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ARTICLE

Physical function, post-traumatic stress disorder, and quality of life in persons with spinal cord injury caused by the Wenchuan earthquake versus nondisaster trauma: a cross-sectional modeling study

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Abstract

Study design Cross-sectional study.

Objectives To compare physical function, post-traumatic stress disorder (PTSD) and quality of life (QOL) between individuals with spinal cord injury (SCI) caused by the Wenchuan earthquake and individuals with SCI caused by nondisaster trauma and to explore the relationship between physical function, PTSD and QOL.

Setting Community, Sichuan, China.

Methods Two hundred individuals with SCI (39 caused by the Wenchuan earthquake, 161 with other traumatic etiology) were surveyed. Physical function was assessed with the Spinal Cord Independence Measure-SR, PTSD with the PTSD Checklist-C, and QOL with the World Health Organization QOL-BREF. Independent sample *t*-tests and rank-sum tests were used to compare the two groups. Structural equation modeling (SEM) was used to analyze the relationship between physical function, PTSD and QOL.

Results QOL of the study participants was at a moderate to low level, physical function was at a medium level. The prevalence of PTSD in the group injured due to the Wenchuan earthquake was 64.1% as opposed to 10.0% in individuals with other traumatic etiology. In the SEM, earthquake-related etiology was strongly related to increased PTSD symptoms which negatively affected QOL. Earthquake-related etiology was however also associated with slightly increased physical function which was associated with better QOL and less PTSD symptoms

Conclusions Prevalence of PTSD in earthquake survivors with SCI was largely increased as compared with people with SCI of other traumatic etiology. In spite of this, the groups did not differ in QOL because of better physical function of earthquake survivors. Effective intervention for PTSD is still needed in earthquake survivors with SCI. Continuous rehabilitative measures to improve physical function and QOL in both groups are also recommended.

Introduction

Spinal cord injury (SCI) is one of the most serious injuries induced by natural disaster, particularly occurring in earthquakes and storms [1–3]. The 2008 Wenchuan earthquake—a massive earthquake reaching a magnitude of 8.0—killed 69,227 people and injured 374,643, with 17,923

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unaccounted for [4]. It has been estimated that SCI accounted for about 2.2 percent (364 cases) of the 16,563 trauma patients hospitalized for serious injuries [5]. However, the incidence of SCI in this disaster may actually be higher due to reasons such as missing record [5].

While it is well known that SCI may entail a significant number of physiological, psychological and social problems, and ultimately reduced quality of life (QOL) [6–9], it has rarely been studied how people who sustained SCI due to natural disaster differ in these outcomes from those with SCI caused by nondisaster-related trauma. It is possible that survivors of disaster-related SCI face increased health-related and psychosocial problems as compared with those who sustained SCI due to nondisaster induced trauma: (1) Physiologically, the degree of SCI may be more severe in disaster survivors, and the incidence of multiple and combined injuries can be as high as 80% [10–12]. (2) Psychologically, disaster survivors with SCI may experience duplicate trauma, firstly from the injury itself and the sudden loss of physical function, and secondly from disaster-related experiences such as loss of family members, relatives, and close friends or the destruction of their homes and important property.

Post-traumatic stress disorder (PTSD) is classified as an anxiety disorder that occurs after an individual experiences an adverse event. The prevalence of PTSD after SCI ranges from 10 to 40% [13–15], and the lifetime prevalence of PTSD remains high among patients who do not receive related psychotherapy: 24.9% of individuals with an average post-injury duration of 10.6 years were still diagnosed with PTSD [15], and up to 29% reported persistent symptoms 30 years after injury [16]. The development of PTSD among individuals with SCI is affected by pre-traumatic, peri-traumatic and post-traumatic experiences. In the long run, patients who had experienced an adverse life event prior to injury were more likely to develop PTSD [17]. However, there is little research on the effect of the etiology of SCI on PTSD. It is not clear whether different etiologies affect the occurrence of PTSD and what the risk factors for PTSD are, whether it's the cause of spinal injury or SCI itself, or both [13, 14]. Multiple traumatic events are likely to be associated with worse psychological outcomes [18]. Studies have shown that disasters survivors show low interpersonal trust and depression and anxiety, and are prone to suffer from PTSD [19, 20]. The severity of traumatic events and exposure intensity also affects the occurrence of PTSD. Many reports confirm that destructive disaster events can cause serious and persistent PTSD symptoms [21, 22]. The experience of traumatic SCI and subsequent disability and the experience of disaster-related adverse events may be two independent sources of PTSD leading to reduced QOL in disaster survivors with SCI as compared with individuals with SCI with a different traumatic etiology [9, 20, 23].

This study aimed to explore the current status and the relationships between sociodemographic and injury characteristics, physical function, PTSD and QOL in individuals with chronic stage traumatic SCI and to compare individuals who sustained SCI from natural disaster with individuals with SCI with nondisaster-related traumatic etiology.

Hypotheses were as follows (see Fig. 1):

H1: Earthquake victims show an increased PTSD symptom severity.
H2: Tetraplegia and complete injuries are related to reduced physical function.
H3: Those with reduced physical function show increased PTSD symptom severity.
H4: Higher PTSD symptom severity is associated with reduced QOL.
H5: Reduced physical function is associated with decreased QOL.
H6: There is a negative indirect effect of etiology (earthquake vs. not) through PTSD on QOL (mediation), i.e., having sustained SCI due to earthquake will increase PTSD symptom severity which will in turn decrease QOL.
H7: There is a positive indirect effect of physical function through PTSD on QOL (mediation), i.e., those with better physical function will have less PTSD symptoms which in turn positively influences QOL.
H8: There is an indirect effect of type and severity of SCI through physical function on PTSD in favor of those with paraplegia and incomplete lesions, i.e., those with incomplete lesions and paraplegia will have better physical function which will decrease PTSD symptoms.

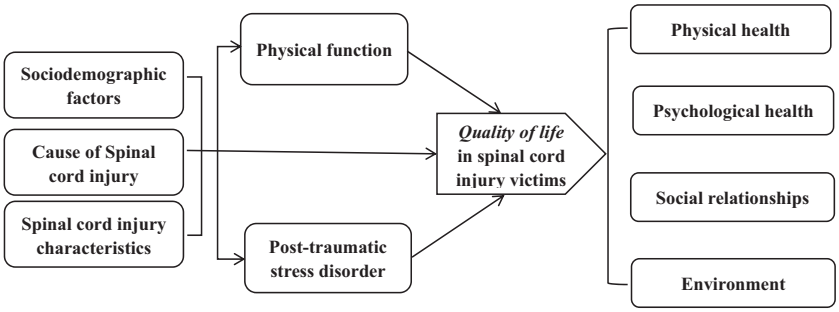

Fig. 1 Conceptual framework of this study.

We had no specific hypotheses regarding demographic variables but they were adjusted for in the respective models to account for differences in demographic composition of the compared groups.

Methods

Study design

This was a cross-sectional study comparing individuals with SCI from the 2008 Wenchuan earthquake and individuals with SCI with nondisaster-related traumatic etiology.

Participants

Inclusion and exclusion criteria were as follows: Participants were adults aged 18 years or above at the time of the study having sustained a traumatic SCI at/around the time of the Wenchuan earthquake and lived in Sichuan Province. Participants should be able to be contacted by mobile phone, communicate in Mandarin Chinese and agreed to participate in the study. Excluded were persons having nontraumatic SCI (such as malignant tumors, scoliosis), or having severe vital organs dysfunction.

Based on the above criteria, two groups of individuals with SCI were recruited: survivors with SCI from the 2008 Wenchuan earthquake (disaster SCI) and individuals with SCI with nondisaster-related traumatic etiology (nondisaster SCI). The participants with SCI due to the Wenchuan earthquake were selected by convenience sampling and snowball sampling, the researchers first contacted the Disabled Persons Federation (DPF) of Mianzhu City, Sichuan Province, one of the most severely affected areas by the Wenchuan earthquake, and interviewed eight individuals with SCI in Mianzhu from June 22 to 23, 2018. The researchers subsequently contacted and interviewed another 31 individuals with SCI who were Wenchuan earthquake survivors. Most of them lived in the cities of Chengdu and Dujiangyan. Thirty-nine participants were enrolled in this group.

As for the nondisaster SCI group, we selected individuals with traumatic SCI who had been injured approximately 10 years prior (to match the duration since injury of earthquake survivors). Stratified random sampling was adopted to select 9 different hospitals in Sichuan Province from a list of hospitals from the Sichuan Health Department. The recruitment process was assisted by the Institute of Disaster Management and Reconstruction (IDMR) at Sichuan University, Chengdu. One-hundred-sixty-seven participants were enrolled in this group.

Data collection procedures

This study used self-reported questionnaires to collect data through on-site investigations, telephone surveys, and WeChat online surveys. All interviews were conducted by the first author.

Research instruments

General information

A questionnaire was used to collect data on socio-demographic variables and SCI related variables. Socio-demographic variables included: age, gender, degree of education, marital status, ethnic group (Han Chinese vs. minority ethnic group). SCI related variables included: cause of SCI and type of injury (para- vs. tetraplegia) and degree of injury (complete vs. incomplete SCI) and type of payment for treatment (out of pocket vs. not). Type and degree of SCI were assessed based on self-report of the participants. It was explained that incomplete lesions meant that some function remained below lesion level and that tetraplegia meant that upper limbs were also affected.

Spinal cord independence measure self-report (SCIM SR)

The spinal cord independence measure self-report (SCIM SR) was employed to measure physical functioning in activities of daily living. SCIM SR is a self-report version of SCIM III that has been tested for validity and reliability in multicenter studies with satisfying psychometric properties [24–26]. The instrument has 19 items and three dimensions: Self-care, Respiration and Sphincter Management, and Mobility. Scores in the three dimensions were calculated according to the instruction. The higher the scores, the better the physical function. The SCIM-SR was developed and has been validated in a clinical study and community survey of people with SCI conducted in Switzerland [27, 28]. SCIM SR has been translated into Chinese according to an international protocol [29]. In the current study, the Cronbach's α coefficient of the instrument was 0.85, and the Cronbach's α coefficients of each dimension ranged between 0.82 and 0.89.

Post-traumatic stress disorder checklist—civilian version (PCL-C)

The post-traumatic stress disorder checklist—civilian version (PCL-C) was used to assess PTSD symptoms of the participants. The PCL-C has 17 items grouped in three clinical symptom dimensions: intrusion, avoidance, and alertness. The possible scores of the PCL-C range from 17

to 85. The higher the scores, the more severe PTSD symptoms a person presents [30]. The Chinese version of PCL-C used in this study was translated and validated by Yang et al. [31]. This study adopted cutoffs for the PCL-C recommended for detecting PTSD in Chinese earthquake victims: ≥44 points indicating a probable diagnosis of PTSD; 37–43 points, indicating a certain degree of PTSD symptoms; ≤36 points, indicating no obvious PTSD symptoms. For a cutoff of 44, the sensitivity was 0.83, and the specificity was 0.97 [32, 33]. In this study, the overall Cronbach's α coefficient of the instrument was 0.88, and the Cronbach's α coefficients of each dimension ranged between 0.88 and 0.91.

The World Health Organization Quality of Life-BREF (WHOQOL-BREF)

QOL in this study was evaluated by the World Health Organization QOL-BREF (WHOQOL-BREF). The first two items of this scale assess the overall QOL and health, while the following 24 items cover 4 domains, including physical health, psychological health, satisfaction with social relationships and satisfaction with the environment, for each of which summary scores were calculated and transformed to a 0–100 scale following the manual's instructions [34]. Higher scores indicate higher QOL. The WHOQOL-BREF had been previously used in Chinese populations demonstrating good internal consistency (Cronbach's alpha = 0.89) and good convergent validity [35]. In this study, the Cronbach's α coefficient of the full scale was 0.87, and the Cronbach's α coefficient of each dimension ranged between 0.72 and 0.88.

Data analysis

The data in this study were analyzed with IBM SPSS Statistics 24 and Stata 14.0 (Stata Corp, TX, USA). Both descriptive statistics and inferential statistics are provided. Data that were normally distributed were statistically described by mean and standard deviation, and quantitative data that were not normally distributed were statistically described by median and quartiles. Categorical data were statistically described by the number of cases and percentages. Independent sample *t*-tests and Wilcoxon rank-sum tests were used to compare the disaster SCI and the nondisaster SCI group. Structural equation modeling (SEM) was used to analyze the relationship between etiology, SCI characteristics, physical function, PTSD and QOL, and to jointly test hypotheses 1–8. SEM is a type of multivariate analysis that combines multiple regression (structural relations between variables) and confirmatory factor analysis (measurement part). It can be used to analyze relations between a number of observed and latent variables, including mediation. To detect a Root Mean Squared Error of Approximation (RMSEA) < 0.08 for a model with 39 df, alpha = 0.05, power = 0.9 a sample size of at least 136 observations is needed. Our sample size was therefore appropriate for the analyzed SEM.

In the model QOL was operationalized as endogenous latent outcome variable with four dimensions constituted by the WHOQOL-BREF subscales. All other variables were observed. QOL was regressed on etiology (earthquake vs. not), physical function and PTSD. PTSD was regressed on etiology and physical function and physical function was regressed on type and severity of SCI. In addition, all pathways were adjusted for the following demographic variables in an initial model: gender, age, being married (vs. not), having primary school or lower education (vs. not), minority ethnic group (vs. Han majority), and out of pocket payment (vs. not), i.e., these variables were used as exogenous predictors of the endogenous mediators, our outcome variables, in addition to the hypothesized predictor variables. The pathways leading to PTSD and QOL were adjusted for SCI type and severity.

For a final model all variables with $p > 0.1$ were removed from the respective pathways and modification indices were consulted to improve model fit. The following model fit statistics were calculated: Chi-squared test of saturated model vs. observed model, RMSEA a measure comparing our model to a fully saturated model with values smaller than 0.05 indicating good fit and values below 0.08 indicating an acceptable fit; Comparative Fit Index (CFI) a statistic comparing the model with a baseline model with values above 0.95 indicative of good fit; and the Standardized Root Mean squared Residual (SRMR) with values below 0.08 indicating good fit; and coefficient of determination (R^2) [36, 37]. Moreover, we used augmented partial residual plots derived from the multivariable regressions implicated by the SEM to detect nonlinearity in relations between continuous variables (dichotomous predictors have linear relations with the outcome anyway). We did not detect evidence for nonlinearity. Eventually, direct, indirect and total effects were calculated to test for mediation according to Sobel [38].

Results

A total of 206 questionnaires were collected in this study, 6 were excluded due to missing values exceeding 20% of the data, hence, 200 responses (39 for disaster group, 161 for nondisaster group) were analyzed.

Table 1 Study population characteristics.

Characteristics	Total $n = 200$	Earthquake survivors $n_1 = 39$	Non-earthquake SCI $n_2 = 161$	*Statistical test value*	*Effect size*	*p value*
Age,years, mean (s.d.)	47.9 (13.2)	46.3 (12.3)	48.3 (13.4)	−0.85[a]	0.15[c]	0.40
Age group, n (%)						
<45years	90 (45.0)	18 (46.2)	72 (44.7)	4.38[b]	0.15[d]	0.11
45-65years	86 (43.0)	20 (51.3)	66 (41.0)			
>65years old	24 (12.0)	1 (2.5)	23 (14.3)			
Gender, n (%)						
Male	144 (72.0)	27 (69.2)	117 (72.7)	0.18[b]	0.03[d]	0.67
Female	56 (28.0)	12 (30.8)	44 (27.3)			
Ethnic group, n (%)						
Han	187 (93.5)	37 (94.9)	150 (93.2)	0.15[b]	0.03[d]	0.52
Minority	13 (6.5)	2 (5.1)	11 (6.8)			
Marital status, n (%)						
Single	28 (14.0)	4 (10.3)	24 (14.9)	20.18[b]	0.32[d]	<0.001
Married	135 (67.5)	24 (61.5)	111 (68.9)			
Cohabiting or in a partnership	1 (0.5)	0 (0.0)	1 (0.6)			
Separated or divorced	19 (9.5)	1 (2.6)	18 (11.2)			
Widowed	17 (8.5)	10 (25.6)	7 (4.4)			
Education, n (%)						
Primary school	62 (31.0)	12 (30.8)	50 (31.0)	1.85[b]	0.10[d]	0.76
Junior high school	51 (25.5)	10 (25.6)	41 (25.5)			
Senior high school	38 (19.0)	5 (12.8)	33 (20.5)			
Junior college	31 (15.5)	8 (20.5)	23 (14.3)			
Bachelor degree	18 (9.0)	4 (10.3)	14 (8.7)			
Skeletal level, n (%)						
Paraplegia	190 (95.0)	38 (97.4)	152 (94.4)	0.61[b]	0.06[d]	0.39
Tetraplegia	10 (5.0)	1 (2.6)	9 (5.6)			
Injury degree, n (%)						
Complete	77 (38.5)	29 (74.4)	48 (29.8)	26.31[b]	0.36[d]	<0.001
Incomplete	123 (61.5)	10 (25.6)	113 (70.2)			
Time since injury, years, mean (s.d.)	8.9 (1.4)	10 (0)	8.8 (1.5)	3.37[a]	n.a.	<0.01
Type of payment for treatment, n (%)						
Out of pocket	103 (51.5)	11 (28.2)	92 (57.1)	10.53[b]	−0.23[d]	<0.001
Other modes of payment	97 (48.5)	28 (71.8)	69 (42.9)			

[a]*T*-test

[b]Chi-squared test

[c]Cohen's d

[d]Cramer'V

Demographics and SCI characteristics

Detailed information about demographic and SCI characteristics of the participants is provided in Table 1. There were statistically significant differences between the disaster SCI group and the nondisaster SCI group in terms of marital status, degree of injury and type of payment for treatment ($p < 0.01$). Individuals of the disaster SCI group were more often widowed, had complete injures and needed to pay treatment out of their own pocket less often. In the disaster SCI group, the relative risk of being widowed was as large as 5.9 (CI {2.4, 14.5})

Outcomes

The median of the SCIM total score for the disaster SCI group was 59.0. The median of the SCIM total score for the nondisaster SCI group was 61.0. There were no significant differences in the scores of the SCIM and its dimensions between the two groups ($p > 0.05$).

The median of the PCL-C total score for the disaster SCI group was 45.0. The median of the PCL-C total score for the nondisaster SCI group was 35.0. There were significant differences in the total score as well as the intrusion, avoidance and alertness dimensions scores between the two groups ($p < 0.01$). The scores of all dimensions of the disaster group were higher than those of the nondisaster group (Table 2). A total of 41 individuals with SCI had probable PTSD according to a PCL-C cut off score of 44. There was a significant difference in the proportion of those with probable diagnosis of PTSD between the two groups ($\chi^2 = 63.23$, $p < 0.01$). The relative risk index for being screened positive for PTSD for individuals with earthquake-related SCI was 6.5 (CI {3.8, 10.9}).

The median of the overall QOL and health items score for the disaster survivor group were 3.0 and 2.0 respectively. Scores in none of the domains were significantly different between the two groups ($p > 0.05$) (see Table 2).

Relationships between physical function, post-traumatic stress disorder and quality of life of the participants

Univariable analysis showed moderate to high correlations between outcomes. The correlation between PCL-C and SCIM-SR was −0.27, correlations of SCIM-SR with QOL subscales ranged from 0.36 (social dimension) to 0.54 (physiological dimension), while correlations between PTSD and QOL ranged from −0.34 (physiological dimension) to −0.51 (environmental dimension). Correlations between PCL-C and QOL scales were somewhat higher in earthquake survivors as compared with those with other traumatic SCI and correlations of SCIM-SR and QOL dimensions were lower for individuals with earthquake-related etiology.

Figure 2 shows the final structural equation model With $\chi^2(\text{df}) = 83.0(39)$, $p < 0.001$; GFI = 0.94, CFI = 0.94, TLI = 0.91, SRMR = 0.05, RMSEA = 0.07(90%CI: 0.05,0.10), and $R^2 = 0.61$ the final model fit was adequate.

Table 2 Physical functioning, post-traumatic stress disorder and quality of life scores.

	Total $n = 200$	Earthquake survivors $n_1 = 39$	Non-earthquake SCI $n_2 = 161$	*Effect size*	*p value*
SCIM-SR					
Total score, median (inter quartile range)	60.0 (52.8)	59.0 (56.6)	61.0 (50.7)	−0.11[a]	0.14
Self-care dimension, median (inter quartile range)	16.0 (13.2)	16.0 (14.2)	16.0 (13.2)	−0.15[a]	0.15
Respiration and sphincter management dimension, median (inter quartile range)	30.0 (26.3)	30.0 (26.3)	31.0 (27.4)	−0.10[a]	0.32
Mobility dimension, median (inter quartile range)	15.0 (15.2)	15.0 (13.2)	14.0 (11.2)	−0.01[a]	0.96
PCL-C					
Total score median (inter quartile range)	36.0 (30.4)	45.0 (42.5)	35.0 (29.4)	0.73[a]	<0.001
Re-experiencing median (inter quartile range)	12.0 (10.2)	16.0 (15.2)	11.0 (9.1)	0.72[a]	<0.001
Avoidance median (inter quartile range)	16.0 (13.2)	20.0 (17.2)	16.0 (13.2)	0.53[a]	<0.001
Heightened sense of threat median (inter quartile range) cutoff score groups	10.0 (8.1)	13.0 (12.2)	10.0 (8.1)	0.66[a]	<0.001
No obvious PTSD symptoms, *n* (%)	104 (52.0)	3 (7.7)	101 (62.7)		
Certain degree of PTSD symptoms, *n* (%)	55 (27.5)	11 (28.2)	44 (27.3)	0.56[b]	<0.001
Probable diagnosis of PTSD, *n* (%)	41 (20.5)	25 (64.1)	16 (10.0)		
WHOQOL-BREF					
Overall QOL rating median (inter quartile range)	3.0 (1.0)	3.0 (1.0)	3.0 (1.0)	−0.11[a]	0.23
Overall satisfaction with health median (inter quartile range)	2.0 (1.0)	2.0 (1.0)	2.0 (1.0)	−0.02[a]	0.87
Physical health, median (inter quartile range)	11.4 (1.7)	11.4 (2.9)	11.4 (1.7)	0.03[a]	0.78
Psychological health, median (inter quartile range)	10.0 (2.0)	10.7 (2.0)	10.0 (2.0)	−0.14[a]	0.18
Social relationship, median (inter quartile range)	10.7 (2.7)	10.7 (4.0)	10.7 (2.7)	−0.20[a]	0.04
Environment, median (inter quartile range)	11.5 (3.0)	11.0 (3.5)	11.5 (2.5)	−0.04[a]	0.67

[a]Somer's d

[b]Cramer'V

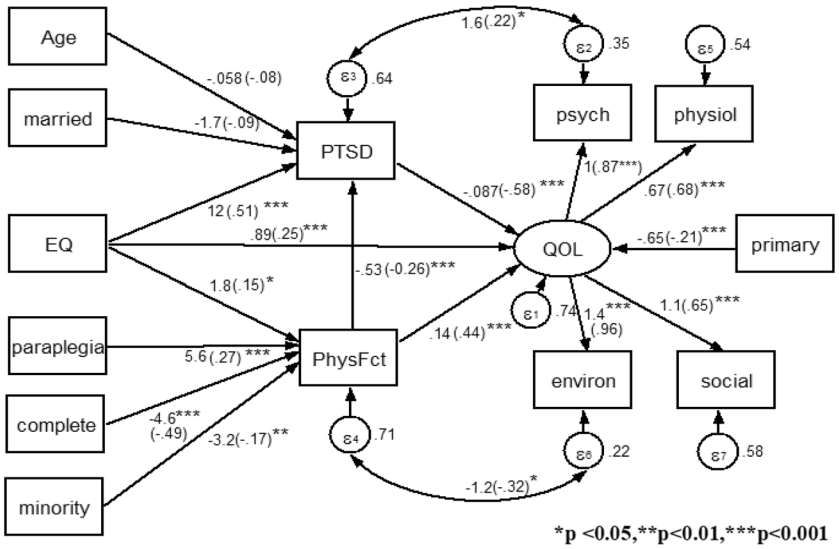

Fig. 2 Structural equation model (SEM) showing associations between physical function, post-traumatic stress disorder and quality of life in 200 study participants. Circles labeled with e1–e7 indicate standardized error variances. Values in brackets are standardized parameters. PTSD post-traumatic stress disorder, PhysFct physical function, QOL quality of life, EQ SCI caused by Wenchuan earthquake vs. other traumatic etiology, complete complete injury vs. incomplete, primary educational level of primary school and below vs. higher.

Table 3 Direct, indirect, and total effects of etiology on quality of life from the structural equation model.

Structural path	Coefficient	*95% CI*	*p*
Direct effect			
Earthquake survivor (reference: other traumatic etiology)	0.89	0.44/1.33	<0.001
Indirect effects			
Earthquake survivor (reference: other traumatic etiology),—PTSD pathway	−1.06	−1.44/−0.68	<0.001
Earthquake survivor (reference: other traumatic etiology),—Physical Function pathway	0.24	0.03/0.45	0.02
Total effect			
Earthquake survivor (reference: other traumatic etiology)	0.10	−0.22/0.42	0.55

Having sustained an SCI due to the Wenchuan earthquake as opposed to other traumatic etiology increased PCL-C scores but was also associated with increased physical function while controlling for type and severity of SCI as well as minority status. Those with paraplegia had significantly better physical function than participants with tetraplegia, while those with complete injuries and people from a minority ethnic group had worse physical function. Better physical functioning also decreased PTSD symptoms. Higher physical function, lower PTSD symptom severity and earthquake-related SCI etiology were associated with increased QOL. Table 3 displays the direct, indirect and total effects of etiology on QOL (a table showing all direct, indirect and total effects from the model can be found in Appendix 1). There was a significant negative indirect effect of earthquake-related etiology of SCI on QOL via PTSD according to Sobel test, i.e., the higher PTSD symptom severity of earthquake survivors was associated with a decrease in QOL. There was however also a positive indirect effect of EQ on QOL via the physical function pathway, i.e., higher physical function of earthquake survivors was associated with an increase in QOL. Given those indirect effects, a direct positive effect of earthquake-related etiology on PTSD remained, i.e., when it was adjusted for other influencing factors earthquake survivors had higher QOL. Taken together these opposite indirect and direct effects of etiology on QOL yielded an insignificant total effect.

Discussion

This was the first study comparing health-related outcomes between individuals with SCI with an earthquake-related etiology and those with another traumatic etiology of SCI.

We found that the risk of PTSD was severely elevated in earthquake survivors. Moreover, this group had more often complete injuries, which is probably owed to the most frequent injury mechanism, i.e., being hit by falling debris. Earthquake survivors were more also often widowed and had greater financial support.

Most of our hypotheses were confirmed by the SEM employed for multivariate analysis. Individuals with SCI with tetraplegia and complete injuries had reduced physical function as opposed to people with paraplegia and incomplete injuries (H2) and reduced physical function was

associated with decreased QOL (H5). Earthquake survivors presented an increased PTSD symptom severity (H1) as well as those with reduced physical functioning (H3), supporting the idea of duplicate trauma Higher PTSD symptom severity was in turn related to reduced QOL (H4). We found a significant negative indirect effect of having sustained SCI due to the Wenchuan earthquake through PTSD on QOL (H6). We had however expected this effect to be larger and did not expect a positive direct effect of etiology (earthquake vs. not) on physical function nor QOL, even when adjusted for PTSD symptom severity. We moreover confirmed indirect effects of physical function through PTSD (H7) and type and severity of SCI through physical function on PTSD (H8).

The WHOQOL-BREF domain scores reported in our study were lower than those in the reference populations of mainland China [39]. Our finding that low educational level had a significantly negative impact on QOL may be related to differential access to rehabilitation. Those with higher education may be more likely to obtain and comply with effective rehabilitative intervention. It may also be easier for them to achieve re-employment. Physical function had a positive effect on QOL confirming previous research [40, 41], and pointing to the need of continuous rehabilitative measures to be provided to individuals with SCI in the community.

The result that PTSD prevalence and symptom severity in disaster survivors with SCI were significantly higher than in those with other traumatic etiologies of SCI confirmed our hypothesis of duplicate trauma. In future studies, it is necessary to conduct professional psychological intervention and longitudinal evaluation for individuals with probable PTSD. Ideally, future research projects should include pathways for referral to timely and effective treatment of those screened positive for PTSD and corresponding funding mechanisms.

Our finding that an earthquake-related SCI etiology was associated with increased physical function when adjusted for type and degree of injury was unexpected and may be explained with more resources being devoted to the rehabilitation of earthquake survivors with SCI and increased social support for this group [42–44] as opposed to individuals with SCI with other traumatic etiology. As confirmed by our data government funds were especially dedicated to the rehabilitation of earthquake victims while other groups mostly had to pay out of their own pocket.

Our finding that participants from minority ethnic groups demonstrated reduced physical function in comparison with the Han majority is novel and alarming. It may be related to the fact that minority ethnic groups such as Yi and Tibetan people more often live in remote mountainous areas of Sichuan Province with less access to health care and rehabilitation and more difficult environments.

Our findings that PTSD had a negative effect on QOL was consistent with results of studies conducted among earthquake survivors, earthquake rescue officers and elderly hip fracture persons [45–47]. A survey on the long-term impact of the Wenchuan earthquake on survivors' QOL also confirmed that PTSD was a mediator in the relationship between earthquake-related exposure and QOL, earthquake-related exposure affected the survivors' QOL mainly mediated by the PTSD symptoms [48]. A range of clinical manifestations of PTSD, such as emotional numbness, invasive memories and sleep disorders, not only aggravates people's psychological function, but also affects the recovery of patients' social function, leading to a decline in QOL [49]. We had not expected that a direct effect of etiology on QOL remained when it was adjusted for other factors, i.e., that earthquake survivors show increased QOL at given values of covariates including education, PTSD symptom severity and physical function. Mechanisms not accounted for in our model may be behind it, e.g., greater government financial support for earthquake victims.

Our findings suggest that Wenchuan earthquake survivors with SCI face increased psychological problems during the chronic phase. Reducing symptoms of PTSD and enhancing independence in physical function through supportive and complementary measures may be effective ways to improve QOL of earthquake survivors with SCI.

The small sample size of the disaster SCI group is a limitation of the present study with regard to an overemphasis on those with non-earthquake-related traumatic SCI in the measurement model of QOL. Since China has not yet established a national level SCI registry, recruitment of individuals with SCI, especially those with disaster-related etiology, is very difficult. Therefore, this study is still exploratory and findings needs to be interpreted with caution. Moreover, earthquakes often have a stronger impact on poorer neighborhoods and living in a poor neighborhood may increase the likelihood of traumatic experiences so that baseline PTSD may have already differed between the groups. Unfortunately, data on PTSD prevalence before the earthquake are not available and we also did not have information on neighborhood socioeconomic status. Earthquake survivors and others did however not differ in income nor education, so that the above scenario is rather unlikely to have contributed.

In conclusion, prevalence of PTSD in earthquake survivors with SCI was largely increased as compared with people with SCI of other traumatic etiology. In spite of this the groups did not differ in QOL because of better physical function of earthquake survivors and possibly other unobserved factors such as government subsidies. Effective intervention for PTSD is urgently needed in earthquake survivors with SCI. Continuous rehabilitative measures to

improve physical function in both groups are also recommended.

Data availability

Data are available from the corresponding author upon reasonable request.

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Author contributions All authors contributed to formulating the research protocol. XF coordinated the study, JL was responsible for collecting and analyzing data and contributed to interpreting results. JDR contributed to building the structural equation model. All authors wrote the manuscript and approved its final version and had final responsibility for the decision to submit for publication.

Compliance with ethical standards

Ethical statement The study was approved by the West China Hospital of Sichuan University Biomedical Research Ethics Committee (No. 2017–469). The study strictly followed the basic principles of biomedical research: respect for human dignity, beneficence and justice. The researcher informed the participants of the contents of study (e.g., background/purpose/method of this study, risk/benefit for the participants.), and started the investigation after having obtained their authorized signature. The study participants could withdraw from the study at any point.

Conflict of interest The authors declare that they have no conflict of interest.

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