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ARTICLE

# Epidemiology of traumatic spinal cord injury in Finland

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## Abstract

**Study design** Prospective cohort study.

**Objectives** To determine the incidence and evaluate the characteristics of newly injured patients admitted to two spinal cord injury (SCI) centers during a 4-year period.

**Setting** Oulu and Tampere University Hospital, Finland.

**Methods** A dedicated multidisciplinary team evaluated all of the patients with new traumatic SCI (TSCI). The data were recorded according to the International Spinal Cord Injury Core Data Sets.

**Results** In a 4-year period, 346 new patients with TSCI were admitted to the study centers. In the Oulu and Tampere University Hospitals' catchment areas, the mean annual incidence of TSCI was 36.6 per million. The leading causes of injury were low-level falls (36.2%), high-level falls (25.5%), and transport-related accidents (19.2%). In the patients >60 years, 72.6% were injured by falling and the proportion of low-level falls was 49.7%. In the patients ≤60 years old, 47.4% were alcohol-related. The proportion of cervical injuries in the patients >60 years was 77.1%, while in the patients ≤60 years the proportion was 59.6%. The incidence of TSCI was higher during the Summer and Autumn months.

**Conclusion** The mean annual incidence of TSCI was 36.6 per million corresponding to 200 new annual cases in Finland. Incomplete tetraplegia due to falling among elderly was overrepresented in the study population. Alcohol-consumption preceded injury in nearly half of the cases in the younger population. The prevention should focus on alcohol-related injuries and falls in the elderly.

## Introduction

Traumatic spinal cord injuries (TSCI) often lead to widespread functional impairment due to sensory and motor innervation loss of limbs and body. Furthermore, the disruption of autonomic regulation can affect breathing, heart rate, blood pressure, temperature control, bowel, bladder, and sexual functions. In order to improve the care and recovery of this infrequent patient group with complex medical problems, specialized SCI centers have been established internationally. Also in Finland, the acute care, subacute rehabilitation, and life-long follow-up of patients with SCI were centralized into three university hospitals situated in Helsinki, Oulu and Tampere in May 2011 [1].

In a 1-year study period after centralization, the incidence of TSCI in Finland was found to be 38.1 per million, which was markedly higher than expected based on the former studies from the other Nordic countries [2]. In Finland, the only prior epidemiological study on TSCI published in the past two decades reported the incidence rate of 13.8 per million [3] while the incidence numbers in Sweden, Norway, Denmark, and Iceland were 19.0, 15.9, 8.3, and 33.5 per million, respectively [4–7]. Moreover, the estimated annual incidence of TSCI worldwide, 23 per million [8], was lower than recent numbers in Finland. The

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global incidence of potential injuries that can lead to TSCI is estimated to be even 130 per million [9].

Injuries that lead to TSCI are mostly preventable. TSCI are among the most devastating events and has a notable impact on the lives of injured individuals but also high health-care costs and significant loss of productivity. Up-to-date knowledge of the incidence rates, epidemiological trends, and outcome of TSCI is essential for further strategic planning of treatment and rehabilitation resources. In addition, it is essential to understand the epidemiology of TSCI to plan and actualize national and wider preventive measures. With effective prevention, it is possible to reduce the amount of these dramatically life-changing and economically costly injuries.

The objectives of our study was to determine the incidence of TSCI and describe its characteristics in terms of etiology, age, injury level, completeness of injury, and also the functional outcome. We hypothesized that the proportion of incomplete cervical lesions due to falls among elderly would be overrepresented in our study cohort. In addition, we aimed to assess how often TSCI is related to alcohol and whether there is a seasonal variation in the occurrence of TSCI.

## Methods

### Setting

Finland is divided into 21 hospital districts, which are responsible for organizing specialized health care in respective areas. Five of these hospital districts are university hospital districts supporting the other hospital districts in their region and providing government-defined highly specialized medical care to these primary referral areas. In addition, the Finnish government decreed on the 1st of May, 2011, that the acute care, subacute rehabilitation and life-long follow-up of patients with SCI is centralized to three university hospitals: Helsinki, Oulu, and Tampere.

### Design

This prospective 4-year multicenter cohort study included a consecutive series of newly injured patients with TSCI admitted to two of the three SCI centers in Finland: Tampere University Hospital (Tampere UH; January 1, 2012 - December 31, 2015) and Oulu University Hospital (Oulu UH; May 1, 2012 – April 31, 2016). The data are missing from the third SCI center in Helsinki University Hospital because the unit opened later. The study includes all patients with traumatic spinal cord injury (SCI), other factors contributing to the fracture, like fracture type or fragility, were not separately evaluated. Patients with non-traumatic etiologies were excluded. The catchment area consists of both urban and rural terrain. The average age of Finnish population is 42.3 years (year 2015) [10] and the population in Finland is rapidly ageing (e.g., the percentage change of the population aged 65 years or older is estimated to be +49.6% from 2010 to 2030 [11]).

Complying with institutional and governmental regulations, the study approval was obtained from the UH administrations (Tampere and Oulu). Formal ethical approval was not required, as all the study data was collected as part of routine medical practice, and the data was analyzed retrospectively in a pseudonymized fashion.

### Subjects and procedure

The annual incidence of TSCI as well as the other epidemiological data is reported from Oulu and Tampere UHs' primary referral areas (overall population: 1,850,584). In these areas, Oulu and Tampere UHs are the only tertiary referral centers with 24/7 neurosurgery and spine surgery service. The study population was stratified into two groups (≤60 and >60 years) based on the age distribution of the sample and the average retirement age in Finland (2019: 61.5 years).

In both SCI centers, a multidisciplinary rehabilitation team was informed of all patients admitted to the hospital with a new SCI and persisting neurological symptoms. A consultant specialist physician together with the support of a rehabilitation team evaluated the patient in the acute phase as a part of a routine treatment and rehabilitation program.

### Collection of clinical data

The International Standards for Neurological Classification of Spinal Cord Injury [12] were used to evaluate and classify the neurological consequence of TSCI. Epidemiological characteristics were collected and classified using the International SCI Core Data Set [13, 14]. In addition falls were divided into high-level (≥1 m; ICD-10: W00-09) and low-level (<1 m; ICD-10: W10-W17) falls. Falling down the stairs was categorized as a high-level fall if the patient was more than one meter above floor level. The ability to move at the time of discharge was classified according to Spinal Cord Independence Measure. The influence of alcohol at the time of injury was retrospectively recorded from the medical records.

### Statistical analyses

Data was analyzed as a whole, but further comparisons were also conducted with regard to the hospital district and age.

Continuous variables were presented with descriptive statistics (mean = M, standard deviation = SD, median = Md, and range). The Mann-Whitney-U test was used to calculate the differences between patient groups. For categorial variables, the frequencies and percentages were calculated. The differences between groups were examined by the Fischer's exact test. A $p$ value $< 0.05$ was considered statistically significant. The statistical analyses were conducted using SPSS version 25 (IBM, Armonk, NY, USA). The incidence rates were calculated using the average population from years 2012 to 2015 according to the Statistics of Finland [10]. The prevailing hospital districts of 2016 were used in the geographical demarcation.

## Results

### Incidence

During the 4-year period, 346 new patients with TSCI were admitted to the Oulu and Tampere UHs. Of those patients, 271 were residents of the Oulu UH's and Tampere UH's primary referral areas, and 75 patients were sent from other UH's primary referral areas. The mean annual incidence of TSCI patients in the Oulu UH's and Tampere UH's primary referral areas was 36.6 per million, whereas the annual incidence rate in the group of patients ≤60 years was 20.8 per million and in the older age group 81.8 per million (Table 1).

### Injury characteristics

The injury characteristics are shown in Table 1. The mean age of the patients was 58.9 years and the proportion of men was 72.3%. The highest number of TSCI occurred in the age group of 61–75 years (Fig. 1). The leading cause of injury was a fall (61.7%). The etiology and the level of injury in different age groups are presented in Fig. 2. The injury resulted most often in incomplete tetraplegia (58.3%). Incomplete tetraplegia was especially prominent among patients injured by low-level falls (70.1%) (Table 2). The comparisons between characteristics of TSCI in age groups are shown in Table 1.

### Contributing factors

TSCI occurred more often in the Summer and Autumn months: June-August, 32.5%; September-November, 27.7%; December-February, 20.3%; and March-May, 19.6% (Fig. 3). Of the patients ≤60 years, 69 (60.5%) were injured during the weekends (Friday to Sunday). In the older age group (>60 years), 71 patients (45.2%) injured during the weekends. Monday was the most common individual day of injury ($n = 40$, 25%). Overall, 34.3% of the injuries were related to alcohol, and in 15.1% of the cases alcohol consumption prior to injury was unknown. In the group of patients ≤60 years, 47.4% were injured under the influence of alcohol, whereas in the older age group (>60 years) the figure was 34.3% ($p = 0.000$).

### Outcome

The mean duration of hospitalization (including acute care and subacute rehabilitation) was 65.9 days. Of the patients, 143 (52.8%) needed care in ICU where the mean length of stay was 9.8 days. The place of discharge was most often a private residence (55.0%). At discharge, 49.8 % of the patients were ambulatory with or without equipment (Table 1).

## Discussion

In our study, the incidence of TSCI was 36.6 per million person-years, which corresponds to 200 new annual cases in Finland. In the current study, it was highlighted that typically an older person was injured by a low-level fall most often resulting in incomplete tetraplegia. Alcohol was an important risk factor for TSCI especially in the younger population. The TSCI incidence was higher during the warm season. Younger patients had a better functional outcome in relation to locomotion compared to the older patients and higher percentage of younger patients were discharged straight to home.

The annual incidence of TSCI in Finland was 38.1 per million in a study on a 1-year period after the centralization of SCI [2]. The incidence was higher than expected compared to the prior Finnish study [3]. This extended follow-up study confirms these higher incidence rates. In a recent Finnish death certification-based study, the annual incidence of fatal TSCI was 13.7 per million [15]. Therefore, the true annual population-based incidence of TSCI in Finland could be estimated to range up to 50 cases per million.

The incidence of TSCI in our study was significantly higher than in a global review of epidemiology of TSCI in Western Europe (median 16 per million person-years) [8]. Compared to the recent studies from other Nordic countries, our incidence rate corresponds quite well to Iceland, 33.5 per million [7]. While in Sweden, Norway, and Denmark, the latest annual incidence rates were significantly lower; 19.0, 15.9, and 8.3, respectively [4–6]. Although the incidence in our study is the highest reported in the Nordic countries, it is quite comparable with the rates from Estonia (39.7 per million) [16], Canada (41 per million) [17], the United States (54 per million) [18] and Japan (49 per

**Table 1** The annual incidence, patient characteristics, treatment periods, and outcomes of new patients with TSCI in two SCI centers in Finland over a 4-year study period.

| Variable | Tampere and Oulu UH's primary referral area | Tampere and Oulu UH's primary referral area | | *p* value |
|---|---|---|---|---|
| | | ≤60 years | >60 years | |
| Population | 1,850,584 | 1,370,812 | 479.772 | |
| Number of patients | 271 | 114 | 157 | |
| Incidence/million/year | 36.6 | 20.8 | 81.8 | |
| Gender (male/female) | 2.6/1 (196/75) | 3.6/1 (89/25) | 2.1/1 (107/59) | 0.076 |
| Age at injury Mean±sd, Md (range) | 58.9 ± 18.5, 63(2-94) | 41.3 ± 14.4, 45(2-60) | 71.5 ± 7.7, 70(61-94) | **0.000** |
| Injury etiology (%) | | | | **0.000** |
| Sports | 23 (8.5) | 19 (16.7) | 4 (2.5) | |
| Assault | 3 (1.1) | 3 (2.6) | 0 (0) | |
| Transport | 52 (19.2) | 30 (26.3) | 23 (14.6) | |
| High-level fall | 69 (25.5) | 33 (28.9) | 36 (22.9) | |
| Low-level fall | 98 (36.2) | 19 (16.7) | 78 (49.7) | |
| Other traumatic cause | 26 (9.6) | 10 (8.8) | 16 (10.2) | |
| Vertebral injury (%) | 218 (80.4) | 90 (78.9) | 128 (81.5) | 0.643 |
| Spinal surgery (%) | 242 (89.3) | 105 (92.1) | 137 (87.3) | 0.236 |
| Neurological level of injury (%) | | | | **0.003** |
| Tetraplegia | 189 (69.7) | 68 (59.6) | 121 (77.1) | |
| Paraplegia | 82 (30.3) | 46 (40.4) | 36 (22.9) | |
| ASIA impairment scale (%) | | | | 0.843 |
| A | 47 (17.3) | 23 (20.2) | 24 (15.3) | |
| B | 25 (9.2) | 11 (9.6) | 14 (8.9) | |
| C | 36 (13.3) | 14 (12.3) | 22 (14.0) | |
| D | 141 (52.0) | 64 (56.1) | 77 (49.0) | |
| E and unknown or not applicable* | 22 (8.1) | 2 (1.8) | 20 (12.7) | |
| Neurological category (%) | | | | 0.095 |
| Ventilator dependent | 9 (3.3) | 3 (2.6) | 6 (3.8) | |
| C1-C4 AIS A, B, C | 44 (16.2) | 13 (11.4) | 31 (19.7) | |
| C5-C8 AIS A, B, C | 14 (5.2) | 7 (6.1) | 7 (4.5) | |
| T1-S5 AIS A, B, C | 43 (15.9) | 25 (21.9) | 18 (11.5) | |
| All AIS D | 141 (52.0) | 64 (56.1) | 77 (49.0) | |
| All AIS E and unknown* | 20 (7.4) | 2 (1.8) | 18 (11.5) | |
| Total days hospitalized, Mean ± s.d., Md (range) | 65.9 ± 57.9, 50(0-308) | 70.7 ± 59.4, 58(0-272) | 62.5 ± 56.7, 46.5(2-308) | 0.355 |
| Days in ICU, Mean ± s.d., Md (range)** | 9.8 ± 13.96, 5(105) | 12.62 ± 20.07, 5(105) | 8.16 ± 8.25, 5.5(38) | 0.474 |
| Place of discharge (%) | | | | **0.000** |
| Private residence | 149 (55.0) | 86 (75.4) | 64 (40.8) | |
| Hospital | 91 (33.6) | 20 (17.5) | 71 (45.2) | |
| Nursing home | 5 (1.8) | 1 (0.9) | 4 (2.5) | |
| Assisted living residence | 15 (5.5) | 6 (5.3) | 9 (5.7) | |
| Deceased | 9 (3.3) | 1 (0.9) | 8 (5.1) | |
| Unknown | 1 (0.4) | 0 (0) | 1 (0.6) | |

**Table 1** (continued)

| Variable | Tampere and Oulu UH's primary referral area | Tampere and Oulu UH's primary referral area | | *p* value |
|---|---|---|---|---|
| | | ≤60 years | >60 years | |
| Locomotion at the time of discharge (%) | | | | **0.001** |
| Walking without equipments | 75 (27.7) | 43 (37.7) | 32 (20.4) | |
| Walking with stick or scrutches | 21 (7.7) | 13 (11.4) | 8 (5.1) | |
| Walking with rollator | 39 (14.4) | 15 (13.2) | 24 (15.3) | |
| Wheelchair | 83 (30.6) | 32 (2.1) | 51 (32.5) | |
| Electric wheelchair | 15 (5.5) | 5 (4.4) | 10 (6.4) | |
| Bed patient | 32 (11.8) | 5 (4.4) | 27 (17.2) | |
| Unknown | 6 (2.2) | 1 (0.9) | 5 (3.2) | |

*ASIA* American Spinal Injury Association, *AIS* ASIA Impairment Scale, *AIS A* motor–sensory complete, *AIS B* motor complete–sensory incomplete, *AIS C–D* motor–sensory incomplete, *AIS E* normal examination, *ICU* intensive care unit, *TSCI* traumatic spinal cord injury, *SCI* spinal cord injury, *UH* University Hospital.

*P* values <0.05 in bold and underlined.

*AIS E and unknown was excluded when examined the differences between groups.

**$n = 143$ in the whole sample, ≤60 years: $n = 53$, >60 years: $n = 90$.

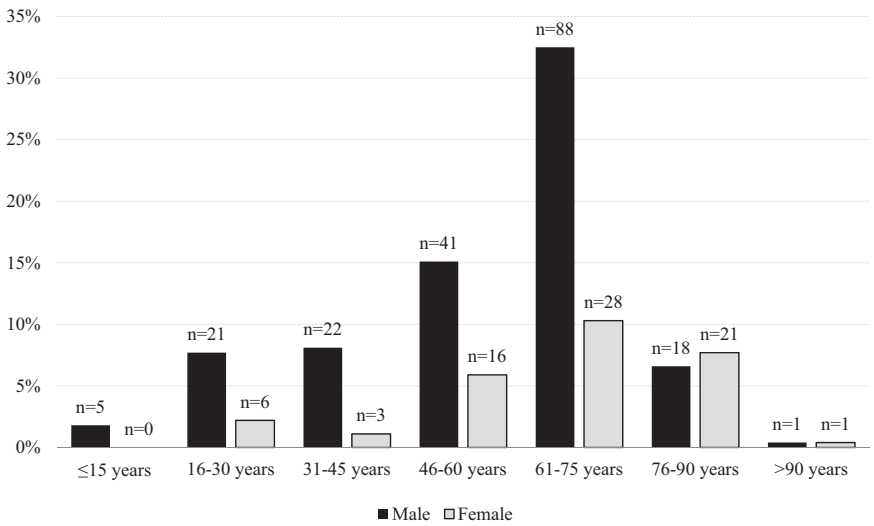


**Fig. 1 The percentages of new TSCI patients in different age groups categorized by gender.** Study period in Oulu UHs' primary referral area May 1, 2012 - April 31, 2016 and in Tampere UHs' primary referral area January 1, 2012 - December 31, 2015.

million) [19]. Direct comparison between studies is hampered by the different study designs. An incomplete case ascertainment may have occurred in many previous studies as they rely on referrals to rehabilitation centers, hence excluding patients with minor motor and sensory dysfunctions not needing institutional rehabilitation and patients with barriers to rehabilitation. In our study, all patients with a new TSCI were enrolled in the acute phase, which enables a better case coverage.

Recent studies have shown an increasing trend in the age at the time of injury, the proportion of cervical injuries and injuries caused by falls [8, 20]. This trend is also seen in Japan, which is the most aging country in the world [19]. In our study, the mean age of the patients was 58.9 years and notably the age has increased since 2005 as a former study from 1976 to 2005 reported an average injury age of 42 years. However, this former study only included patients from one rehabilitation center [3]. In our study, almost half of the older patients were injured by low-level falls and the majority of those patients suffered from an incomplete cervical TSCI. The same trend was also seen in a study 1 year after centralization where most of the patients

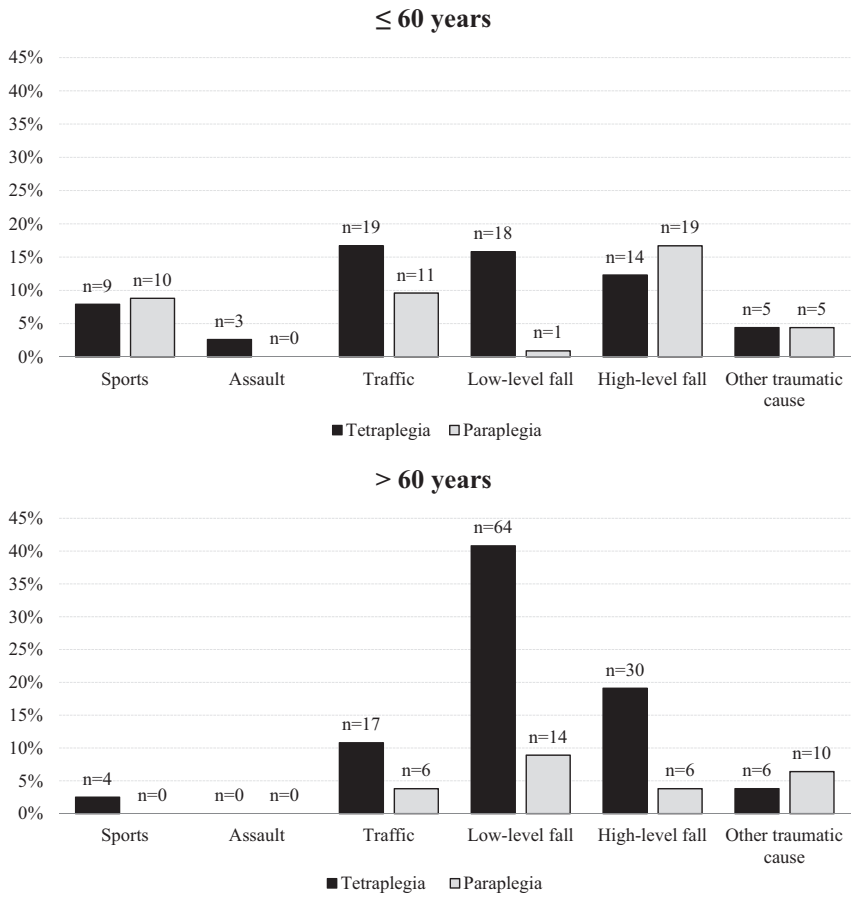


**Fig. 2 The etiology of TSCI for the period May 1, 2012 - April 31, 2016 in Oulu UHs' primary referral area and for the period January 1, 2012 - December 31, 2015 in Tampere UHs' primary referral area.** Proportions in age groups under and over 60 years stratified by the level of injury.

**Table 2** The level and completeness of TSCI in relation to the injury etiology over the 4-year study period.

| | | Tetraplegia | | Paraplegia | |
|---|---|---|---|---|---|
| Etiology | *n* | Complete (%) | Incomplete (%) | Complete (%) | Incomplete (%) |
| Sports | 23 | 13 | 43.5 | 8.7 | 34.8 |
| Assault | 3 | 0 | 100 | 0 | 0 |
| Transport | 53 | 11.3 | 56.6 | 7.5 | 24.5 |
| Low-level fall | 97 | 14.4 | 70.1 | 0 | 15.5 |
| High-level fall | 69 | 8.7 | 55.1 | 8.7 | 27.5 |
| Other traumatic cause | 26 | 7.7 | 34.6 | 15.4 | 42.3 |
| Total | 271 | 11.4 | 58.3 | 5.9 | 24.4 |

*TSCI* traumatic spinal cord injury.

≥60 years were injured by falling and the majority of patients were tetraplegic. In Finland, the incidence of cervical spine injuries, including SCIs, caused by falling has been steeply increasing in the elderly population during the last decades [21]. Globally, the older population is growing at an unprecedented rate. It has been predicted that, without preventive measures, fall-induced injuries of the cervical spine in Finland will rise by 50% from 2011 to 2030 [21]. Besides TSCI, also the amount of other injuries resulting from falls, like hip fractures and traumatic brain injuries, are increasing among the elderly population [22, 23]. During the last years, several programs to prevent falling in the elderly have been developed in Finland. In general, these programs aim to map persons' individual risk factors for falling and constitute individualized plans of action for prevention [23].

In our study, alcohol consumption preceded TSCI in one-third of the cases in the whole sample. In the younger patients, almost half of the injuries occurred under the influence of alcohol. In addition, younger patients were injured more often during weekends thus reflecting most likely the binge drinking habits typical for Finns [24, 25]. In

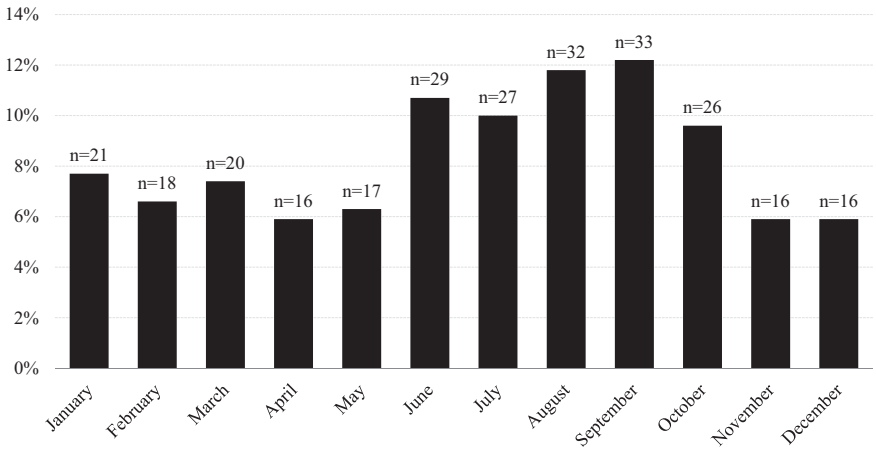


**Fig. 3 The seasonal variation in TSCI incidence.** The percentages of new TSCI patients per month in Oulu UHs' primary referral area for the period May 1, 2012 - April 31, 2016 and in Tampere UHs' primary referral area for the period January 1, 2012 - December 31, 2015.

Finland, alcohol consumption is focused on weekends from Friday to Sunday and binge drinking is most common in the 20-29-year-olds [24, 25]. The focus of TSCI prevention especially in the younger population should be on alcohol-education and increased awareness regarding the connection between alcohol and severe traumatic events [26].

The occurrence of TSCI in Finland is related to seasonal change, hence the incidence of TSCI seems to be higher during the Summer and Autumn months. This could probably reflect the increasing physical activity among Finns with better weather conditions during the non-snowy months. Also, the amount of alcohol consumption goes hand in hand with the major holidays and vacations [24]. Comparable findings have been observed in a recent Norwegian study [5]. Although Summer is the main vacation time in Finland, the increasing incidence of TSCI should be taken into account in the hospitals' resource planning during the holiday seasons.

Almost 80% of the patients ≤60 years were discharged home from the SCI unit, while 40.8% of the patients aged older than 60 years were discharged temporarily to another hospital before discharge to home or to another long-term residence. Coherently, the majority of the patients in the younger age group walked with or without equipment (62.3%) at the time of discharge while that proportion was only 40.8% in the older age group. Possible explanations for the functional outcome differences between the age groups is that the prevalence of medical comorbidities prior to TSCI is higher among the elderly and they also suffer from more frequent in-hospital secondary complications [27, 28]. Furthermore, prior studies show that patients with older age and those acquiring TSCI as a result of a fall seem to benefit from rehabilitation but achieve less independence in some areas, like mobility, bowel and bladder management compared to patients in the younger age group and patients injured due to other etiologies [29]. With these results in mind, it is especially profitable to invest in the rehabilitation of working age patients and to prevent falls in the elderly.

## Strengths and limitations

Our study has several strengths. All the new TSCI patients were evaluated in the acute phase according to the International SCI Core Data Set by a dedicated rehabilitation team. This enabled a low frequency of missing cases, especially concerning the milder injuries not requiring inpatient rehabilitation. This practice also minimized the risk of false-positive cases. As a limitation, the SCI center of Helsinki UH was missing from our study. In addition, so that the likelihood of missing cases would be low, only data from Tampere and Oulu UHs' primary referral areas were taken into account in the analysis. It is possible that patients who are residents of Tampere UHs' or Oulu UHs' primary referral areas but were injured elsewhere are missing from the data. The case coverage is less certain in Turku and Kuopio UHs' primary referral areas, because the acute care and rehabilitation of those patients may partially have taken place in their own and Helsinki UH's hospital districts. In the future, the national SCI register will offer nationwide and population-based data of TSCI in Finland.

## Conclusions

Compared with globally estimated data, our data demonstrated a high incidence of TSCI in Finland. Above all, elderly low falls resulting in incomplete tetraplegia was the most prominent patient subgroup. A significant proportion of injuries were related to alcohol, which was highlighted in the younger patient group. With these results in mind, improved primary prevention strategies are needed, targeting alcohol-related injuries and fall prevention in the elderly.

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**Author contributions** EJ contributed to the data analysis, data interpretation, and article preparation. TL contributed to the data interpretation and article preparation. AV contributed to the article preparation. A-MK contributed to the article preparation. MK contributed to the article preparation. EV contributed to the data collection and article preparation. EK contributed to the study design, data collection, data interpretation, and article preparation.

## Compliance with ethical standards

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

**Statement of ethics** Formal ethical approval was not required, as all the study data was collected as part of routine medical practice, and the data was analyzed retrospectively in a pseudonymized fashion

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