Traumatic Spinal Cord Injury Caused by Low Falls and High falls: A Comparative Study

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Abstract

Background: Quite a few patients with spinal cord injury (SCI) are caused by falls. However, the comparison of different causes of SCI or the epidemiological characteristics of SCI caused by falls of different heights are rare. This study investigated the epidemiological characteristics of traumatic SCI caused by falls and conducted a comparison between low falls and high falls.

Method: Data from traumatic SCI cases admitted to China Rehabilitation Research Center from 2010 to 2019 were collected, including age, gender, occupation, cause, level and severity of the injury, combined injuries, complications, and rehabilitation length of stay. Mann-Whitney U and Chi square ($\chi 2$) tests were used to assess the differences between two groups at a statistical significance level of 0.05.

Result: Patients with fall-induced SCI were older and a longer rehabilitation length of stay than those with nonfall-induced SCI. Patients with high fall-induced SCI were younger and more likely to suffer from paraplegia, severer injuries, and combined injuries, and had longer time from injury to rehabilitation and rehabilitation length of stay, compared with patients with low fall-induced SCIs.

Conclusion: Falls, especially high falls, are the primary causes of SCI. Special attention should be paid to the prevention of high falls in the working environment. Low falls are also worthy of attention due to their high incidence and constitute a considerable proportion of causes of SCI.

Background

A fall is defined as an injury to a person that occurs after landing due to slipping, tripping, stumbling, collision or after descent from a higher place, such as a furniture, ladder, scaffold, building, work area, or other elevated place (1). Falls, including high falls and low falls, are a common and serious problem, which causes an enormous burden to both the family and society in terms of healthcare and costs (2). It has been reported that the incidence of fall-related injuries among older Chinese people ranged from 0.6–19.5% and the cost ranged from US$16 to US$3812 per person per fall (3). In particular, falls from height, which are usually unintentional (92.2%), result in higher disability and mortality rates (4).

Falls play an important role in traumatic spinal cord injury (SCI). The percentage of SCI cases associated with falls increased from 28% in 1997–2000 to 66% in 2010–2012 in patients aged 65 years or older (5). Injuries caused by falls represented 49.8% of cases in Saint Petersburg from 2012 to 2016, and elderly women more often suffered from low falls than men (6). A systematic review on an epidemiological survey of SCI in China showed that falls resulted in 23.9–65.3% of all SCI cases, and that falls were the primary causation of injury in most cities of China (7). Moreover, another retrospective investigation inn Northwest China from 2014 to 2018 showed that falls resulted in 85.1% (low falls 47.7%, high falls 37.3%) of all SCI cases (8). Although epidemiological features of SCI vary dramatically around the world, it can still be inferred that falls have a great influence on the occurrence of SCI.

A specific survey of the causes of falls resulting in SCI revealed that different demographic characteristics were present in patients and that varied situations led to the falls (9). Here, we provide an in-depth description of the epidemiological characteristics of SCI caused by falls in order: (1) to understand the epidemiology of SCI resulting from both falls and nonfalls; and (2) to examine demographic and clinical characteristics of patients with SCI that were the result of low falls and high falls. We believe this investigation could provide evidence for preventing or reducing fall-induced SCI in China and helping clinicians better diagnose and treat patients caused by falls

Methods

Aim

This study investigated the epidemiological characteristics of traumatic SCI caused by falls and nonfalls and conducted a comparison between low falls and high falls.

Participants And Processes

Detailed information of patients with traumatic SCI was obtained from the Medical Record System of China Rehabilitation Research Center, Beijing, China from January 1st 2010 to December 31st 2019, including age, gender, occupation, cause, level and severity, vertebra fracture and dislocations, complications, and rehabilitation length of stay (LOS). Two independent researchers examined the patients and studied medical records and images to determine the cases that were the result of falls. After grouping patient data, cases that resulted from falls were analyzed in depth.

Measures And Definition

The participants were divided into six age groups: 0–15, 16–30, 31–45, 46–60, and > 60 years. The etiologies included falls (low fall, height < 1 m; high fall, height ≥ 1 m) and nonfalls (including motor vehicle collisions, object striking, sports-related, assault, work-related, and others) (10). Neurological functions were evaluated according to the American Spinal Injury Association Impairment Scale (AIS) as AIS grade A, B, C, D, and E (AIS grade A for complete SCI, AIS grade B, C, D, and E for incomplete SCI) (11).

Statistical analysis

In data processing, Statistical Product and Service Solutions (version 25.0 Inc., Chicago, IL, the United States) statistical software was used. Categorical and continuous data were reported in the form of percentage and median with interquartile range (IQR). Mann-Whitney U and Chi square (χ^2) tests, as appropriate, were used to assess the differences between two groups at a statistical significance level of 0.05.

Results

A total of 1858 cases were identified; the median age was 38 (IQR = 27–49) years old; and the median rehabilitation LOS was 117 (IQR = 55–239) days.

Participant Characteristics: Fall Vs Nonfall Etiologies

Table 1 summarizes the demographic, injury, and medical characteristics patients with fall-induced SCI (41.7%, 775/1858) compared with patients with nonfall-induced SCI (58.3%, 1083/1858). Specifically, motor vehicle collisions represented 31.3%; struck by object, 13.9%; work-related, 5.8%; sports related, 4.0%; assault, 1.3%; and others, 1.7%. Generally, patients with fall-induced SCI (40 years old, IQR = 28 − 51) were older than those with nonfall-induced SCI (37 years old, IQR = 26 − 47) ($P < 0.001$).

Table 1
Characteristics of participants resulted from fall and non-fall (N = 1858)

Characteristics	Non-fall group	Fall group	P value
	n = 1083 (%)	n = 775 (%)	
Age (years)			$\chi2 = 26.009$, $P < 0.001$
0–15	93 (8.6%)	31 (4.0%)	
16–30	303 (28.0%)	204 (26.3%)	
31–45	367 (33.9%)	246 (31.7%)	
46–60	267 (24.6%)	236 (30.5%)	
61 and above	53 (4.9%)	58 (7.5%)	
Sex			$\chi2 = 11.502$, $P = 0.001$
Male	819 (75.6%)	637 (82.2%)	
Female	264 (24.4%)	138 (17.8%)	
Level of injury			$\chi2 = 2.130$, $P = 0.144$
Tetraplegia	460 (42.5%)	303 (39.1%)	
Paraplegia	623 (57.5%)	472 (60.9%)	
Severity of the injury			$\chi2 = 2.975$, $P = 0.085$
Incomplete	529 (48.8%)	410 (52.9%)	
Complete	554 (51.2%)	365 (47.1%)	
Complication			$\chi2 = 0.850$, $P = 0.357$
Yes	720 (66.5%)	531 (68.5%)	
No	363 (33.5%)	244 (31.5%)	
Rehabilitation LOS (IQR)	126 (58, 268)	100 (50, 194)	$P < 0.001$*

* Mann-Whitney U test; IQR, interquartile range; LOS, length of stay

Statistically significant differences were found between patients with fall- and nonfall-induced SCI with regard to age range, gender, rehabilitation LOS rather than level of injury, severity, and complications (Table 1). Patients with fall-induced SCI tended to be older were usually male (43.8% male vs 34.3% female).

Participant Characteristics: Low Fall Vs High Fall Etiologies

Falls from buildings were the most common cause of fall-induced SCI (22.7%), followed by scaffolding (16.8%), and slipping, tripping, and stumbling at the same height (15.0%). Other falls from height accounted for 23.1%, but the specific situation was not clear.

Table 2 summarizes the demographic, injury, and medical characteristics of patients with fall-induced SCI. Specifically, 212 cases (27.4%) were the result of a low fall and 563 cases (72.6%) were the result of a high fall. Patients with low fall-induced SCI were older than those with high fall-induced SCI [52 (IQR = 37.25-60) years old vs 37 (IQR = 27.00–46) years old, respectively $P < 0.001$]. Patients were transferred to rehabilitation hospitals 47 (IQR = 24–124) days after injury.

Table 2
Characteristics of participants resulted from low-fall and high-fall (N = 775)

Characteristics	Low fall group	High fall group	P value
	n = 212 (%)	n = 563 (%)	
Age (years)			$\chi2 = 166.975$, $P < 0.001$
0–15	17 (8.0%)	14 (2.5%)	
16–30	22 (10.4%)	182 (32.3%)	
31–45	36 (17.0%)	210 (37.3%)	
46–60	88 (41.5%)	148 (26.3%)	
61 and above	49 (23.1%)	9 (1.6%)	
Sex			$\chi2 = 2.332$, $P = 0.127$
Male	167 (78.8%)	470 (83.5%)	
Female	45 (21.2%)	93 (16.5%)	
Level of injury			$\chi2 = 134.059$, $P < 0.001$
Tetraplegia	153 (72.2%)	150 (26.6%)	
Paraplegia	59 (27.8%)	413 (73.4%)	
AIS grade			$\chi2 = 103.288$, $P < 0.001^{\#}$
A	49 (23.1%)	316 (56.1%)	
B	31 (14.6%)	108 (19.2%)	
C	53 (25.0%)	67 (11.9%)	
D	79 (37.3%)	69 (12.3%)	
E	0 (0.0%)	3 (0.5%)	
Cases with spine surgery	186 (87.7%)	555 (98.6%)	$\chi2 = 43.168$, $P < 0.001$
Vertebrae fracture or dislocation			$\chi2 = 275.529$, $P < 0.001$
Yes	92 (43.4%)	538 (95.6%)	

* Mann-Whitney U test; # Fisher's Exact Test; AIS, American Spinal Injury Association Impairment Scale; IQR, interquartile range; LOS, length of stay.

Characteristics	Low fall group	High fall group	P value
	n = 212 (%)	n = 563 (%)	
No	120 (56.60%)	25 (4.40%)	
Major vertebrae fracture or dislocation			$\chi2 = 49.240$, $P < 0.001^{\#}$
C1-C2	3 (3.2%)	1 (0.2%)	
C3-C7	50 (53.8%)	124 (23.0%)	
T1-T4	0 (0.0%)	10 (1.9%)	
T5-T9	11 (11.8%)	52 (9.7%)	
T10-L2	28 (30.1%)	330 (61.3%)	
L3-L5	1 (1.1%)	21 (3.9%)	
Complication			$\chi2 = 0.422$, $P = 0.516$
Yes	149 (70.3%)	382 (67.9%)	
No	63 (29.7%)	181 (32.1%)	
Other combined injuries			
Extremity bones fracture	11 (5.2%)	131 (23.3%)	$\chi2 = 33.638$, $P < 0.001$
Craniocerebral injury	38 (17.9%)	129 (22.9%)	$\chi2 = 2.267$, $P = 0.132$
Thoracic injury	6 (2.8%)	111 (19.7%)	$\chi2 = 34.258$, $P < 0.001$
Abdominal injury	1 (0.5%)	28 (5.0%)	$\chi2 = 8.665$, $P = 0.003$
Pelvis fracture	0 (0.0%)	27 (4.8%)	$\chi2 = 10.534$, $P = 0.001$
≥ 1 extraspinal lesions	50 (23.6%)	300 (53.3%)	$\chi2 = 54.857$, $P < 0.001$
≥ 2 extraspinal lesions	6 (2.8%)	101 (17.9%)	$\chi2 = 29.545$, $P < 0.001$
Median time from injury to rehabilitation (IQR)	41 (21, 110.5)	50 (25,126)	P = 0.043*
Rehabilitation LOS	78.5 (33, 150.25)	112 (58, 215)	P < 0.001*

* Mann-Whitney U test; # Fisher's Exact Test; AIS, American Spinal Injury Association Impairment Scale; IQR, interquartile range; LOS, length of stay.

Patients with low fall-induced SCI were more likely to suffer from tetraplegia (72.2%) and have incomplete injuries (76.9%). In contrast, patients with high fall-induced SCI were more likely to suffer from

paraplegia (73.4%) and have complete injuries (56.1%).

A total of 630 patients had vertebral fractures and dislocations, accounting for 81.3% of all cases. Patients with high fall-induced SCI were more likely to have either vertebral fractures or dislocations (95.6% vs 43.4%, $P < 0.001$) that were mainly located at the thoracolumbar vertebral level (T10–L2, 61.3%). Among the 145 SCI cases without vertebral fractures, 82.6% were the result from a low fall. Overall, 48 cases were without fractures or dislocations, 51 had cervical spinal stenosis, and 36 had cervical disc herniation or clamping.

During the rehabilitation hospitalization, 531 patients (68.5%) suffered from complications, and no difference between patients with fall- or nonfall-induced SCIs was found. However, whether SCI was induced by a high fall or a low fall, were all prone to complications, such as intestinal dysfunction, urinary tract infection, neuropathic pain, and respiratory infection.

Patients with high fall-induced SCI had a higher risk of combined injuries than patients low fall-induced SCI (53.3% vs 23.6%; $\chi^2 = 54.857$, $P < 0.001$), and the same were in extremity bones fracture, thoracic injury, abdominal injury, and pelvis fracture. Craniocerebral injury was common in patients with low fall-induced SCI, accounting for 17.9% of low-fall cases.

Different neurological level of injury characteristics: low fall vs high fall etiologies

As shown in the Fig. 1, there were two peaks in patients with fall-induced SCI, including at the cervical (C4–T1, 31.5%) and lower thoracic (T9–T12, 32.9%) spinal cord. Patients with low fall-induced SCI were more likely to have cervical level-related SCI, especially at C4 (34.4%). Patients with high fall-induced SCI were likely to have lower thoracic level-related SCI (T9–T12, 40.1%); however, injury at the C4 levels was also common (11.2%).

Occupation Characteristics: Low Fall Vs High Fall Etiologies

A total of 657 patients had specific occupations before injury, accounting for 84.8% of total SCI cases (173 low fall-induced SCI and 484 were high fall-induced SIC). The proportion of manual laborers and subsistence farmers with SCI caused by a high fall was considerably higher than that caused by a low fall (37.4% vs 17.9% and 22.7% vs 8.7%, respectfully). The total proportion of patients with low fall- and high fall induced SCI that identified as ‘retired’ represented 22.5% and 1.4%, respectfully, of total cases. Details are shown in the Table 3.

Table 3
Proportion of patients with different occupations (N = 657)

Occupations	Low fall group	High fall group	Total
	n = 173 (%)	n = 484 (%)	N = 657 (%)
Manual laborers	31 (17.9%)	181 (37.4%)	212 (32.3%)
Subsistence farmers	15 (8.7%)	110 (22.7%)	125 (19.0%)
Unemployed	38 (22.0%)	78 (16.1%)	116 (17.7%)
Retired	39 (22.5%)	7 (1.4%)	46 (7.0%)
Students	7 (4.0%)	34 (7.0%)	41 (6.2%)
Staff	17 (9.8%)	23 (4.8%)	40 (6.1%)
Freelancers	11 (6.4%)	14 (2.9%)	25 (3.8%)
Civil servants	8 (4.6%)	7 (1.4%)	15 (2.3%)
Professional skill workers	4 (2.3%)	9 (1.9%)	13 (2.0%)
Active duty soldiers	0 (0.0%)	11 (2.3%)	11 (1.7%)
Self-employed	2 (1.2%)	8 (1.7%)	10 (1.5%)
Enterprise administrators	1 (0.6%)	2 (0.4%)	3 (0.5%)

Discussion

Falls is a common cause of SCI. Different demographic characteristics result in different causes of injury, which may also lead to different clinical prognoses. Here, the characteristics of SCI caused by falls and nonfalls were different. Patients with fall-induced SIC were older and had a longer rehabilitation LOS than with nonfall-induced SCI. Compared with patients who fell from a low height or no height, patients who fell from a high height were younger; more likely to suffer from paraplegia, vertebral fractures or dislocations, and severe and combined injuries; have longer time from injury to rehabilitation and hospitalization LOS; and undergo spine surgery.

Among patients with high fall-induced SCI, the 16–45 year old age group accounted for 69.6% of all cases. Overall, 37.4% of patients with high fall-induced SCI were manual laborers and 22.7% were subsistence farmers. Compared with patients with low fall-induced SCI, more patients with high fall-induced SCI suffered from paraplegia (73.4% vs 27.8%) and complete SCI (56.1% vs 23.1%). This is consistent with the results of a multi-center survey in the United States (9). Thoracolumbar vertebra fractures were the most common (T10–L2, 61.3%). This may be related to the way in which the patients were injured. The thoracolumbar vertebrae are the transition site of the thoracic vertebrae and lumbar vertebrae. The orientation of the facet joints changes, resulting in increased stress in the vertebrae. The

body weight also shifts from the front to the back of the vertebrae, making the region more vulnerable when the patient falls from a high place (12).

In patients with low fall-induced SCI, fractures and dislocations of the lower cervical vertebrae were the most common (C2–C7, 53.8%), with the age of patients likely to be > 45 years (64.6%). However, a report in Chongqing, China found that among 996 elderly patients with spinal fractures, the most common fracture areas were in the lumbar (48.4%) and thoracic (43.0%) regions, and not the cervical region (8.2%) (13). This apparent discrepancy in results may be related to the fact that 55.4% of the study participants were not caused by a fall, and that only 7.5% of patients in our cohort were 61 years or older. Low falls result in an acceleration-deceleration force or change in velocity that causes significant head and neck movement, which would typically lead to blunt cervical spine injuries (14). Thus, this relatively lower imparted energy leads to more tetraplegia patients and/or incomplete injuries. Falls at the same level from slipping, tripping, and stumbling were the most common causes of fall-induced SCI (20%), followed by falls from building (16%), stairs and steps (16%), and ladders (9%) (9). Therefore, attention should be paid to increase awareness of fall prevention, regardless of the type.

In Saudi Arabia, the mean time of 90 patients with traumatic SCI between injuries and admission to rehabilitation was 37.7 days and the mean total LOS was 123 days (15), which is shorter than the results obtained in the current study. The time from injury to rehabilitation and rehabilitation LOS patients with high fall-induced SIC were longer than those with low fall-induced SCI. Patients with complete traumatic SCI had higher risks of complications than patients with incomplete injuries, which may lead to longer LOS (16, 17). In addition, it has been shown in previous studies that patients with complications after traumatic SCI have longer LOS (18, 19). The presence of some complications does affect the patient's LOS, such as pressure ulcers (20). High falls are associated with increased force and is more likely to cause severer injuries, such as complete SCI, leading to longer LOS.

Falls are the leading causes of SCI among patients over 60 years of age, and continue to increase, especially in women at home (9, 21). This may be due to osteoporosis and the increased risk of falls in the elderly (22). With aging of the population in China, increasing numbers of elderly people are living alone, and thus more attention should be paid to prevent fall in the home. Home safety checklist should be generated (23) and older people's living environments should be improved, such as removing clutter, loose carpets and uneven floor surfaces, and providing good lighting, hand rails, and appropriate toilets and beds (24). For younger adults, especially for manual laborers and subsistence farmers, safety awareness is very important, including proper equipment use and training, safety inspections and testing, as well as environmental modifications. Community-based health efforts, such as awareness, and also physiotherapy, occupational therapy, and physician-led interventions, will also have a positive role in preventing of falls (25).

Rehabilitation has become the key health strategy of the 21st century (26). Among 3487 patients with SCI in Northwest China, only 15.14% received long-term rehabilitation treatment (8); however, in that study, the definition of long-term rehabilitation was not explained. Attention should also be paid to patients with

SCI. An investigation of multicenter specialized rehabilitation centers in Sweden showed that 50% of patients reported more than two falls in 1 year, therefore, fall prevention programs should be focused on ambulatory, younger, and more active individuals who are at the highest risks for recurrent falls (27). Early assessment of the risk of falls in patients with SCI can provide targeted training for patients with SCI (28).

Limitations

As a retrospective study in a single rehabilitation center, the accuracy and completeness of documentation in the medical records was assumed. Second, patients had undergone surgery in other hospitals before transfer to the rehabilitation center, which made it impossible to obtain surgical and follow-up information. Moreover, admission bias also exists for individuals in this cohort as all were rehabilitation inpatients, which limited epidemiological characteristic comparisons with other surveys. Finally, more detailed data are needed to support the in-depth study of the included variables.

Conclusion

Falls, especially high falls, are the primary causes of SCI. Patients with fall-induced SCI were older and a longer rehabilitation LOS than those with nonfall-induced SCI. Patients who fell from height were younger and more likely to suffer from paraplegia, combined injuries, severer injuries, and had longer hospitalization LOS and time from injury to rehabilitation, compared with patients who fell from a low height or at the same level. Special attention should be paid to the prevention of high falls in the working environment. Low falls are also worthy of attention due to their high incidence.

Abbreviations

AIS, American Spinal Injury Association Impairment Scale

IQR, interquartile range

LOS, length of stay

χ^2, Chi square

Declarations

- Ethics approval and consent to participate

This study was approved by the China Rehabilitation Research Center. Data that could identify the personal characteristics of patients blinded to the Implementers.

- Consent for publication

Not applicable

- Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due to personal privacy but are available from the corresponding author on reasonable request.

- Competing interests

The authors declare that they have no competing interests.

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- Authors' contributions

Dr. Wang FY proposed this subject, and all authors discussed and revised it together. All authors participated in the retrieval of the literature, and carried out screening, data extraction and data analysis. Finally, all authors discussed the results and commented on the manuscript. Zhang ZR and Wu Y contributed equally.

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Figures

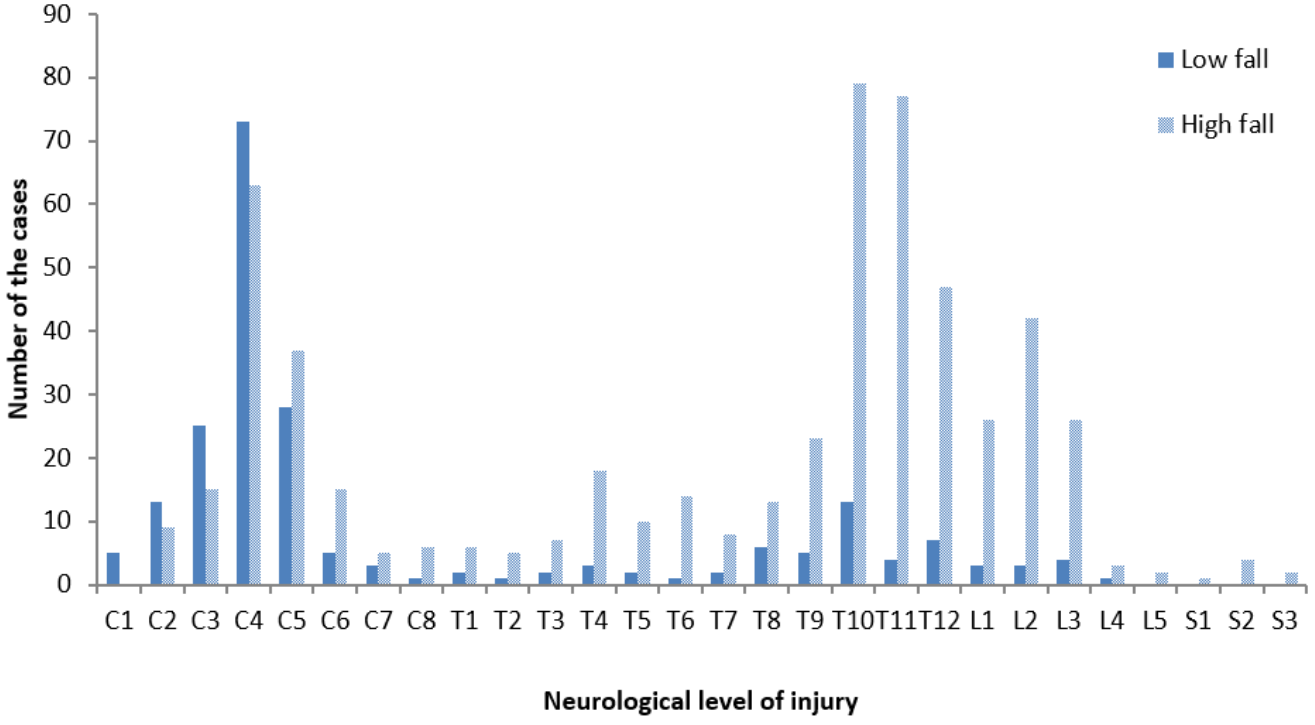

Figure 1

Number of cases with different neurological levels of injury (n = 775)