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ORIGINAL REPORT

FACTORS AFFECTING FUNCTIONAL OUTCOME OF SICHUAN-EARTHQUAKE SURVIVORS WITH TIBIAL SHAFT FRACTURES: A FOLLOW-UP STUDY

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Objective: **The aim of this study was to analyse the various factors affecting functional recovery of earthquake survivors with tibial shaft fractures in Sichuan, China, and to provide a clinical reference for the future management of people injured in earthquakes.**

Methods: **A total of 174 earthquake survivors with tibial shaft fractures were investigated using a face-to-face survey 15 months after the earthquake. Functional recovery after fracture was evaluated by Johner-Wruhs' criteria. Thirteen of the parameters that may influence functional recovery after fracture were included. Univariate and multiple stepwise logistic regression analyses were employed.**

Results: **Functional recovery was positively associated with rehabilitation intervention (odds ratio 5.3 (95% confidence interval 2.38–11.67)), but negatively correlated with the immobilization duration (odds ratio (per 10 days increase) 0.87 (95% confidence interval 0.798–0.947)), age (odds ratio (per 10 years increase) 0.54 (95% confidence interval 0.418–0.707)) and depressive symptomatology (odds ratio 0.21 (95% confidence interval 0.063–0.716)).**

Conclusion: **Functional recovery of post-earthquake survivors with tibial shaft fractures is related mainly to availability of rehabilitation intervention, duration of immobilization, post-earthquake depressive symptomatology, and age. These results may support the future development of strategies for optimizing functional recovery of survivors with lower limb fracture after massive natural disasters.**

Key words: tibial shaft fracture; functional restoration; immobilization; depression; rehabilitation; earthquake.

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INTRODUCTION

On 12 May 2008, an earthquake measuring 8.0 on the Richter scale struck the densely populated region of Sichuan Province in southwest China, leaving approximately 37,000 injured survivors. Our earlier survey showed that fractures of the tibia and fibula were the most common type of injury among the survivors (1). Prevention of complications, such as non-union, and promoting functional restoration, have been studied in recent years (2, 3). Several studies have presented various surgical methods to promote fracture healing (4–6), but few address early non-surgical interventions.

The aims of this study were: to identify factors contributing to the functional restoration of earthquake survivors with tibial shaft fracture; to gather evidence about the importance of rehabilitation intervention for injured survivors after major natural disasters; and to provide a basic reference for the present work of local rehabilitation models in earthquake-affected areas.

METHODS

Subjects

A total of 2287 earthquake survivors were interviewed in a survey conducted between September 2008 and May 2009 in Mianzhu city, the major earthquake area with most survivors after the disaster. Individual patient files were collected during the interviews. A total of 260 cases of tibia and fibula fractures were identified among this group of survivors, of which 198 were tibia shaft fractures. These survivors were selected as potential participants for the present study.

Inclusion and exclusion criteria

Two candidates diagnosed with cognitive dysfunction were excluded from the study. Twenty-two cases were lost due to change of address. A final total of 174 ambulatory earthquake survivors were included in the study. Ambulatory survivors were defined as those subjects who were able to walk independently unaided or using an assistive device, such as a cane or walker, or with direct support from another person.

The age distribution of participants is shown in Table I.

The study was approved by the human research committees concerned, and written informed consent was obtained from all participants.

Table I. *Age distribution of study participants*

Age, years	*n* (%)
≤10	3 (1.7)
11–20	7 (4.0)
21–30	12 (6.9)
31–40	32 (18.4)
41–50	28 (16.1)
51–60	38 (21.8)
61–70	38 (21.8)
71–80	14 (8.1)
>80	2 (1.2)

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Questionnaire and interview

Between August 2009 and February 2010, the research coordinator, with the help of other caregivers, identified all ambulatory earthquake survivors who had tibial shaft fractures recorded at the "Earthquake Survivors Rehabilitation Centre of Mianzhu".

According to the predefined inclusion criteria, these people were informed about the on-site interview. The baseline evaluation included a general and medical questionnaire, anthropometric measurements and leg X-ray. The general information collected included gender, age, educational status, hospitalization time, and presence of any chronic diseases, such as diabetes, hypertension, coronary heart disease, etc.

Potential influencing factors

The level of fractures (proximal, middle, or distal shaft) was classified according to AO classification. The method of fracture fixation was divided into internal and external fixations. The external fixation approach included casting braces. The presence of multiple fractures and comminution of fractures were identified.

In addition to the general information, the history of fracture treatments received was also recorded. Radiological evidence of the bone healing progress (callus formation) was evaluated by a single specialist radiologist.

Institution-based rehabilitation interventions for clients included in this study were delivered by a team of experienced physiotherapists in a rehabilitation centre. This professional team was formed for the management of earthquake survivors, by a group of professional volunteers who came from all over the country 5 months after the earthquake. Appropriate rehabilitation treatment modalities were prescribed based on the professional assessments, including range of motion (ROM), muscle strength, ability in activities of daily living (ADL), pain and scar problems, etc. The main therapeutic modalities adopted for the clients in this study were muscle strengthening exercises, joint mobilization and muscle stretching to improve ROM, standing and walking exercises, scar treatment, and other electromagnetic and heat treatments as necessary.

Each treatment session lasted for a minimum of 40 min, with at least two sessions per day, for a period of more than 1 month.

Depressive symptomatology was assessed using the Center for Epidemiologic Studies Depression Scale (CES-D) (7). This is a valid and frequently used measuring tool for depressive symptomatology, which is applicable to adults (8, 9) and children (10, 11).

Recovery of tibial shaft fracture

On completion of the bone healing process, the outcome results were evaluated according to Johner-Wruhs' criteria (12, 13), which take functional, clinical, radiological and subjective outcomes into account (Table II). The presence of complications, including non-union and osteomyelitis, were assessed. The collected clinical and imaging data for the survivors were analysed by an orthopaedic surgeon. Fracture healing was judged by an on-site physical examination and a series of follow-up X-rays reviewed by the surgeon.

The ROM of the knee and ankle were measured and compared bilaterally. Pain intensity was measured by visual analogue scale (VAS) (14) and the outcome was categorized as excellent, good, fair or poor, with VAS values scoring 0, 1–3, 4–6, and 7–10, respectively. A grade of "excellent" meant no pain, "fair" meant that pain had caused some sleep disturbance, and "poor" described pain beyond the patient's tolerance.

Data processing

For the analysis of functional recovery, subjects were categorized into "normal union" or "abnormal union". Normal union were those who achieved excellent or good functional recovery according to Johner-Wruhs' criteria in the final outcome evaluation. Those with fair or poor functional recovery according to the same criteria were categorized as abnormal union. The status of functional recovery was dichotomized for its use in the analysis (0 = normal union and 1 = abnormal union). Other independent variables were: gender, age at baseline (per 10 years), immobilization duration at baseline (per 10 days), hospitalization duration at baseline (per 10 days), open or closed type of fracture, presence of a chronic disease, presence of baseline depressive symptoms, open or closed treatment technique, fracture site, AO fracture classification, whether they received rehabilitation intervention, and the presence of fracture comminution and/or multiple injury.

Statistical methods

The factors related to functional recovery after tibial shaft fractures were estimated with odds ratios (OR) and 95% confidence intervals (CI) using logistic regression analysis. Significant factors revealed in univariate analysis were subjected to multivariate stepwise logistic regression analysis. SPSS software (version 11.0, SPSS Inc., Chicago, USA) was used for the analyses. $p < 0.05$ was considered statistically significant.

RESULTS

Table III shows the descriptive characteristics of the sample at baseline. The follow-up period was 15–21 months after the earthquake. Non-union occurred in 7 patients out of the 174 subjects, with an overall incidence of 4.0%. According to Johner-Wruhs' criteria for outcome evaluation, a total of 43 patients (24.7%) were excellent, 46 (26.4%) were good, 21 (12.1%) were fair, and 64 (36.8%) were poor. Accordingly, there were 89 patients (51.1%) characterized as either excellent or good in functional recovery.

Table II. *Johner-Wruhs' criteria for evaluation of final results*

	Excellent (left = right)	Good	Fair	Poor
Non-union, osteomyelitis, amputation	None	None	None	Yes
Neurovascular disturbances	None	Minimal	Moderate	Severe
Deformity				
Varus/valgus, º	None	2–5	6–10	> 10
Anteversion/recurvation, º	0–5	6–10	11–20	> 20
Rotation, º	0–5	6–10	11–20	> 20
Shortening, mm	0–5	6–10	11–20	> 20
Mobility, %				
Knee	Normal	> 80	> 75	< 75
Ankle	Normal	> 75	> 50	< 50
Subtalar joint	> 75	> 50	< 50	
Pain	None	Occasional	Moderate	Severe
Gait	Normal	Normal	Insignificant limp	Significant limp
Strenuous activities	Possible	Limited	Severely limited	Impossible

Table III. *Characteristics of the subjects according to Johner-Wruhs' criteria*

Factor	Excellent $n=43$	Good $n=46$	Fair $n=21$	Poor $n=64$
Age, years, mean (SD)	37.0 (17.12)	47.0 (12.63)	52.1 (16.20)	59.2 (13.09)
Immobilization duration, days, mean (SD)	57.4 (51.13)	67.7 (37.13)	91.7 (48.36)	96.5 (65.96)
Hospitalization time, days, mean (SD)	53.9 (34.08)	65.8 (42.45)	64.1 (27.73)	55.5 (27.70)
Gender, *n* (%)				
Male	22 (51.2)	23 (50.0)	6 (28.6)	23 (35.9)
Female	21 (48.8)	23 (50.0)	15 (71.4)	41 (64.1)
Education, *n* (%)				
Illiteracy	6 (14.0)	11(23.9)	7 (33.3)	34 (53.1)
Literacy	37 (86.0)	35 (76.1)	14 (66.7)	30 (46.9)
Open vs closed fracture, *n* (%)				
Closed	31 (72.1)	28 (60.9)	11 (52.4)	36 (56.2)
Open	12 (27.9)	18 (39.1)	10 (47.6)	28 (43.8)
Chronic disease, *n* (%)				
No	39 (90.7)	39 (84.8)	19 (90.5)	47 (73.4)
Yes	4 (9.3)	7 (15.2)	2 (9.5)	17 (26.6)
Baseline depressive symptoms, *n* (%)				
No	40 (93.0)	43 (93.5)	17 (81.0)	47 (73.4)
Yes	3 (7.0)	3 (6.5)	4 (19.0)	17 (26.6)
Open vs closed technique, *n* (%)				
Closed	33 (76.7)	34 (73.9)	15 (71.4)	47 (73.4)
Open	10 (23.3)	12 (26.1)	6 (28.6)	17 (26.6)
Comminuted fracture, *n* (%)				
No	33 (76.7)	22 (47.8)	12 (57.1)	37 (57.8)
Yes	10 (23.3)	24 (52.2)	9 (42.9)	27 (42.2)
Multiple injury, *n* (%)				
No	36 (83.7)	38 (82.6)	16 (76.2)	56 (87.5)
Yes	7 (16.3)	8 (17.4)	5 (23.8)	8 (12.5)
Fracture site, *n* (%)				
Proximal	6 (14.0)	10 (21.8)	3 (14.3)	6 (9.4)
Mid-shaft	24 (55.8)	18 (39.1)	12 (57.1)	28 (43.7)
Distal	13 (30.2)	18 (39.1)	6 (28.6)	30 (46.9)
AO fracture classification, *n* (%)				
A	27 (62.8)	14 (30.4)	11 (52.4)	20 (31.2)
B	11 (25.6)	23 (50.0)	7 (33.3)	27 (42.2)
C	5 (11.6)	9 (19.6)	3 (14.3)	17 (26.6)
Rehabilitation training, *n* (%)				
No	16 (37.2)	12 (26.1)	13 (61.9)	44 (68.8)
Yes	27 (62.8)	34 (73.9)	8 (38.1)	20 (31.2)

SD: standard deviation.

Excellent or good functional recovery had a positive association with rehabilitation training (Table IV) (adjusted OR 4.4, 95% CI 2.35–8.38; $p<0.001$). Excellent or good functional recovery had a negative association with immobilization duration per 10 days increase (adjusted OR 0.88, 95% CI 0.826–0.946; $p<0.001$), age per 10 years increase (adjusted OR 0.51; 95% CI 0.402–0.648; $p<0.001$), female sex (adjusted OR 0.51; 95% CI 0.275–0.933; $p<0.05$), depressive symptoms at baseline (adjusted OR 0.23; 95% CI 0.088–0.610; $p<0.01$), and co-morbidity with chronic disease (adjusted OR 0.49; 95% CI 0.218–1.103; $p=0.085$).

Hospitalization time, open vs closed type of fracture, multiple injury, open vs closed treatment technique, fracture site, AO fracture classification, and fracture comminution had no significant association with functional recovery of tibial shaft fractures (Table IV).

Significant factors revealed in univariate analysis were subjected to multivariate stepwise logistic regression analysis, such as rehabilitation training, immobilization duration, age, female sex, depressive symptoms at baseline, and co-morbid chronic disease (logistic regression model, $p<0.001$).

Multivariate stepwise logistic regression showed that several factors were significantly associated with functional recovery. Rehabilitation training had a positive association with excellent or good functional recovery ($p<0.001$); adjusted OR for excellent or good functional recovery was 5.3 (95% CI 2.38–11.67) with no rehabilitation training as reference.

Excellent or good functional recovery had a negative association with immobilization duration per 10 day increase (adjusted OR 0.87, 95% CI 0.798–0.947; $p<0.01$), and age per 10 year increase (adjusted OR 0.54; 95% CI 0.418–0.707; $p<0.001$). Depressive symptoms at baseline was negatively associated with excellent or good functional recovery ($p<0.05$); adjusted OR was 0.21 (95% CI 0.063–0.716) with no depressive symptoms as reference (Table V).

In contrast, no significant associations between functional recovery of excellent or good grade and gender or presence of co-morbid chronic disease were observed by the multivariate analysis.

Table IV. *Univariate logistic regression analysis of factors for functional recovery*

Factor	OR (95% CI)	p
Age/10 years	0.51 (0.402–0.648)*	<0.001
Immobilization duration/10 days	0.88 (0.826–0.946)*	<0.001
Hospitalization time/10 days	1.0 (0.94–1.12)	0.603
Gender		
Female	0.51 (0.275–0.933)*	0.029
Male	1.0	
Open vs closed fracture		
Open	0.63 (0.341–1.161)	0.138
Closed	1.0	
Chronic disease		
Yes	0.49 (0.218–1.103)	0.085
No	1.0	
Baseline depressive symptoms		
Yes	0.23 (0.088–0.610)*	0.003
No	1.0	
Open vs closed technique		
Closed	1.1 (0.57–2.23)	0.725
Open	1.0	
Comminuted fracture		
Yes	0.84 (0.459–1.543)	0.577
No	1.0	
Multiple injury		
Yes	1.1 (0.50–2.53)	0.780
No	1.0	
Fracture site		
Distal	0.48 (0.188–1.249)	0.134
Mid-shaft	0.59 (0.234–1.489)	0.264
Proximal	1.0	
AO fracture classification		
C	0.53 (0.231–1.210)	0.132
B	0.76 (0.388–1.472)	0.411
A	1.0	
Rehabilitation training		
Yes	4.4 (2.35–8.38)*	<0.001
No	1.0	

*$p < 0.05$.
OR: odds ratio; CI: confidence interval.

DISCUSSION

The availability of timely and appropriate rehabilitation training, duration of immobilization, presence of depressive symptomatology, and age influenced the odds for functional recovery of survivors with tibial shaft fracture after a major earthquake. Several studies have demonstrated that a timely and adequate rehabilitation programme can effectively reduce complications after fractures and improve functional outcomes of the injured limb (15, 16). In the present study, the final functional condition of the survivors who had received comprehensive rehabilitation interventions were obviously better than those who did not have such interventions. When an earthquake of similar scale occurred in Haiti in 2010, Cuba's health authorities were able to arrange to provide rehabilitation services for 59,578 survivors in the first 3 months after the earthquake. These services were provided in 10 hospitals, and 20 clinics across earthquake-affected areas of Haiti (17).

In our study, Mianzhu was the only city with a rehabilitation service facility in the district, and those earthquake survivors without access to proper rehabilitation treatments were those living a long distance from the city. The lack of rehabilitation professionals and facilities to implement early rehabilitation in most of the large or medium-sized hospitals in China were the major obstacles to providing timely appropriate rehabilitation management for these survivors. However, since this major earthquake, central government health authorities in China are more aware of the importance of developing medical rehabilitation services, and it is hoped that this may result in improvement of rehabilitation facilities across the country.

An increased period of immobilization increases the risk of poor fracture healing, whereas appropriate, timely implemented rehabilitation training reduces this risk. Earthquake survivors were often severely injured. Because of the lack of sufficient healthcare professionals and other relevant resources in the earthquake-affected region, many of the injured survivors were transferred quickly to other provincial hospitals in China for medical treatment after they were rescued. These patients were sent back home or to local hospitals 1–2 months later. Throughout these periods of hospitalization, and after returning home or to local hospitals, these patients were left lying in bed most of the time. Such prolonged bed rest would no doubt increase the risk of developing various complications. Problems such as muscle wasting, oedema, and joint stiffness resulted primarily from disuse (18), phlebothrombosis (19), or immobilization (20). This general phenomenon was also evident in the present study, as the percentage of poor end-results was positively associated with increased duration of immobilization.

The occurrence of depressive symptoms after fractures (21) has been reported in many studies, and this will have a significant impact on the general and social functions of these survivors (22, 23). Our study showed similar outcomes for the functional recovery of earthquake survivors with tibial shaft fractures associated with depressive symptomatology. Only 20% (OR 0.21) of the earthquake survivors with signs and symptoms of depression achieved excellent or good recovery of function, compared with a much larger proportion of those

Table V. *Multivariate stepwise logistic regression analysis of factors for functional recovery*

	B	SE	Wald	p	OR	95% CI
Rehabilitation training	1.66	0.405	16.847	<0.001	5.3	2.38–11.67
Immobilization duration/10 days	–0.14	0.044	10.245	0.001	0.87	0.798–0.947
Age/10 years	–0.61	0.134	20.643	<0.001	0.54	0.418–0.707
Depressive symptoms	–1.55	0.619	6.255	0.012	0.21	0.063–0.716
Constant quantity	3.84	0.830	21.355	<0.001		

B: regression coefficient; SE: standard error; Wald: Wald value; OR: odds ratio; CI: confidence interval.

without depressive symptoms. More attention should be focused on the psychological state of survivors of large-scale natural disasters, and this factor should be taken into account by government authorities in future policymaking and management planning. Timely psychological intervention would enhance the rehabilitation outcome of survivors, particularly those with low levels of emotional and social support.

The findings of the present study are consistent with the results of other studies, that age is an important factor affecting functional recovery (24). With increasing age the proliferation of osteoblasts decreases and that of osteoclasts increases; therefore fractures in elderly people will take longer to heal. Several studies have also found that, during disasters, disruption of treatment and lack of medication is common among patients with various types of chronic diseases (25, 26). When a large physical and mental impact occurs, it results in an exacerbation of chronic conditions during and immediately after the disaster (27). In our study the outcome for earthquake survivors with fractures and chronic diseases was poorer than for those without chronic disorders. In addition to focusing on fracture treatment, continuity of treating co-morbidities after a disaster should not be neglected. This is especially important for those who were receiving long-term medication or rehabilitation treatment before the disaster (28, 29).

AO classification is concerned more with measuring fracture union than with functional outcomes. Thus, the result of our study, which shows no significant correlation of AO classification with functional recovery of tibial shaft fractures, is not unexpected. Women play non-dominant roles in the culture of productivity in Mianzu district. This may promote their prolonged bed rest after returning home. Thus, the finding of influence of gender may be due to the impact of longer immobilization period of women. This may be a possible explanation for why the gender had been removed from the results of multivariate stepwise logistic regression analysis, despite it being described as a significant factor in the univariate analysis. However, further in-depth investigation is needed to interpret the exact relationship between gender and functional recovery of earthquake survivors with fractures.

This study has some limitations. Firstly, the subjects, centred in Mianzhu district of Sichuan, do not cover all the earthquake-affected areas. Nevertheless, Mianzhu was the area with the largest number of injured survivors in this disaster, thus we consider the study population to be relatively representative. Secondly, this is only an observational study. Allocation of injured patients to rehabilitation intervention, which is the most significant factor associated with good functional outcome, could not be randomized. Thirdly, some cases were missing because they had probably moved away from their previous addresses to rebuild their homes, and at the same time telephone numbers were likely to be changed, making contact impossible.

In conclusion, the functional recovery of tibial shaft fractures after earthquake is mainly related to the availability of timely and appropriate rehabilitation treatments, immobilization duration, any signs and symptoms of depression at the first assessment after the earthquake, and age. The results of this study may provide the basis for future development of strategy for optimizing the functioning and rehabilitation of survivors with lower limb fracture after massive natural disasters.

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