Research Article

# Epidemiological features of traumatic spinal cord injury in Beijing, China

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**Objective:** To describe epidemiological features of traumatic spinal cord injury (TSCI) and to conduct a comparison with data from 2002.
**Design:** Retrospective research.
**Setting:** China Rehabilitation Research Center (CRRC), Beijing.
**Methods:** Five hundred and ninety patients with TSCI were admitted to the CRRC from 1st January 2011 to 31st December 2019. We collected data on sex, age, marital status, etiology, occupation, neurological level of injury, and the American Spinal Injury Association Impairment Scale on admission, time of injury and treatment.
**Results:** Statistically significant differences were observed between data from 2002 and the present results ($P < 0.001$). The mean age of patients with TSCI was 46.3 ± 15.5 years, and the male/female ratio was 4.73:1. The incidence of TSCI increased gradually with age and peaked in the 40–49 age group. The most common occupation was worker (28.6%), followed by office clerk (16.8%) and retired (15.4%). Fall from heights (30.8%), followed by traffic accidents (27.6%) and low falls (25.1%), were the leading etiologies of TSCI. A majority of patients (54.9%) had cervical injuries, 91.9% underwent surgical treatment, and the lowest number of injuries were recorded during winter (19.6%).
**Conclusion:** According to the changes in the epidemiological characteristics of TSCI, preventative strategies should be readjusted. We should pay more attention to the risk of low falls of the elderly. The authors recommend that stricter regulatory practices and safety measures should be developed alongside infrastructure improvements to reduce, and perhaps prevent TSCI.

**Keywords:** Traumatic spinal cord injury, Epidemiology, Prevention, Beijing

## Introduction

Traumatic spinal cord injury (TSCI) is one of the most catastrophic injuries in human beings.[1] TSCI is associated with high mortality, disability, and treatment costs as well as long-term rehabilitation treatment.[2] It causes sensorimotor dysfunction, urinary incontinence, and sexual dysfunction below the injured segment. Although its incidence has increased in conjunction with the development of the economy, there has been no apparent breakthrough in the clinical treatment of spinal cord injury, and proactive prevention seems to be the only way forward.[3]

A 2010 study showed that the incidence of TSCI worldwide ranged from 13.1–52.2 per million people.[4] The estimated annual incidence of TSCI in Asia varied from 12.06 per million to 61.6 per million in 2012.[5] Unlike most developed countries, China currently lacks a national spinal cord injury registration system.[6] According to the global mapping of spinal cord injury epidemiology compiled by ISCoS (The International Spinal Cord Society), during the period of 1959–2011, the incidence rate in China was 30–49 per million per year.[7] In a study that examined data from 2002, the incidence in Beijing was estimated to be around 60.6 cases/million/year,[8] which is closer to 86 per million/year in Japan's most rapidly aging areas.[9] The incidence calculation in 2002 had estimated

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that Beijing would report 1300 spinal cord injury cases in 2018.[8]

In other areas, such as Tianjin, Heilongjiang, and Chongqing, there have been several studies on the epidemiological and injury features of TSCI, but few in case of Beijing in recent years.[10–12]

Beijing is the capital of the People's Republic of China. It is located in North China with a total area of 16,410.5 square kilometers, with a resident population of 21.5 million as of 2018. In this population, men accounted for 50.9% (11 million), women accounted for 49.1% (10.6 million), and those aged 60 and over accounted for 16.9% (3.6 million).[13] Its GDP grew by 6.6% in 2018 and it ranks among the first-tier cities in China, along with Shanghai and Guangzhou, attracting a large number of migrant workers. In terms of terrain, Beijing is surrounded by mountains on three sides, such as Huairou, Miyun, and other counties. The environment is harsh and the terrain is complex; as such, incidents of frequent falls from heights require constant monitoring.

In this study, we aimed to describe epidemiological features of traumatic spinal cord injury (TSCI) and to conduct a comparison with data from 2002. Ultimately, our goal was to report findings which can help facilitate the implementation of effective preventive measures.

## Methods

### *Study setting*

To our knowledge, a regional population-based registry system of total TSCI has not yet been developed in Beijing. The China Rehabilitation Research Center (CRRC) is the largest rehabilitation hospital in Beijing. Although not all patients with TSCI in Beijing are treated in CRRC, it has a certain representative significance in the epidemiology of TSCI. The International Classification of Diseases, Version 10, and the diagnostic code of TSCI was used to identify cases of TSCI during this period.

### *Participants*

Two researchers retrospectively reviewed the medical records of 590 patients with TSCI admitted to the CRRC between 1st January 2011 and 31st December 2019. The International Spinal Cord Injury Core Data Set (version 1.1) was used, considering which patients' medical records were included if they had spinal cord injury or cauda equina injury of traumatic origin, and were residents of Beijing at the time of injury.[14] We excluded patients with intervertebral disc disease, vertebral injuries without TSCI, and incomplete medical records or uncertain diagnosis.

### *Data collection*

We extracted data regarding age, marital status, sex, occupation, etiology, neurological level of nerve injury, time of injury, treatment, and neurological functions below the injury site which were evaluated using the American Spinal Injury Association (ASIA) Impairment Scale (AIS) according to the 2011 revision of the International Standards for Neurological Classification of Spinal Cord Injury.[15] Patients were divided into six groups based on age: 0–19, 20–29, 30–39, 40–49, 50–59 and 60 and above. Occupations included farmer, worker, student, office clerk, retired, and others (including soldier, armed police, driver, athlete, self-employed, civil servant, and unrecorded). The etiology of injury included traffic accident, fall (including low fall: $<1$ m and fall from height: $\geq 1$ m), being struck by an object, assault, machinery-related injury, and sports-related injury. The neurological level of injury was classified as cervical, thoracic, or lumbar/sacral.

### *Previous research description*

Li *et al.* collected the epidemiological data of 264 patients on traumatic spinal cord injury in Beijing from January 1 to December 31, 2002.[8] With the same inclusion criteria as ours, these patients were residents of Beijing at the time of injury and under the same risk.

### *Statistical analysis*

SPSS 21.0 (IBM, Armonk, NY, USA) and Microsoft Excel (Microsoft Corporation, Redmond, WA, USA) were used to manage and analyze the data. Patient characteristics were expressed as numbers or mean value ± standard deviations. In this study, frequency analysis was used for examining data and calculating percentages. To explore the differences in characteristics by etiology and across two periods, a descriptive study of relevant variables was carried out. Categorical variables were analyzed by performing a between-group chi-square test. A $P$ value $< 0.05$ was considered statistically significant.

### *Ethical considerations*

This study was approved by the Ethics Committee of the China Rehabilitation Research Center, and the ethical approval number is CRRC-IEC-RF-SC-005-01.

## Results

### *Differences in characteristics by two periods*

As seen in Table 1, there were differences in patients' ages between the two periods ($P < 0.001$). The percentage of patients aged 60 and over increased rapidly from 11.7% in 2002–20% in 2011–2019, while the

**Table 1 Characteristics of traumatic spinal cord injury in Beijing across two periods.**

| Variables | No. of patients in previous study (%) | No. of patients in this study (%) | *P*-value |
|---|---|---|---|
| *Age* | | | < 0.001 |
| 0–19 | 13 (4.9%) | 14 (2.4%) | |
| 20–29 | 30 (11.4%) | 100 (16.9%) | |
| 30–39 | 96 (36.2%) | 73 (12.4%) | |
| 40–49 | 61 (23.1%) | 151 (25.6%) | |
| 50–59 | 33 (12.6%) | 134 (22.7%) | |
| 60– | 31 (11.8%) | 118 (20%) | |
| *Sex* | | | < 0.001 |
| Male | 200 (75.8%) | 487 (82.5%) | |
| Female | 64 (24.2%) | 103 (17.5%) | |
| *Occupation* | | | < 0.001 |
| Farmer | 86 (32.6%) | 51 (8.6%) | |
| Worker | 79 (29.9%) | 169 (28.6%) | |
| Office clerk | 15 (5.7%) | 99 (16.8%) | |
| Civil servant | 4 (1.5%) | 14 (2.4%) | |
| Others | 80 (30.3%) | 257 (43.6%) | |
| Retired | – | 90 (15.4%) | |
| Student | – | 12 (2.0%) | |
| Driver | – | 20 (3.4%) | |
| Self-employed | – | 16 (2.7%) | |
| Soldier | – | 1 (0.2%) | |
| Armed police | – | 1 (0.2%) | |
| Unrecorded | – | 116 (19.7%) | |
| *Etiology* | | | < 0.001 |
| Traffic accident | 59 (22.3%) | 163 (27.6%) | |
| Struck by object | 49 (18.6%) | 56 (9.5%) | |
| Falls | 109 (41.3%) | 330 (55.9%) | |
| Fall from height | – | 182 (30.8%) | |
| Low fall | – | 148 (25.1%) | |
| Others | 47 (17.8%) | 41 (7%) | |
| Assault | 1 (0.4%) | 6 (1.0%) | |
| Sport-related | 3 (1.1%) | 17 (2.9%) | |
| Machinery-related | – | 3 (0.5%) | |
| Unrecorded | 43 (16.3%) | 15 (2.6%) | |

TSCI: Traumatic Spinal Cord Injuries.

corresponding percentage in the 30–39 age group decreased from approximately 36.4% to 12.4% during this period. There were statistically significant differences in sex and occupation (both $P < 0.001$). The percentage of farmers decreased from 32.6% to 8.6%. Further, there was a statistically significant difference in etiology between the two periods ($P < 0.001$). The percentage of falls increased rapidly from 41.3% in 2002–55.9% during the present study period, while the percentage of patients who were struck by objects decreased from 18.6% to 9.5%.

### Sex and age

As shown in Table 1, the majority of patients were male, with a male to female ratio of 4.73:1. The oldest patient was 85 years old, and the youngest was four years old, with a mean age of 46.3 ± 15.5 years (males 46.4 ± 15.2 years, females 46.1 ± 16.8 years). Furthermore, the age group of 40–49 was the most common (25.6%), followed by the 50–59 age group (22.7%).

### Occupations

The most common occupation was worker (28.6%; $n = 169$), followed by office clerk (16.8%; $n = 99$) and retired (15.4%; $n = 90$) (Table 1). Workers were categorized as construction workers, electricians, air conditioning installation workers, sanitation workers, and cleaners. We found that, in addition to 56.2% of workers who did not specify their work type, 35.5% were construction workers, 3.0% were electricians, 2.4% were sanitation workers, 1.2% were car repairmen, 0.6% were air conditioning installation workers, 0.6% were cleaners, and 0.6% were steelworkers. At least 62.7% of the workers had been injured at work. Figure 1 indicates that traffic accidents among office clerks are the main cause of TSCI, accounting for 43.4% of these injuries. Low falls accounted for 70% of TSCI among retirees, traffic accidents accounted for 80% of TSCI among drivers, and falling from height accounted for 35.3% of injuries among farmers. Additionally, 53.3% of workers were injured by falling from a height, followed by being struck by an object 23.1%.

### Marital status

Most patients, (83.9%; $n = 495$) were married. The percentage of unmarried patients was 16.1%, including the divorced, widowed, and patients who had not provided details about their marital status.

### Etiology

Falling from a height was the key reason for a hospital visit, followed by traffic accidents and low falls (Table 1). Low falls were categorized as follows: 1) a fall on a level surface (39.9%; $n = 59$), 2) a fall down the stairs (17.6%; $n = 26$), and 3) other falls (42.6%; $n = 63$). In traffic accidents, 49.7% were related to motor vehicles, 28.3% were related to non-motor vehicles, and 22% of the records were missing the cause of the traffic accident. Among patients who experienced low falls, 80.4% had injured segments in C3–4 and 75% had an injury severity of Grade C or D. In the 60 years and over age group, 62.3% were injured by low falls and 28.1% by traffic accidents, of which 50% were related to bicycles and electric bicycles (Figure 2).

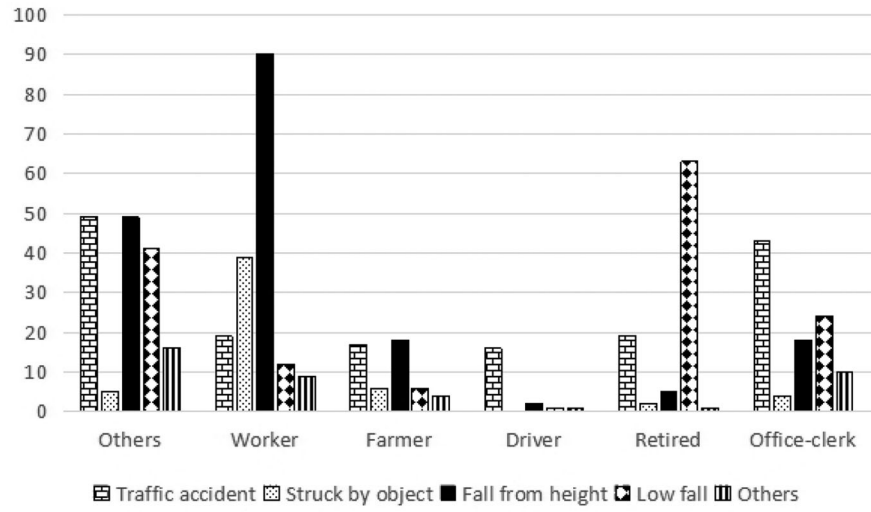



**Figure 1 Distribution of etiologies in various occupations.**

### *Neurological level and severity of the injury*

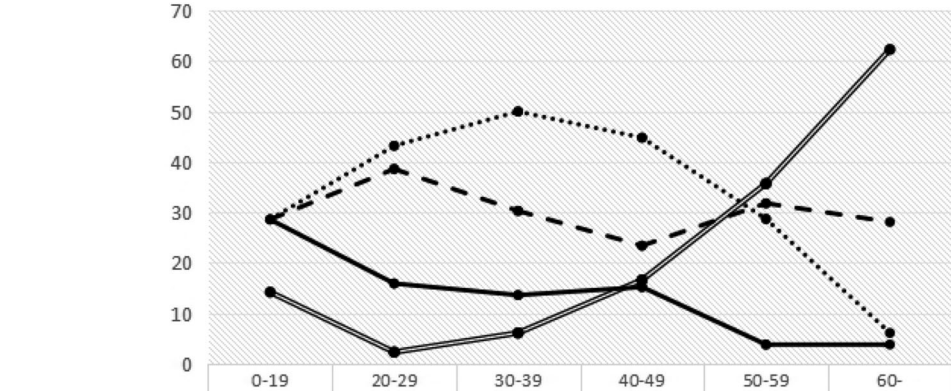
Table 2 shows that more than half of the patients had a cervical spinal cord injury and a third had a thoracic segment injury. Most patients had incomplete injuries (Grades B to D) with some motor or sensory function below the injury site; however, over a third had complete injuries (Grade A). Among patients with a cervical segment injury, the majority (35.8%) were classified as Grade D followed by Grade C (26.9%). Patients with thoracic segment injury accounted for the majority (59.6%) of Grade A classifications (Figure 3).

### *Time and treatment conditions*

The fewest cases were recorded during winter (Table 2). Among 61.2% of the patients, there was a vertebral fracture at the site of injury. Most patients had undergone surgery, including laminoplasty, spinal decompression, fusion, and internal fixation, with only a small proportion (8.1%) having undergone conservative treatment (Table 2).

## Discussion

To our knowledge, this is the first epidemiological study on TSCI in Beijing since Li *et al.*'s (2002) data.[8] In the present study, the male/female ratio of patients with TSCI in Beijing was 4.73:1, which is higher than the 3.1:1 that was previously reported.[8] Males are increasingly more involved in commercial construction as they constitute the main labor force; most workers who come to Beijing to work in high-risk and heavy-




| | 0-19 | 20-29 | 30-39 | 40-49 | 50-59 | 60- |
|---|---|---|---|---|---|---|
| Low fall | 14.2 | 2.3 | 6.1 | 16.6 | 35.7 | 62.3 |
| Traffic accident | 28.6 | 38.6 | 30.3 | 23.4 | 31.8 | 28.1 |
| Struck by object | 28.6 | 15.9 | 13.6 | 15.2 | 3.8 | 3.5 |
| Fall from height | 28.6 | 43.2 | 50 | 44.8 | 28.7 | 6.1 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 |

**Figure 2 Distribution table of etiology by age.**

**Table 2 Characteristics and treatment data of individuals with traumatic spinal cord injuries.**

| Variable | No. of patients | % |
|---|---|---|
| *Neurological level of TSCI* | | |
| Cervical | 324 | 54.9 |
| Thoracic | 193 | 32.7 |
| Lumbar/sacral | 73 | 12.4 |
| *AIS* | | |
| A | 195 | 33.1 |
| B | 80 | 13.6 |
| C | 145 | 24.5 |
| D | 170 | 28.8 |
| *Treatment* | | |
| Conservative | 48 | 8.1 |
| Surgery | 542 | 91.9 |
| *Season* | | |
| Spring | 160 | 27.1 |
| Summer | 159 | 26.9 |
| Autumn | 156 | 26.5 |
| Winter | 115 | 19.5 |

AIS: American Spinal Injury Association Impairment Scale.

duty construction industries are males. Workers replaced farmers as the primary group of patients with TSCI. In this group, most injuries occur at work and most are engaged in construction. In recent years, buildings and subways have been the main focus of construction in Beijing. Unfortunately, owing to irregular construction management, the contractors of most new projects are individuals who implement outdated safety measures. In addition, there are a small number of electricians who experience fall from height after an electric shock. To prevent the occurrence of work accidents, safety precautions (such as the use of safety ropes or straps) should be used when working. We should also strengthen the awareness of production safety and educate workers on safety in accordance with operating standards. The treatment of spinal cord injuries is very difficult and time-consuming, resulting in significant economic losses and pressure on workers' families and employers.

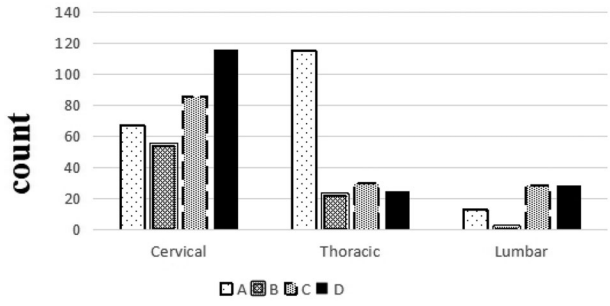



**Figure 3 AIS of TSCI classified by neurological level of TSCI. Note. AIS: American Spinal Injury Association Impairment Scale; TSCI: traumatic spinal cord injury.**

Beijing is now classified as an aging city, with a population of elderly people over 60 as high as 16.9%. The age group with the highest incidence of TSCI was 40–49, which was delayed many years compared with previous studies in other developing countries.[16] Moreover, the percentage of the 60 and over age group (20.0%) is much higher in this study than the 11.8% reported by Li *et al.* (2002).[8] The findings of this study indicate that low falls have become the main cause of TSCI in the 60 and over age group, accounting for 62.3% of all TSCI in the present sample, which is far higher than the other factors. Degenerative changes are common in the cervical spine in older adults, leading to a reduction in the cervical spinal canal reserve gap.[17] Overextension of the cervical spine caused by low-energy trauma such as low fall can squeeze the spinal cord in the narrow spinal canal, resulting in edema, bleeding, and/or axonal degeneration in the central spinal cord.[18,19] Similar to previous research, most of the spinal cord injury segments caused by low falls were in C3–5, with the injury classified as Grade C or D.[20] Older adults contend with many subtle hazards because of their age; therefore, attention should be paid to implementing preventative measures for reducing the risk of injury. Some countermeasure recommendations include implementing unobstructed environment transformation; removing items that could make them trip; being careful on stairs and icy surfaces; ensuring good lighting, foothold, and railings on stairs; ensuring installation of non-slip surfaces in bathroom and kitchens; using bed rails; and keeping things within an easily reachable distance.[21]

Among office clerks, traffic accidents were the main cause of TSCI. In this study, we found that most traffic accidents were related to motor vehicles. Automobile companies should pay attention to the improvement of traffic vehicle safety performance. Laws should be passed to mandate the wearing of motor bike helmets and vehicular safety standards should be developed. Attention should also be paid to popularize and broadcast traffic safety knowledge in schools and communities and broadcasting. When compared to the cost of death and major injury (head injury and SCI), the cost of prevention is much lower. Emergency acute medical and rehabilitation services should be improved to lessen the effects of injury. Programs, laws, and community education will help in preventing road accidents resulting in SCI.[21]

Among drivers, traffic accidents were the main cause of TSCI. When driving, they should follow traffic rules, avoid driving when fatigued, and should sleep in the car when parked in a safe area if needed. The vehicular

speed and blood alcohol levels in drivers should also be limited.

In Norway, various sports and falls have become the main cause of spinal cord injury.[22] It is expected that with the development of China's economy and the hosting of the Beijing Winter Olympics, the epidemiological features of spinal cord injury will broaden. Therefore, adequate protective gear should be used when skiing and engaging in other sports.

Similar to previous studies, in most patients with cervical injuries, the injury was graded D and mainly concentrated in C3–5.[22,23] Thoracic injury was mainly graded A, and the injury segments were mostly concentrated in T10–12. The physiological structure of the spine determines that these parts are liable to cause fractures in traumatic conditions and lead to spinal cord injury.[23] During this period, percentages of ASIA A, B, C, and D injuries were 33.1%, 13.6%, 24.5%, and 28.8%, respectively, and ASIA A and D injuries comprised the majority of TSCI cases. Increased attention should be paid to ASIA A patients when they encounter TSCI, as they are more prone to suffer from depressive disorders and suicide ideation.[24,25]

The lowest number of patients with TSCI in our study were injured during winter. Winter in Beijing is extremely cold, and most construction projects are suspended during the winter; therefore, it is possible that the decrease in injuries are due to reduced construction.

This study has the following limitations: 1) owing to variations in how doctors maintain records, some information may be inaccurate or missed, and there is the possibility of errors having been introduced when data were entered into medical records; 2) although this hospital is the largest rehabilitation hospital in Beijing, it is not feasible for it to accept all patients with TSCI in Beijing; 3) the hospital does not have a database and registration system, owing to which all information was manually recorded and extracted by the medical staff and manually extracted by the research team, respectively. and 4) owing to the inherent problems in manual maintenance of medical records, some details were unavailable, such as the number of construction workers or workers in specific occupations. Therefore, although we employed a rigorous research attitude to interpret the findings based on real injury situation, the data in this study are only conservative estimates and the actual problems may be more serious.

## Conclusion

In summary, according to the changes in the epidemiological characteristics of TSCI, preventative strategies should be readjusted. The results of this study provide epidemiological data on patients with TSCI in Beijing from 2011 to 2019. The top three high-risk groups were workers, office clerks, and the retired. The main etiologies of TSCI in workers were falls from heights and being struck by an object at work. The primary etiology for injuries in office clerk was traffic accidents, and injuries in older adults were mainly caused by low falls. In addition to traffic accident management proposed in previous studies, the improvement of the working environment for construction workers and the renovation of living facilities for the retired should be focused upon for prevention of TSCI. In this study, the authors put forward their perspectives on the reasons for the observed trends and possible preventative strategies based on the details present in the medical records. The study findings can be used as a reference for policymakers in the prevention of TSCI in Beijing.

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## Disclaimer statements

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**Conflict of interest** The authors declare no conflict of interest.

## Data availability

The data sets generated during the current study are available from the corresponding author on request.

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