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ARTICLE

Epidemiological changes in traumatic spinal cord injuries for the last 30 years (1990–2019) in South Korea

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STUDY DESIGN: Retrospective descriptive study.
OBJECTIVES: To identify the characteristics of and epidemiological trends in traumatic spinal cord injuries (TSCIs) in Korea from 1990 to 2019.
SETTING: National Rehabilitation Center affiliated with the Ministry of Health and Welfare in Korea.
METHODS: The medical records of 3395 individuals with TSCIs were retrospectively reviewed. Three groups were formed based on onset period (1990–1999, 2000–2009, and 2010–2019) and six groups based on age (≤15, 16–30, 31–45, 46–60, 61–75, and ≥76 years). Pearson's chi-square and analysis of variance tests were used for statistical analysis.
RESULTS: From 1990 to 2019, the mean age (standard deviation, [SD]) at the time of injury increased from 32.4 (SD = 12.4) years in the 1990s to 47.1 (SD = 16.2) years in the 2010s ($F = 222.317$ $p = <0.001$). Land transport and falls were the most common causes of TSCIs. The number of injuries from land transport gradually decreased, while that from falls increased (24.9% in 1990s to 46.3% in 2010s [$\chi^2 = 134.415$ $p < 0.001$]). In the >60 years group, falls were the most common cause of injury, which resulted in 42.9% TSCIs in the 1990s to 59.1% in the 2010s ($\chi^2 = 10.398$, $p > 0.05$). Tetraplegia ($n = 769$, 58.6%) was more common than paraplegia; incomplete tetraplegia (entire population: =564, 43%; >60 years group: $n = 186$, 43%) was the highest in the 2010s.
CONCLUSIONS: Falls have been the most common cause of TSCIs after 2010s. Implementing national education and campaigns for preventing falls is important to reduce/prevent TSCIs caused by falls in the aged population.

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INTRODUCTION

A spinal cord injury (SCI) or disease causes abnormalities in all body systems due to somatic dysfunction of motor and sensory and damage to the autonomic nervous system [1]. The causes of SCIs are broadly classified into traumatic and nontraumatic causes [2].

The World Health Organization and International Spinal Cord Society have emphasized the consolidation of national data on SCI epidemiology [3]. However, only SCI epidemiologic data from traumatic injuries are commonly used worldwide because of the relatively few occurrences of non-traumatic SCIs and the insufficiency of the relevant data [4]. The United States (US) annually publishes traumatic spinal cord injury (TSCI) statistics through the National Spinal Cord Injury Statistical Center [5]. In regions or countries with a prospective spinal cord injury register (PSCIR) or a population health registry, such as in North America, Australia, or Western Europe, articles about the incidence and epidemiology of TSCIs are continuously updated [6]. However, excluding Taiwan and Japan, most Asian countries do not have TSCI registries, and hence, it is difficult to accurately assess epidemiological data and TSCI characteristics [7].

Korea neither has a PSCIR for TSCI nor a population health registry; hence, it is difficult to identify the incidence and prevalence of TSCIs. Besides, people with SCI in South Korea register disabilities with the Health Insurance Corporation. Therefore, they are not categorized in the SCI group but in the physical disability group. And there are no accurate statistics for SCIs.

Not many studies in Korea have focused on the SCI epidemiology; of the two available studies, one describes the use of diagnostic codes to view the incidences of acute SCIs from 2007 to 2017 [8], and the other reports the epidemiological changes in SCI in 629 individuals from a single hospital [9]. Our study, in contrast, includes a large sample size of 3395 TSCIs from 1990 to 2019, enabling us to identify the epidemiological changes over a 30-year period.

The aim of this study was to identify the demographic and SCI-related characteristics of TSCIs in Korea in the last 30 years from 1990 to 2019, analyze the changes in its trends, and provide basic data for the epidemiological investigation of TSCIs.

MATERIALS AND METHODS

The National Rehabilitation Center (NRC) is the only rehabilitation hospital affiliated with the Ministry of Health and Welfare in Korea. On average, about 200 SCI individuals are hospitalized for rehabilitation annually. The NRC has the largest number of hospital beds for SCI individuals in Korea and individuals with SCIs are admitted to the Spinal Cord Injury Unit of the NRC for rehabilitation. This study was conducted on 3395 individuals with TSCIs from a total of 4951 individuals with SCIs who were hospitalized between 1990 and 2019. However, from the total number of admitted

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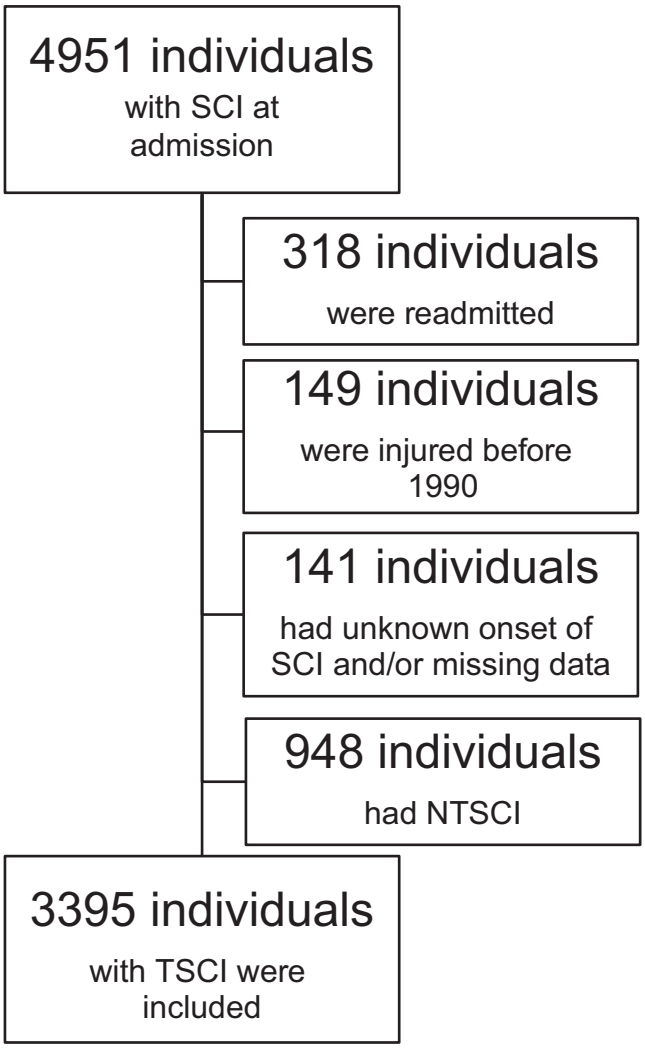

Fig. 1 Flow diagram of individuals included with traumatic spinal cord injuries. Figure 1 is a flow diagram that extracts 3,395 TSCI individuals from the first 4951 SCI individuals in this study.

individuals, those who were re-admitted or injured before 1990, or had an unknown onset or missing data were excluded.

We retrospectively identified and reviewed the medical records of individuals with TSCIs at NRC. Prior to 2015, data were extracted manually from the inpatient chart, while after 2015, they were extracted from the electronic medical chart. The included data were age at injury, sex, onset, the cause of injury (etiology), neurological level of injury, and American Association Spinal Cord Injury Impairment Scale (AIS) score. These were based on the International SCI core data set [10], to which we prioritized codes of traumatic spinal cord injuries [11]. The codes were classified into sports (1), violence/assault (2), land transport (3), falls (4), and others (5). The neurological level and severity of injury were assessed by a doctor. In most cases, the examination was performed during the first week after admission. Approval for this project was obtained from the Institutional Review Board of the NRC before conducting the research (approval number: NRC-2019-04-025).

The data were divided into three groups, by ten-year increments, based on the onset of injuries (years 1990–1999; 2000–2009; and 2010–2019). Six groups were formed based on age (≤15, 16–30, 31–45, 46–60, 61–75, and ≥76 years). The causes of injury were classified into land transport, falls, violence/assault, sports, and others (including iatrogenic causes). Korean workers affiliated with the Industrial Accident Compensation Insurance (IACI) are treated at designated hospitals. NRC became an IACI designated hospital in June 2012, after which individuals with work-related TSCIs were also admitted. Thus, TSCIs due to work-related causes were not classified separately in our study but were linked to the injury mechanism, such as falls, land transport, etc.

Statistical analysis

All statistical analyses were performed using IBM SPSS Statistics for Windows, ver. 26 (IBM Corp., Armonk, NY, USA). Categorical data were compared using Pearson's chi-square test; the mean age was compared using the analysis of variance test and the median age was compared using the analysis of variance based on ranks. For all tests, a significance level of 5% ($p < 0.05$) was used, and all confidence intervals (CI) were expressed at 95%.

RESULTS

Demographic and SCI-related factors in individuals with SCIs

Among them, 318 were excluded because they were re-admitted, 149 because they were injured before 1990, and 141 because their SCI onsets were unknown and/or data on their diagnosis or neurological classification were missing, 948 because they were injured by nontraumatic spinal cord injury (Fig. 1). Among the 3395 remaining individuals, 688 were hospitalized in 1990–1999, 1394 in 2000–2009, and 1313 in 2010–2019. From 1990 to 1999, the number of inpatients increased due to the hospital's gradual expansion of bed capacity from 20 to 50 beds from 1990 to 2000.

Age and sex

The mean (SD) age increased from 32.4 (12.4) years in the 1990s to 40.1 (15.2) years in the 2000s to 47.1 (16.2) years in the 2010s ($F = 222.317$, $p = < 0.001$) (Table 1). The median age (interquartile range [IQR]) increased from 31 (22–42) years in the 1990s to 41 (30–53) years in the 2000s to 53 (40–62) years in the 2010s ($p = < 0.000$). From the 1990s to 2010s, the number of individuals in the ≤15 and 16–30 years groups decreased gradually, while that in the 46–60, 61–75, and ≥76 years groups increased gradually. There was no consistent increase or decrease in number in the 31–45 years group (Fig. 2).

The male-to-female ratio was 3.7:1 in the 1990s and 3.6:1 in the 2010s. Upon examination, the relationship between sex and onset age was not statistically significant ($\chi^2 = 2.845$, $p > 0.05$).

Etiological changes

The common causes of TSCIs were land transport and falls. The incidence of land transport-based TSCIs decreased from 65% of all injuries in 1990–1999 to 41.9% in 2010–2019, while that of fall-based TSCIs gradually increased from 24.9% in 1990–1999 to 46.3% in 2010–2019 ($\chi^2 = 134.415$, $p < 0.001$) (Table 1). Falls became the leading cause of TSCIs in 2010–2019. There were no consistent changes in TSCIs caused by violence/assault or sports in the entire period.

Land transport was the most common cause of TSCIs in the < 60 years group, while fall was most common cause of TSCIs in the >60 years group (Fig. 3). TSCIs caused by violence/assault were the highest in the 31–45 years group, at only 0.9%. TSCIs caused by sports were the highest in the 10–15 years group (9.3%), followed by the 16–30 years group (2.6%).

Neurological level and severity of injury

Tetraplegia (57.2%) occurred more than paraplegia (42.8%) in the entire period ($\chi^2 = 6.934$, $p < 0.05$) (Table 1). Compared to the 1990s, tetraplegia increased from 52.8% to 58.6% and paraplegia decreased from 47.2% to 41.4% in the 2010s.

AIS-A was the most common in both tetraplegia and paraplegia (Table 1). AIS-A decreased and AIS-D increased from 1990 to 2019 ($\chi^2 = 85.512$, $p < 0.001$). AIS-B and AIS-C showed no consistent increase or decrease in frequency.

In the 2010s, incomplete tetraplegia (43%) was the most common, followed by complete paraplegia (22.5%), incomplete paraplegia (18.9%), and complete tetraplegia (15.6%).

The most common level of injury from 2015 to 2019 was C4 (24%), followed by C5 (15.3%), C3 (8.2%), C6 (6.5%), and L1 (5.3%).

Table 1. Injury profiles of people over 60 years with traumatic SCIs in the last three decades.

	(1990–1999)	(2000–2009)	(2010–2019)	Total	χ^2	P
Sample size	14 (100%)	153 (100%)	296 (100%)	463 (100%)		
Etiology					10.398	>0.05
Land transport	6 (42.9%)	56 (36.6%)	89 (30%)	151 (32.6%)		
Fall	6 (42.9%)	80 (52.3%)	175 (59.1%)	261 (56.4%)		
Violence/Assault	0 (0%)	0 (0%)	1 (0.3%)	1 (0.2%)		
Sports	1 (7.1%)	1 (0.7%)	2 (0.7%)	4 (0.9%)		
Others	1 (7.1%)	16 (10.4%)	29 (9.9%)	46 (9.9%)		
Level and severity of injury					3.470	>0.05
Tetraplegia	13 (92.9%)	108 (70.6%)	220 (74.3%)	341 (73.7%)		
AIS-A	2 (14.3%)	18 (11.8%)	34 (11.5%)	54 (11.7%)		
AIS-B	0 (0%)	14 (9.1%)	16 (5.4%)	30 (6.5%)		
AIS-C	3 (21.4%)	26 (17%)	62 (20.9%)	91 (19.7%)		
AIS-D	8 (57.2%)	50 (32.7%)	108 (36.5%)	166 (35.8%)		
Paraplegia	1 (7.1%)	45 (29.4%)	76 (25.7%)	122 (26.3%)		
AIS-A	0 (0%)	15 (9.8%)	17 (5.7%)	32 (6.9%)		
AIS-B	0 (0%)	5 (3.3%)	5 (1.7%)	10 (2.2%)		
AIS-C	0 (0%)	8 (5.2%)	25 (8.5%)	33 (7.1%)		
AIS-D	1 (7.1%)	17 (11.1%)	29 (9.8%)	47 (10.1%)		

Values are presented as numbers (percentages).
SCI spinal cord injury, *AIS* American Spinal Injury Association Impairment Scale.

Analysis of individuals with TSCIs aged over 60 years

In the over 60 years group, falls were the most common cause of TSCI. In the 1990s, the incidence of land transport-related (42.9%) and fall-related (42.9%) TSCIs were similar (Table 2). In the 2010s, the incidence of land transport-related TSCIs decreased to 30%, while that of fall-related TSCIs increased to 59.1% ($\chi^2 = 10.398$, $p > 0.05$). Upon analysis of the level and severity of injuries in the 2010s, incomplete tetraplegia (62.8%) was the most common, followed by incomplete paraplegia (20%), complete tetraplegia (11.5%), and complete paraplegia (5.7%) ($\chi^2 = 3.470$, $p > 0.05$).

DISCUSSION

This study was conducted to describe the demographic and SCI-related characteristics of Korean individuals with TSCIs between 1990 and 2019 and to identify the associated changes in trends.

Although our data were from only a single hospital center, we included 3,395 individuals with TSCIs over 30 years. Of the other Korean studies on SCI, one study by Choi et al. is of note; after adopting the International Classification of Disease (ICD)−10 for screening individuals from the Health Insurance Review and Assessment Service, the authors revealed that the Korean national health insurance system covered over 98% of the Korean population [8]. They included 12,137 cases of acute TSCI that occurred from 2007 to 2017. During the same period, 2118 individuals with TSCI were admitted to NRC, which means that on average, about 17.5% of individuals with TSCIs in Korea are admitted to NRC. Our study is limited by the fact that it cannot be generalized for the entire South Korean population with TSCI. Though the large sample size in this study subdues this limitation, further large population-based studies are warranted for prevention planning.

The average age at the time of TSCIs increased over time in our study. According to the 2019 population projections for Korea from Statistics Korea, the mean age of the general population increased from 29.5 years in 1990 to 42.2 years in 2019, an increase of 12.7 years over the period, while the median age increased from 27.0 years in 1990 to 43.1 years in 2019, an increase of 16.1 years [12]. This shows that the Korean population is progressively aging, as observed in other studies; the increase in the elderly population may be due to the increase in average life expectancy. TSCIs in developed (high-income category) and developing countries primarily affect males aged from 18–32 years, and in developed countries, due to the aging population, affect males and females >65 years [6]. Hence, we need to pay attention to elderly TSCI individuals.

In our study, the number of injuries due to falls gradually increased, and falls became the leading cause of TSCIs. This was coherent with the trend observed in other countries, where TSCIs due to traffic accidents decreased, while those due to falls increased, particularly in the elderly [13, 14]. Fall was also the most common cause of TSCI in our study in >60 years group. In Nordic countries, low falls, which lead to incomplete cervical lesions, have been reported to occur most often in the group aged >61 years [15]. Older people are more prone to injuries because of degenerative spine conditions, such as stenosis, spondylolisthesis, and degenerative disc disease [16].

According to the results of our study, it is important to prevent falls in older people to prevent SCIs, and strategies to effectively treat incomplete tetraplegia are required in the rehabilitation treatment sector. In particular, injuries of the central cord syndrome type are common in individuals with incomplete tetraplegia. The traits of individuals with central cord syndrome include the ability to walk with significantly deteriorated functions in the upper extremities. Identifying suitable rehabilitation programs for such individuals is an imperative task. The increasing global incidence of both traumatic brain injuries and SCIs in individuals ≥70 years shows the importance of preventive measures for injuries, particularly in the aging population [17]. It is necessary to actively implement education and campaigns for preventing falls at the national level to reduce and prevent the occurrence of SCIs caused by falls in the aged population.

Consistent with the results of other studies, the male-to-female ratio of TSCIs did not change significantly over time [18]. This is because females perform less risky activities than males and take necessary precautions when performing such activities [19].

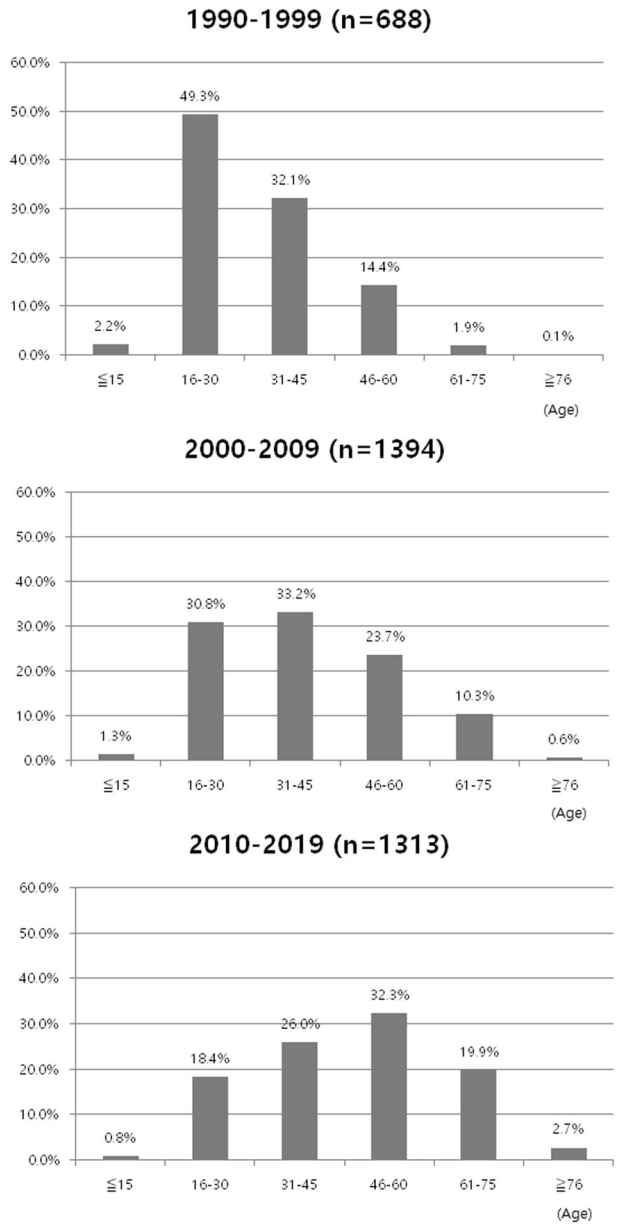

Fig. 2 Trends in the age distribution of traumatic spinal cord injury. Figure 2 consists of three figures. The top figure shows the age distribution of TSCI individuals from 1990–1999. The middle figure corresponds to 2000–2009 data and the bottom figure corresponds to 2010-2019 data, respectively. The total percentages of the six age groups (15, 16–30, 31–45, 46–60, 61–75, and 76 years) are 100%.

Land transport is one of the important causes of TSCIs, but the number of cases from this cause gradually decreased from the 1990s to the 2010s, in this study. This is similar to other studies conducted in developed countries that have reported the proportion of TSCIs resulting from land transport as stable or decreasing [6]. In Spain, the decrease in the number of injuries resulting from land transport has been attributed to improved campaigns and car safety devices, such as the inclusion of airbags and safety belts in the rear seats [20]. The public institutions in Korea are also making efforts to reduce the occurrence of injuries due to land transport by reinforcing road traffic laws, such as by making seat belts mandatory for all seats in 2018 and adjusting the maximum allowable driving speed for cars in 2020 [21].

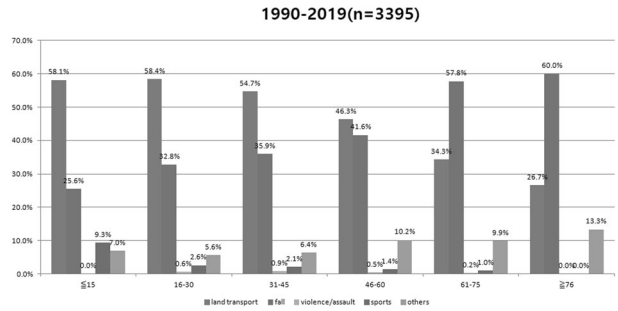

Fig. 3 Trends in injury etiology grouped by the year of injury. Figure 3 shows the etiology distribution according to the age group for last three decades. Within each of the six age groups, the total percentage of the five etiology is 100%.

In our study, violence accounted for only 0.5% of all cases in the 2010s, consistent with other countries where firearm use is prohibited [22]. This is in contrast to the US where legal firearm use contributes to the higher proportion of violence-related injuries (14% of all TSCIs) [5].

TSCIs caused by sports were the highest in the under 15 years group (9.3%) in our study, in line with other studies [23]. For pediatric SCIs ($n = 2297$) in the US, land transport ($n = 1088$, 47%) was the major cause, followed by sports/recreations ($n = 450$, 20%) [23].

In this study, TSCIs in the cervical region accounted for 57.2% of all TSCIs in the 2010s, of which C4–6 accounted for the largest proportion. In Northwest China, the proportion of SCIs in the cervical region was 41.2%, especially in C4–6 [24]. Cervical injuries are more frequent than those at the thoracic and lumbar levels and are most often associated with falls [25].

In this study, AIS-A appeared to be the most common severity level of TSCIs, but the number of cases with AIS-C and AIS-D also increased. Similarly, the number of incomplete cervical lesions due to falls among the older adults increased in Iceland, which emphasized the importance of preventing falls in the older population [22]. Besides, the number of tetraplegia and motor incomplete cases (AIS-C and -D) increased in injuries due to land transport and falls; a similar trend was also observed for all TSCI cases. According to the National Spinal Cord Injury Statistical Center data released in the United States in 2020, incomplete tetraplegia was the most frequent neurological category since 2015 [5].

The limitations of this study are as follows: first, these data are not representative of the epidemiological characteristics of all individuals with SCIs in Korea as the data were obtained from a single institution. In addition, there was insufficient information on individuals who were admitted to other institutions without going through the NRC or were discharged directly from acute hospitals. Second, individuals who required ventilators or intensive care in the intensive care unit were not admitted to NRC because the center did not have a system capable of treating critically ill people. Individuals admitted to the intensive care unit are usually admitted with high cervical cord or multiple level injuries, but information on such groups was limited in this study. Nevertheless, this study is significant because it was conducted on a large number of individuals with SCIs compared to the other studies in Korea and it determined the changes in trends over 30 years.

CONCLUSIONS

Over 30 years, the mean age (SD) at the time of injury increased from 32.4 (12.4) to 47.1 (16.2) years ($F = 222.317$ $p = <0.001$), and the median age (IQR) from 31 (24–42) to 53 (40–62) years ($p = <$ 0.000). TSCI caused by falls increased to 46.3% of all injuries in the

Table 2. Injury profiles of people with SCI over the last three decades.

	1990–1999	2000–2009	2010–2019	Total	χ^2	*P*
Sample size	688(100%)	1394(100%)	1313(100%)	3395(100%)		
Sex					2.845	>0.05
Male	543(78.9%)	1062(76.2%)	1030(78.4%)	2635(77.6%)		
Female	145(21.1%)	332(23.8%)	293(21.6%)	760(22.4%)		
Male to female ratio	3.74(543/145)	3.20(1062/332)	3.64(1030/283)	3.47(2635/760)		
Etiology					134.415	<0.001
Land transport	447(65.0%)	725(52.0%)	550(41.9%)	1722(50.7%)		
Fall	171(24.9%)	547(39.2%)	608(46.3%)	1326(39.1%)		
Violence/Assault	5(0.7%)	9(0.6%)	6(0.5%)	20(0.6%)		
Sports	28(4.1%)	19(1.4%)	21(1.6%)	68(2.0%)		
Others	37(5.4%)	94(6.8%)	128(9.7%)	259(7.6%)		
Level and severity of injury					6.934	<0.05
Tetraplegia	363(52.8%)	809(58.0%)	769(58.6%)	1941(57.2%)		
AIS-A	158(23.0%)	307(22.0%)	205(15.6%)	670(19.7%)		
AIS-B	78(11.3%)	169(12.1%)	148(11.3%)	395(11.6%)		
AIS-C	73(10.6%)	140(10.0%)	161(12.3%)	374(11.0%)		
AIS-D	54(7.8%)	193(13.8%)	255(19.4%)	502(14.8%)		
Paraplegia	325(47.2%)	585(42.0%)	544(41.4%)	1454(42.8%)		
AIS-A	211(30.7%)	379(27.2%)	296(22.5%)	886(26.1%)		
AIS-B	38(5.5%)	60(4.3%)	70(5.3%)	168(4.9%)		
AIS-C	51(7.4%)	74(5.3%)	88(6.7%)	213(6.3%)		
AIS-D	25(3.6%)	72(5.2%)	90(6.9%)	187(5.5%)		
Age at injury					*F*	*P*
Mean age (SD)	32.6 (12.4)	40.1 (15.2)	47.6 (16.2)	41.5 (16.1)	222.317	<0.001
Median Age(IQR)	31(24–42)	41(30–53)	53(40–62)	44(30–57)		<0.000

Values are presented as numbers (percentages).
SCI spinal cord injury, *AIS* American Spinal Injury Association Impairment Scale, *IQR* Interquartile range, *SD* Standard deviation.

2010s ($\chi^2 = 134.415$ $p < 0.001$). In the over 60 years group, the number of TSCIs due to falls increased from 42.9% in the 1990s to 59.1% in the 2010s ($\chi^2 = 10.398$, $p > 0.05$). In 2010–2019, incomplete tetraplegia (43%) was the most common, followed by complete paraplegia (22.5%) ($\chi^2 = 3.470$, $p > 0.05$). The average age of individuals with TSCIs continues to increase, and injuries due to falls in the elderly population are increasing. It is necessary to actively implement national education and campaigns for preventing falls to reduce and prevent the occurrence of SCIs caused by falls in the aged population.

DATA AVAILABILITY STATEMENT

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

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AUTHOR CONTRIBUTIONS

BSL was responsible for designing the review protocol, conducting the search, screening potentially eligible studies. OYL and DHH were responsible for updating reference lists and creating tables and figures. All authors (BSL, OYL, and DHH) were responsible for writing the protocol and report, extracting and analyzing data, interpreting results, approving the final version of the manuscript.

COMPETING INTERESTS

The authors declare no competing interests.

STATEMENT OF ETHICS

Approval was obtained from the Institutional Review Board of the National Rehabilitation Center for this project before conducting the research (approval number: NRC-2019-04-025). We certify that all applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed during the course of this research.

ADDITIONAL INFORMATION

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