groups

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Abstract

Background: Resilience is an important trait of health care workers (HCWs), especially those who are exposed to disasters and disaster rescue efforts. However, few studies have examined the long-term impact of disaster exposure on HCWs' resilience.

Objectives: This study aimed to compare the resilience of HCWs exposed to the Wenchuan earthquake to those who were not exposed 11 years after the earthquake. Additionally, it aimed to examine the effect of HCWs' workplaces, individual sociodemographic factors and post-trauma growth on their resilience.

Methods: A cross-sectional self-administrated survey was used. The Connor-Davidson Resilience Scale (CD-RISC25) was used to measure resilience. Sociodemographic factors were evaluated using descriptive statistical analyses and the relationship between resilience and exposure to the Wenchuan earthquake was assessed using multilevel regression analysis.

Results: Both exposed and unexposed HCWs reported low levels of resilience. Disaster exposure was not significantly associated with their resilience 11 years post-earthquake. Participants who worked in larger hospitals reported a higher level of resilience. Females and those with higher educational levels, longer service length or higher post-trauma growth scores had significantly increased resilience across different regression models.

Conclusions: The findings suggest the need for resilience interventions for all HCWs in disaster-prone areas, especially in the case of junior HCWs with lower educational levels working in small hospitals. Further research is warranted to identify optimal strategies to build and advance HCWs' resilience and sustain their mental health when responding to disasters.

Keywords: resilience, Connor-Davidson Resilience Scale, Post-Traumatic Growth Inventory, health care workers, the Wenchuan earthquake

Introduction

Resilience describes an individual's ability to recover from adversity and setbacks [1, 2]. It is important for health care workers (HCWs) to build resilience, especially for those exposed to disasters and disaster rescue efforts [3-6]. Resilience can help HCWs to prevent anxiety and depression [7], reduces the negative effects of disaster-associated secondary traumatic stress [8], and reduces stress and emotional burnout and improves wellbeing over time [9]. Resilience is also an important indicator of the mental health status of HCWs who are affected by disasters [10]. Therefore, assessing resilience and investigating associated factors have become increasingly important goals of studies examining HCWs' occupational mental health.

Disaster exposure is an important factor to consider when examining HCWs' resilience [6]. The United Nations Office for Disaster Risk Reduction has defined exposure as 'the situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas' [11]. On the one hand, HCWs are exposed to disasters as rescue team members. When responding to disasters, HCWs build the rescue team and provide interprofessional health care to the individuals, families and communities affected by the disaster [12]. They usually work under harsh conditions and make critical clinical decisions in the field [13]. They may also encounter extreme difficulties, such as family causalities, housing damage and financial loss caused by disaster [14]. Moreover, they may feel afraid of potential disaster recurrence and the necessity of providing healthcare services for an unknown period [15]. Disaster relief efforts are thus of paramount importance for the physical and psychological welfare of HCWs themselves [16, 17]. A relatively high proportion of probable post-traumatic stress disorder (PTSD) has been reported among HCWs who participate in disaster rescue [18, 19].

On the other hand, HCWs living in disaster-prone and disaster-affected communities are also survivors themselves [20]. Like the public, their experiences of the disaster (not necessarily as rescue team members) significantly influences HCWs' disaster preparedness [21]. Individuals who have experienced past disasters are often more prepared for future disasters through preparation of emergency supplies at home [22]. Additionally, age at the time of the disaster can alter the disaster's impact on the survivor's mental health. In a study of multiple hurricanes, it was found that adolescent survivors experienced reduced depression and PTSD up to 9 years post-disaster compared to adult survivors [23]. According to a three-year longitudinal study of the 2011 Great East Japan Earthquake, survivors, especially adolescent/young survivors, typically experienced significantly increased resilience post-disaster [24]. Thus, past disaster experiences in adolescence were included as an associated factor when examining HCW's resilience.

A devastating disaster can affect the physical and mental health of both rescue team members [25] and survivors for decades [26]. However, few studies have examined the resilience of HCWs in the aftermath of such disasters [6, 27]. Moreover, few studies have examined the long-term (e.g. > 10 years) impact of disaster exposure on HCWs' resilience [20]. Additionally, most previous studies lack unexposed comparison groups to distinguish the specific impact of the disaster on resilience [27]. Our study aimed to address these shortcomings by comparing resilience between disaster-exposed and unexposed HCWs more than 10 years after a devastating disaster. The 2008 Wenchuan earthquake was selected as a case-study to investigate the resilience of HCWs in a post-disaster setting. Earthquakes are the result of complex seismogenic dynamics that lead to severe aftershocks alternately releasing residual stress at both ends of the fissures [28]. The Wenchuan earthquake struck the Sichuan Province

of southwest China on May 12, 2008. It was one of the most destructive earthquakes to occur in China because of the large area affected and number of disaster-associated losses [29]. According to estimates from August 25, 2008, 69,226 people were killed, along with 374,643 injured and 17,923 missing [29]. Moreover, the earthquake damaged approximately 23 million housing units, with a total direct economic loss of RMB 845.1 billion [29]. The Wenchuan earthquake triggered significant developments in disaster medicine [30], disaster nursing [31] and disaster-related research [32] in China. Therefore, it is important to examine the long-term (e.g. > 10 years) effects of the Wenchuan earthquake on HCWs' resilience.

In addition to disaster exposure, the workplace (e.g. hospital characteristics) is an important factor that might significantly affect HCWs' mental health when responding to disasters [33]. Moreover, sociodemographic factors, such as marital status, are significantly associated with the resilience of adult disaster survivors, findings supported by a study five years after a severe earthquake [34]. Furthermore, post-traumatic growth is an essential factor influencing individual resilience [35, 36]. Post-traumatic growth is 'the experience of positive change that occurs as a result of the struggle with highly challenging life crises' [37]. Post-traumatic growth can occur at both personal and professional levels after a disaster, giving HCWs a greater appreciation of life and their relationships, enhancing their self-esteem and providing a sense of accomplishment and a better understanding of their work [10]. Therefore, disaster exposure, workplace characteristics, sociodemographic factors and post-traumatic growth are important factors to consider when examining HCWs' post-disaster resilience.

This study aims to compare the resilience of HCWs exposed to the Wenchuan earthquake to unexposed HCWs 11 years post-disaster. Specifically, the study addressed the following research questions:

RQ1: What are the differences in the resilience of HCWs exposed to the Wenchuan earthquake and those who were not exposed?

RQ2: What associations exist between HCWs' resilience and Wenchuan earthquake exposure, workplace characteristics, individual sociodemographic factors and post-traumatic growth?

Methodology

Study Design

A cross-sectional survey design was used in this study. There were three field sites (Hospital A, B and C) located in the Sichuan Province of China (Figure 1). The three hospitals were selected according to (i) experiencing different Wenchuan earthquake intensities and different levels of resultant damage and (ii) variable numbers of HCWs and beds and different rankings in the 3-tier Chinese hospital system.

Specifically, hospitals A and B are in Chengdu, the capital city of Sichuan Province. The hospitals were located in level VI to VII areas during the Wenchuan earthquake according to the China seismic intensity scale, whereas Hospital C, in Mianzhu, was in a level IX to X region [38]. Mianzhu was one of the 10 counties that experienced the most severe earthquake damage [39]. In level X areas, cyclists fall off their bikes, people have the sense of being thrown up in the air and many buildings collapse [38]. All three hospitals rank at the tertiary level, but they share different numbers of HCWs and beds (Table 1). Hospital A is the largest hospital in

Sichuan Province, with the greatest number of beds (4,300) and workers (~10,000, including 2,021 medical doctors and 3,922 registered nurses). Hospital C has the fewest beds (800) and workers (1,163, including 344 medical doctors and 557 registered nurses) among the three hospitals. The project also collected data from another hospital, located in Fujian Province, East China. However, the data from this hospital was not included in the study of the long-term effects of disaster exposure on HCWs' resilience because it is located far from the epicentre of the Wenchuan earthquake.

<Table 1. Profiles of the three field sites about here>

<Figure 1. Map of the sampled hospitals about here>

Participants

Inclusion into criteria were as follows: (a) being a medical doctor or registered nurse in any of the included hospitals and (b) willingness to complete the online questionnaire. Exclusion criteria were (a) prolonged sick leave due to illness or (b) maternity leave.

The sample size was large enough to ensure that parameter estimates were within the acceptable margin of error of 4%, with a confidence level of 95%. Approximately 500 valid questionnaires were collected from each hospital (Table 1). However, the percentages of participating medical doctors and nurses varied. Hospital C had the highest proportion of participants (149/535, 27.9%), whereas only one medical doctor from Hospital B participated in the study (1/503, 0.2%).

Measurements

Individual resilience: In this study, resilience referred to the individual psychological capability of HCWs and their ability to recover from disastrous events. The full version of the Connor-Davidson Resilience Scale (CD-RISC25) [1] and its validated Chinese version [40] were used to assess the individual resilience of HCWs in China. The HCWs were asked to rate the 25 statements using a 5-point Likert scale ranging from 0 ('not true at all') to 4 ('true nearly all the time'), for a total score ranging from 0 to 100. A higher total score indicated a higher level of personal resilience. The CD-RISC25 has been validated and has good internal consistency. The Cronbach's alpha score of the CD-RISC25 was 0.89 when it was first validated using samples of the public in the United States [1], whereas a survey of HCWs during the COVID-19 pandemic in China scored 0.96 [41]. For the present study, Cronbach's alpha was 0.97.

Disaster exposure: Informed by the methods used to assess disaster exposure in a study of HCW stress and burnout after the 2009 L'Aquila earthquake [20] and the local context of Sichuan, we divided the participants into three groups according to their direct exposure to the Wenchuan earthquake, including unexposed HCWs (who did not report any experience of the Wenchuan earthquake), exposed HCWs as survivors (who experienced the Wenchuan earthquake as survivors), and exposed HCWs as rescuers (who experienced the Wenchuan earthquake as rescue team members).

Hospitals: Three hospitals participated in the survey (Hospital A, B, and C). They each had different geographical locations and different numbers of HCWs and beds (see Table 1).

Sociodemographic factors: Sociodemographic factors included gender (male/female), education levels (college or below/university or above), marital status (unmarried/married), professional (medical doctor/registered nurse), age and length of service in years.

Post-traumatic growth: The validated Chinese version of the Post-Traumatic Growth Inventory (PTGI) [42] was used in this study, which includes 21 items to measure post-traumatic growth [43]. A 5-point Likert scale ranging from 0 ('I did not experience this change as a result of my crisis') to 5 ('I experienced this change to a very great degree as a result of my crisis') was used by participants to rate each item of the PTGI. The total score of the PTGI ranged from 0 to 105, with a higher score indicating a higher level of post-traumatic growth. The PTGI is comprised of five domains: relating to others (7 items, score of 0–35), new possibility (5 items, score of 0–25), personal strength (4 items, score of 0–20), spiritual change (2 items, score of 0-10) and appreciation of life (3 items, score of 0–15) [43, 44].

Procedure

A self-administered online questionnaire survey was used to assess HCWs' resilience in May 2019, the same month as the occurrence of the Wenchuan earthquake. An online survey tool, Wenjuanxing [45], and the Chinese versions of the scales were used in the dissemination of the online questionnaire. Official consent was obtained from each participant before the survey. This study was reviewed and approved by the Human Subjects Ethics Sub-Committee of the affiliated university (Ref. HSEARS20190416035).

Statistical analysis

A descriptive analysis was carried out to understand the sociodemographic factors and resilience levels of the HCWs. Multilevel regression models were established to examine the effects of the Wenchuan earthquake, workplace characteristics, sociodemographic factors and post-traumatic growth on HCWs' resilience. All analyses were conducted using SPSS software, version 25.0, with the threshold for statistical significance set at a two-tailed $\alpha = 0.05$. The beta coefficient (β), associated two-tailed p-values (p) and 95% confidence interval (CI) were reported for each independent variable in the regression models. One-way analysis of variance (ANOVA), p-values and R^2 values were used to assess the performance of each model.

Results

Descriptive analysis

Among the 1,527 HCWs, 33.5% experienced the Wenchuan earthquake (512/1,527), and 66.5% did not experience it (Table 2). Almost equal sized samples were collected in each of the three hospitals. However, significant differences were found in HCWs' disaster exposure by hospitals ($\chi^2(4) = 71.965$, $p < 0.001$), as expected based on their locations. Specifically, Hospital C reported the largest percentage of participants who were exposed to the Wenchuan earthquake as survivors (51.5%, 104/202) and rescuers (45.5%, 141/310). Hospitals A and B reported a smaller percentage of exposed HCWs.

There were more female HCWs than males in across all three hospitals (1,350 vs. 177). No significant gender difference was found between the unexposed and exposed groups ($\chi^2(2) = 1.221$, $p = 0.543$). More participants had a college or below education level than a university or above level (889 vs. 638). The education level of the HCWs was significantly higher than

that of the public in Sichuan province [46]. A significant difference in education level was noted between the unexposed and exposed HCWs ($\chi^2(2) = 29.566$, $p < 0.001$). The percentage of exposed HCW survivors with a university education or higher was the lowest (49/202, 24.3%) among the three groups. More married participants were sampled than unmarried participants (1,074 vs. 453). A significant difference was observed between unexposed and exposed HCWs regarding marital status ($\chi^2(2) = 115.107$, $p < 0.001$).

Over 80% of participants were registered nurses (1,355/1,527, 88.7%). Among the participants who were exposed to the Wenchuan earthquake, 89.3% were nurses (457/512). The mean participant age was 31.7 with an SD of 7.0, and the mean of the length of their service as HCWs was 10.2 years with an SD of 7.6. Significant differences were identified between unexposed and exposed groups regarding profession ($\chi^2(2) = 13.402$, $p < 0.001$), age ($F(2) = 182.711$, $p < 0.001$) and length of service in years ($F(2) = 138.815$, $p < 0.001$). The exposed HCW survivors were predominantly registered nurses (193/202, 95.5%), young (mean = 25.5, SD = 2.0) and had the shortest length of service (mean = 4.2, SD = 3.6) among the three groups.

The mean PTGI score was 35.4 with an SD of 24.0. No significant differences were found in mean PTGI scores between the three groups of HCWs with different extents of disaster exposure ($F(2) = 0.029$, $p = 0.972$). Similar results were found for each of the five subdomains.

<Table 2. Descriptive analysis of the exposed and unexposed HCWs about here>

The resilience of HCWs

The mean of CD-RISC25 for the total sample was 59.7 with an SD of 19.6. The group of exposed HCWs as rescuers had a slightly higher CD-RISC25 score (mean = 61.9, SD = 17.7) compared to the group of exposed HCWs as survivors (mean = 58.7, SD = 19.7) and unexposed HCWs (mean = 59.2, SD = 18.6, Table 3). However, these differences were not significant ($F(2) = 2.454$, $p = 0.086$).

Participants from different hospitals had significantly different CD-RISC25 scores ($F(2) = 17.020$, $p < 0.001$). Participants from Hospital A had the highest scores (mean = 63.7, SD = 17.1), whereas those from Hospital C reported the lowest scores (mean = 56.8, SD = 22.0).

Female HCWs (mean = 60.1, SD = 18.9) reported significantly higher CD-RISC25 scores than their male counterparts (mean = 56.2, SD = 23.6, $F(1) = 6.308$, $p < 0.05$). Moreover, HCWs with university or higher degrees (mean = 61.8, SD = 20.4) had higher CDRIS-25 scores than the ones with education levels of college or below (mean = 58.2, SD = 19.1, $F(1) = 12.994$, $p < 0.001$).

Furthermore, registered nurses (mean = 60.1, SD = 18.9) reported significantly higher CD-RISC25 scores than their male counterparts (mean = 56.8, SD = 23.8, $F(1) = 1.287$, $p < 0.05$).

Additionally, no significant differences were identified in HCWs' resilience when cross-tabulated with marital status ($F(1) = 0.001$, $p = 0.990$), age ($F(1) = 3.084$, $p = 0.079$) or length of service in years ($F(1) = 2.341$, $p = 0.126$).

<Table 3. CD-RISC25 score by different groups of HCWs about here>

The impact of disaster exposure, workplace characteristics, sociodemographic factors and post-traumatic growth on HCWs' resilience

Five different regression models were established to examine the effects of exposure to the Wenchuan earthquake, workplace characteristics, sociodemographic factors (including gender, education, marital status, profession and length of service) and post-traumatic growth on HCWs' resilience (Table 4, Models 1–5). The beta coefficient (β) of each model represents how much the dependent variable changes when the independent variables are increased by one standard deviation (SD). Age was not included in the regression models because of its high collinearity with length of service.

First, exposure to the Wenchuan earthquake as a survivor was not significantly associated with HCWs' resilience 11 years after the earthquake across different models (Models 1–5, Table 4). However, disaster exposure as a rescuer was significantly associated with resilience in the absence of any confounding variables (Model 1) and when the workplace was included as a confounding variable (Model 2).

Second, working in Hospital B was associated with a significant decrease in resilience by 4.660 SD (Model 5, β = −4.660, 95% CI: −7.088, −2.231), whereas earthquake exposure, sociodemographic factors and PTGI score remained constant. Moreover, working in Hospital C resulted in a decrease in resilience by 5.710 SD (Model 5, β = −5.710, 95% CI: 8.255, −3.165), whereas earthquake exposure, sociodemographic factors and PTGI score remained constant.

Third, females, higher education levels and longer length of service were significantly and positively associated with resilience in Models 3–5. Specifically, female HCWs experienced an increase in resilience by 3.714 SD (Model 5, β = 3.714, 95% CI: 0.199, 7.230), whereas earthquake exposure and PTGI score remained constant. Obtaining a university degree or higher increased resilience by 3.482 SD (Model 5, β = 3.482, 95% CI: 1.368, 5.597). Each additional year of service resulted in an increase in resilience by 0.278 SD (Model 5, β = 0.278, 95% CI: 0.136, 0.421).

Fourth, a one-point increase in PTGI score (range: 0–105) was associated with an increase in resilience of 0.096 SD (Model 4, β = 0.096, 95% CI: 0.056, 0.136). In terms of the specific subdomains of the PTGI, new possibilities (Model 5, β = 0.435, 95% CI: 0.029, 0.840) and personal strength (Model 5, β = 0.835, 95% CI: 0.420, 1.250) were significant positive predictors of HCWs' resilience. In contrast, spiritual change was significantly and negatively associated with resilience. A one-point increase in the spiritual change score resulted in a 0.696 SD decrease in HCWs' resilience (Model 5, β = −0.696, 95% CI: −1.346, −0.046), whereas earthquake exposure, workplace characteristics and sociodemographic factors remained constant. Neither relating to others nor appreciation of life were significantly associated with resilience.

Finally, neither marital status nor profession (medical doctor or registered nurse) played a significant role in predicting HCWs' resilience across the different regression models (Table 4).

<Table 4. Multilevel regression modelling of HCWs' resilience after the Wenchuan earthquake about here>

Discussion

HCWs' resilience after the Wenchuan earthquake

The public, HCWs and their communities experienced a long recovery period following the Wenchuan earthquake [47-49]. HCWs who participated in this study reported a lower level of resilience 11 years after the Wenchuan earthquake (mean = 59.7, SD = 19.6) compared to that of the public in the United States (mean = 80.4, SD = 12.8) [1] or the public in China (mean = 64.5, SD = 13.9) [40]. Their resilience was also lower than that of individuals who sustained spinal cord injuries in the 2015 Nepal earthquake one year post-injury (mean = 64.8, SD = 14.0) [50], and those affected by the Deepwater Horizon oil spill 4.5 years post-spill (mean = 69.3, SD = 18.1) [51]. However, HCWs' resilience in this study was higher than that reported by survivors of a large-scale maritime disaster that occurred in South Korea in 2014 in the month following the disaster (mean = 50.0, SD = 15.8) [52]. Thus, the effects of different types of disasters on the reilience of different populations (e.g. disaster survivors and HCWs) vary in different countries/areas over time.

Our study found that disaster exposure, especially as survivors, did not have a significant impact on HCWs' resilience 11 years after the Wenchuan earthquake. In fact, unexposed HCWs (mean = 59.2, SD = 18.6), exposed HCWs as survivors (mean = 58.7, SD = 19.7) and exposed HCWs as rescuers (mean = 61.9, SD = 17.7) reported similar levels of resilience to survivors from the public five years after the Wenchuan earthquake (female survivors: mean = 58.0, SD = 12.0; male survivors: mean = 61.3, SD = 12.8) [34]. Moreover, no significant differences in PTGI score were identified across the three groups, suggesting that the effects of the disaster do not persist in terms of individual psychological resilience. Rather than exposure to the Wenchuan earthquake, daily life and work-related stressors might be important factors influencing the mental health and resilience of HCWs [53].

HCWs with higher education levels had higher CD-RISC25 scores. An association of higher education levels with higher CD-RISC25 scores was also identified in a survey of nursing students (undergraduate, postgraduate and continuing education) following the 2010 New Zealand earthquake [54]. In the 2011 Great East Japan Earthquake, it was found that nurses who had more knowledge of radiation tended to report better mental health and enhanced abilities to cope with disaster-associated stress and daily work [55]. Therefore, providing more continuing education opportunities for HCWs, such as part-time 'college-to-Bachelor's' programmes [56] and Master's programmes [57], could enhance HCWs' resilience. Thus, HCWs with lower education levels should be considered a vulnerable group when designing and implementing resilience interventions.

Moreover, HCWs' resilience was influenced by workplace characteristics. The participants in the largest hospital reported the highest CD-RISC25 scores (mean = 63.7, SD = 17.1), whereas the smallest hospital, also located in the epicentre of the Wenchuan earthquake, reported the lowest scores (mean = 56.5, SD = 22.0). This might be because the development of disaster-associated resilience results from preventing resource losses or recovering resources, which relates to the initial amount, strength and diversity of one's resource [58]. Hospital resources are crucial for HCWs' preparation and response to disasters. Important resources that aid nurses in carrying out their roles during disasters include support from co-workers, providing support to others, personal resourcefulness and leadership [17]. More resources are available in larger hospitals, such as Hospital A in this study. Therefore, when considering interventions to

improve HCWs' resilience, those who are working in small hospitals with fewer resources should be prioritised.

Participation in disaster response and relief efforts can significantly increase the levels of post-traumatic growth and instil a desire to become an HCW among medical students according to a survey carried out in Japan three years after the 2011 Great East Japan Earthquake [59]. Studies of Chinese HCWs have found that post-traumatic growth was significantly positively associated with resilience 11 years after the Wenchuan earthquake, which is consistent with the previous research carried out in non-disaster contexts [35, 36]. However, not every subdomain of the PTGI was associated with altered resilience. Among the five subdomains of the PTGI, new possibilities and personal strength were significantly positively associated with HCWs' resilience, whereas spiritual change was significantly negatively associated. Relating to others and appreciation of life were not significantly associated with resilience. Spiritual change was likely negatively correlated with HCWs' resilience because it does not align with Chinese culture [60-62]. Interventions designed to increase individual resilience are important to build and improve adaptive responses to challenges when working in disaster-prone areas [9, 63, 64]. Therefore, tailored and evidence-based workplace resilience training programmes are warranted for HCWs to ensure disaster preparedness and promote personal growth in response to crises [64].

Limitations

This study measures the impact of disaster exposure on HCWs' resilience with respect to a comparison group of unexposed participants more than 10 years after a major disaster. However, several limitations of the study must be acknowledged and considered when evaluating the results.

First, this study was limited by its sampling methodology and the unbalanced ratio between medical doctors and registered nurses among the three selected hospitals. Second, instead of binary (e.g. exposed or unexposed) or ternary (e.g. unexposed HCWs, exposed HCW survivors and exposed HCW rescuers) categorisation, assessment of disaster exposure could be improved by including more information, such as the injuries endured by and the financial losses of individuals and families. Third, resilience could be influenced by many other factors, such as personality strengths [27], family and social support [35, 65, 66] and relevant mental health conditions, including PTSD, anxiety and depression [18]. The explanatory powers of the models (R^2) were low, similar to other studies examining individual resilience after disasters using cross-sectional surveys [e.g. 34]. Future research should discern whether other factors could explain a larger proportion of HCWs' resilience. Finally, the cross-sectional study design used did not allow for the determination of temporal associations between the study variables. Longitudinal studies needed to examine the dynamic resilience of disaster relief workers over time.

Conclusion

This research examined the resilience of HCWs 11 years after the Wenchuan earthquakes and identified the factors associated with their resilience, which included disaster exposure, workplace characteristics, sociodemographic factors and post-traumatic growth, given that these workers live and work in disaster-affected communities concurrently as survivors and disaster relief workers. Our findings suggest the need for the development of resilience

interventions for HCWs in disaster-prone and disaster-affected areas, especially for male junior HCWs with low education levels working in small hospitals. More research, particularly longitudinal studies, is warranted to explore the dynamic nature of HCWs' resilience in the face of disasters over time and develop measures to sustain their mental health in the face of adversity.

Acknowledgements

We thank Ms Shaohua Chen, Professor Xianqiong Feng, Dr Xin Jiang, Ms Xuemei Luo and Ms Rui Xia, who provided assistance in data collection.

Funding

This research was supported by the grant of Dean's Reserve (FHSS & FENG), The Hong Kong Polytechnic University (Project ZZHH).

Conflict of Interest

All authors declare that they have no conflict of interest.

Ethical approval

The study was reviewed and approved by Human Subjects Ethics Sub-Committee in the Hong Kong Polytechnic University (Ref. HSEARS20190416035).

Authors' contributions

Chunlan Guo: methodology, data curation, formal analysis, visualization, writing – original draft, writing -review & editing; Sijian Li: conceptualization, funding, resource, writing - review & editing; Sunshine S. S. Chan: conceptualization, funding, resource, writing - review & editing.

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573

574 **Table 1. Profiles of the three hospitals in Sichuan, China.**

	Hospital A	Hospital B	Hospital C
Geographical location	Chengdu, Sichuan (Urban)	Chengdu, Sichuan (Urban)	Mianzhu, Sichuan (Suburban)
Level of intensity affected by Wenchuan earthquake[#]	VI–VII	VI–VII	IX–X
Total number of beds	4,300	1,450	800
Total number of workers	About 10,000	About 3,500	1,163
Medical doctor	2,021	1,047	344
Registered nurse	3,922	1,234	557
Level of the hospital[†]	Tertiary grade A	Tertiary grade A	Tertiary grade B
N of samples	503(100%)	489(100%)	535(100%)
Medical doctor	1(0.2%)	22(4.4%)	149(27.9%)
Nurse	488(99.8%)	481(95.6%)	386(72.1%)
Percentage of HCWs participating in the survey[^]	8.5%	21.4%	59.4%

575 [#]The scale of intensity followed China seismic intensity scale (Liedu scale), higher levels
576 indicate significant effects on people on the ground and greater damage [38].
577 [†] There are three tiers of hospitals in China: primary (less than 100 beds), secondary (100–500
578 beds) and tertiary hospitals (more than 500 beds); for each tier, the hospitals are further
579 subdivided into three subsidiary levels: A, B and C.
580 [^]The percentage was calculated by dividing the number of samples by the total number of
581 medical doctors and registered nurses employed at the hospital.
582

583 **Table 2. Descriptive analysis of the exposed and unexposed HCWs.**

	Total N = 1,527	Unexposed HCWs N = 1,015	Exposed HCWs as survivors N = 202	Exposed HCWs as rescuers N = 310	Chi-squared/ANOVA[#]
Workplace					$\chi^2(4) = 71.965$, $p < 0.001$
Hospital A (Ref.)	503 (32.9%)	340 (35.5%)	57 (28.2%)	106 (34.2%)	
Hospital B	489 (32.1%)	385 (37.9%)	41 (20.3%)	63 (20.3%)	
Hospital C	535 (35.0%)	290 (28.6%)	104 (51.5%)	141 (45.5%)	
Gender					$\chi^2(2) = 1.221$, $p = 0.543$
Male (Ref.)	177 (11.6%)	124 (12.2%)	20 (9.9%)	33 (10.6%)	
Female	1,350 (88.4%)	891 (87.8%)	182 (90.1%)	277 (89.4%)	
Education					$\chi^2(2) = 29.566$, $p < 0.001$
College or below (Ref.)	889 (58.2%)	567 (55.9%)	153 (75.7%)	169 (54.5%)	
University or above	638 (41.8%)	448 (44.1%)	49 (24.3%)	141 (45.5%)	
Marital status					$\chi^2(2) = 115.107$, $p < 0.001$
Unmarried (Ref.)	453 (29.7%)	315 (31.0%)	108 (53.5%)	30 (9.7%)	
Married	1,074 (70.3%)	700 (69.0%)	94 (46.5%)	280 (90.3%)	
Professional					$\chi^2(2) = 13.402$, $p < 0.001$
Medical doctor (Ref.)	172 (11.3%)	117 (11.5%)	9 (4.5%)	46 (14.8%)	
Registered nurse	1,355 (88.7%)	898 (88.5%)	193 (95.5%)	264 (85.2%)	
Age	31.7 (7.0)	31.5 (6.7)	25.5 (2.0)	36.4 (6.8)	$F(2) = 182.711$, $p < 0.001$
Length of service in years	10.2 (7.6)	10.0 (7.2)	4.2 (3.6)	14.7 (7.9)	$F(2) = 138.815$, $p < 0.001$
Post-Traumatic Growth Inventory	35.4 (24.0)	35.4 (24.4)	35.3 (23.2)	35.7 (23.1)	$F(2) = 0.029$, $p = 0.972$
Relating to others	12.0 (8.4)	12.0 (8.5)	12.0 (8.2)	11.9 (8.0)	$F(2) = 0.040$, $p = 0.961$
New possibilities	7.9 (6.1)	8.0 (6.1)	7.9 (6.1)	7.7 (5.8)	$F(2) = 0.372$, $p = 0.690$
Personal strength	7.5 (5.4)	7.4 (5.4)	7.5 (5.4)	7.9 (5.2)	$F(2) = 0.953$, $p = 0.386$
Spiritual change	2.7 (2.4)	2.7 (2.4)	2.7 (2.3)	2.6 (2.4)	$F(2) = 0.086$, $p = 0.918$
Appreciation of life	5.3 (3.8)	5.2 (3.8)	5.2 (3.6)	5.6 (4.0)	$F(2) = 1.573$, $p = 0.208$

584 [#]Significant results in the Chi-squared test/ANOVA ($p < 0.05$) indicated statistical differences between the three
585 sub-groups studied.

586

587 **Table 3. CD-RISC25 scores for different groups of HCWs (N = 1,527).**

	Mean	SD	ANOVA
The Wenchuan earthquake exposure			F(2) = 2.454, p = 0.086
Unexposed HCW *(Ref.)*	59.2	20.0	
Exposed HCW as a survivor	58.7	19.7	
Exposed HCW as a rescuer	61.9	17.7	
Workplace			**F(2) = 17.020, p < 0.001**
Hospital A (Ref.)	**63.7**	**17.1**	
Hospital B	**58.7**	**18.5**	
Hospital C	**56.8**	**22.0**	
Gender			**F(1) = 6.308, p < 0.05**
Male (Ref.)	**56.2**	**23.6**	
Female	**60.1**	**18.9**	
Education			**F(1) = 12.994, p < 0.001**
College or below (Ref.)	**58.2**	**19.1**	
University or above	**61.8**	**20.4**	
Marital status			F(1) = 0.001, p = 0.990
Unmarried (Ref.)	59.7	19.6	
Married	59.7	19.6	
Professional			**F(1) = 1.287, p < 0.05**
Medical doctor (Ref.)	**56.8**	**23.8**	
Registered nurse	**60.1**	**18.9**	
Age group[#]			F(1) = 3.084, p = 0.079
< 29 years (Ref.)	58.5	19.5	
≥ 29 years	60.4	19.6	
Length of service in years			F(1) = 2.341, p = 0.126
< 10 years (Ref.)	59.1	19.5	
≥ 10 years	60.7	19.6	

588 [#]< 29 years: an adolescent (< 18 years) at the time of the Wenchuan earthquake; ≥ 29 years:
589 an adult at the time of the Wenchuan earthquake.

Table 4. Multilevel regression modelling of HCWs' resilience after the Wenchuan earthquake (N = 1,527).

Factors	Items	Model 1	Model 2	Model 3	Model 4	Model 5
Wenchuan earthquake exposure	*Exposed HCW as a survivor*	−0.582, $p = 0.699$ [−3.538, 2.374]	0.191, $p = 0.900$ [−2.776, 3.158]	1.649, $p = 0.296$ [−1.446, 4.744]	1.636, $p = 0.297$ [−1.438, 4.709]	1.594, $p = 0.306$ [−1.462, 4.650]
	Exposed HCW as a rescuer	**2.618, $p < 0.05$ [0.128, 2.107]**	**2.972, $p < 0.05$ [0.473, 5.470]**	1.805, $p = 1.171$ [−0.780, 4.391]	1.767, $p = 0.177$ [−0.800, 4.335]	1.598, $p = 0.222$ [−0.968, 4.165]
Workplace	*Hospital B*		**−4.713, $p < 0.001$ [−7.136, −2.291]**	**−4.544, $p < 0.001$ [−7.000, −2.089]**	**−4.565, $p < 0.001$ [−7.004, −2.126]**	**−4.660, $p < 0.001$ [−7.088, −2.231]**
	Hospital C		**−7.000, $p < 0.001$ [−9.376, −4.623]**	**−5.716, $p < 0.001$ [−8.292, −3.140]**	**−5.735, $p < 0.001$ [−8.293, −3.177]**	**−5.710, $p < 0.001$ [−8.255, −3.165]**
Gender	*Female*			**3.604, $p < 0.05$ [0.055, 7.154]**	**3.890, $p < 0.05$ [0.363, 7.417]**	**3.714, $p < 0.05$ [0.199, 7.230]**
Education	*University or above*			**3.484, $p < 0.01$ [1.346, 5.623]**	**3.475, $p < 0.01$ [1.351, 5.599]**	**3.482, $p < 0.01$ [1.368, 5.597]**
Marital status	*Married*			−1.956, $p = 0.094$ [−4.244, 0.332]	−1.764, $p = 0.128$ [−4.038, 0.509]	−1.574, $p = 0.173$ [−3.840, 0.692]
Profession	*Registered nurse*			1.541, $p = 0.447$ [−2.436, 5.519]	1.544, $p = 0.443$ [−2.406, 5.493]	1.612, $p = 0.423$ [−2.334, 5.558]
Length of service in years	*Years*			**0.287, $p < 0.001$ [0.143, 0.432]**	**0.278, $p < 0.001$ [0.135, 0.422]**	**0.278, $p < 0.001$ [0.136, 0.421]**
Post-Traumatic Growth Inventory					**0.096, $p < 0.001$ [0.056, 0.136]**	**-**
	Relating to others					−0.209, $p = 0.132$ [−0.480, 0.063]
	New possibilities					**0.435, $p < 0.05$ [0.029, 0.840]**
	Personal strength					**0.835, $p < 0.001$ [0.420, 1.250]**
	Spiritual change					**−0.696, $p < 0.05$ [−1.346, −0.046]**
	Appreciation of life					−0.423, $p = 0.057$ [−0.857, 0.0012]
Model performance		$F(2) = 2.454$ $p < 0.05$ $R^2 = 0.003$	$F(4) = 9.929$ $p < 0.001$ $R^2 = 0.025$	$F(9) = 7.905$ $p < 0.001$ $R^2 = 0.045$	$F(9) = 9.443$ $p < 0.001$ $R^2 = 0.059$	$F(13) = 8.443$ $p < 0.001$ $R^2 = 0.073$

Beta coefficients (β), p-values and 95% confidence intervals are reported for each factor.

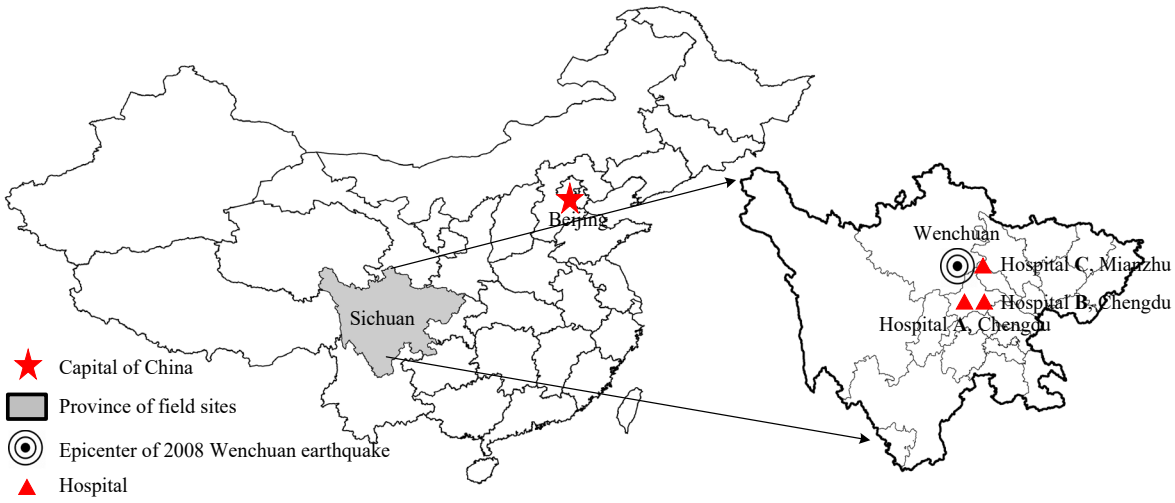

Figure 1. Map of the hospitals sampled.