Global Incidence and Prevalence of Traumatic Spinal Cord Injury

Julio C. Furlan, Brodie M. Sakakibara, William C. Miller, Andrei V. Krassioukov

ABSTRACT: This systematic review examines the incidence and prevalence of traumatic spinal cord injury (SCI) in different countries worldwide and their trends over time. The literature search of the studies published between 1950 and 2012 captured 1,871 articles of which 64 articles on incidence and 13 articles on prevalence fulfilled the inclusion and exclusion criteria. The global incidence of SCI varied from 8.0 to 246.0 cases per million inhabitants per year. The global prevalence varied from 236.0 to 1,298.0 per million inhabitants. In addition to regional differences regarding the prevalence rates of SCI across the globe, there has been a trend towards increasing prevalence rates over the last decades. Our results suggest a relatively broad variation of incidence and prevalence rates of SCI among distinctive geographic regions. These results emphasize the need for further studies on incidence and prevalence of SCI, and for international standards and guidelines for reporting on SCI.

RÉSUMÉ: Incidence et prévalence mondiales de lésions traumatiques à la moelle épinière. Cette revue systématique examine l'incidence et la prévalence des lésions traumatiques à la moelle épinière (LTMÉ) dans différents pays à travers le monde et leur évolution à travers le temps. Une recherche documentaire a identifié 1 871 articles publiés entre 1950 et 2012, dont 64 articles portant sur l'incidence et 13 articles sur la prévalence qui remplissaient les critères d'inclusion et d'exclusion de notre étude. L'incidence et la prévalence mondiales de LTMÉ variaient de 8,0 à 246,0 cas et de 236,0 à 1 298,0 cas par 1 000 000 habitants par année respectivement. En plus de différences régionales entre les taux de prévalence de LTMÉ à travers le monde, il existait une tendance vers une augmentation du taux de prévalence au cours des dernières décennies. Selon nos résultats, il existerait une variation relativement élevée des taux d'incidence et de prévalence de LTMÉ parmi les différentes régions géographiques du monde. Ces résultats soulignent la nécessité de procéder à des études plus poussées sur l'incidence et la prévalence de LTMÉ et d'établir des standards et des lignes directrices internationales concernant la façon de les rapporter.


Traumatic spinal cord injury (SCI) can result in motor, sensory and autonomic dysfunction, all of which can be devastating for the individual, both socially and economically. Further, many individuals with SCI require extensive medical attention due to the complexities and secondary conditions associated with this injury. Therefore, effective healthcare policies to promote efficient practices are of utmost importance to ease the burden on the healthcare system, while at the same time maintaining high standards of care.

A deeper understanding of the epidemiology of SCI is required in order to gain a better appreciation of the potential impact of healthcare management strategies and health policies to prevent and minimize the consequences of SCI. In the past decade, at least five studies have reviewed the incidence and prevalence of SCI across the world1-3. In 2004, Ackery et al. reviewed the SCI literature in PubMed from 1992 to 2003, and reported an incidence of SCI between 11.5 and 57.8 cases per million people yearly based on six papers2. Their results suggested that countries with similar economic profile had alike incidence rates2. In 2006, Wyndaile and Wyndaile published a review on the incidence and prevalence of SCI based on two papers with prevalence data and 17 papers with incidence data that were captured in their search of the PubMed database. The authors reported that the incidence of SCI varied from 10.4 to 83 cases per million people, but there was an insufficient amount of data to provide accurate estimates of its prevalence3. In 2010, Cripps et al. reviewed 13 studies where the prevalence of SCI varies from 236 to 1009 cases per million, and the incidence in North America, Australia, and Western Europe were reported as 39, 16, and 15 cases per million population yearly, respectively4. In another recent review of publications from the PubMed and Medline databases, Chiu et al. reported the incidence of SCI to vary from 13.1 to 52.2 cases per million population yearly among 13 different countries5. Recently, van den Berg et al. found incidence rates of SCI to vary between 12.1 and 57.8 cases per million in different countries6. Those prior reviews also indicate that there are difficulties comparing data from different countries because diverse methods of reporting and classifying SCI are used. This partially explains the differences observed in...
the prevalence and incidence estimates reported in each of the review papers. However, those differences can also be related to the variable number of included publications in those reviews, which is likely due to the fact that different databases or combination of databases were searched for relevant literature. The inclusion of a limited number of studies can also lead to selection bias which can result in worldwide variations of incidence and prevalence of SCI.

Given the paucity of comprehensive reviews on measures of frequency of traumatic SCI in populations, the purpose of this study is to comprehensively and systematically review the literature with respect to: (1) the estimations of incidence, age-adjusted incidence, and prevalence of traumatic SCI in different countries worldwide; and (2) the trends of the incidence and prevalence of traumatic SCI over time.

**MATERIALS AND METHODS**

Measuring the frequency of disease and/or clinical conditions in populations requires specification of diagnostic criteria or case definition. For the purpose of this review, articles were included if the SCI was a lesion of traumatic nature within the spinal cord resulting in the disruption of nerve fiber bundles that convey ascending sensory and descending motor information.

**Inclusion and exclusion criteria**

This review included only original articles that estimated either incidence and/or prevalence of traumatic SCI among adults, where:

- Incidence is the proportion of a group initially free of the condition that develops it over a given period of time. In this review, incidence is standardised as the number of new cases of traumatic SCI per million inhabitants a year; and
- Prevalence is the proportion of a group of individuals having a clinical condition at a given point in time. In this review, prevalence is expressed as the number of cases of traumatic SCI per million population in a given time point.

Case reports, editorial articles and meeting abstracts were excluded.

**Literature search strategy**

In the primary literature search strategy, the MEDLINE, EMBASE, CINAHL, PSYCHInfo, and Cochrane databases were reviewed. A secondary search was done by reviewing the reference lists of the articles that were captured in the primary search.

<table>
<thead>
<tr>
<th>Reference (N)</th>
<th>Geographic Area</th>
<th>Inclusion and exclusion criteria</th>
<th>Incidence rates by year</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) N=2385</td>
<td>Ontario, Canada</td>
<td>1994-1999 Hospital admissions for SCI in Ontario Trauma Registry.</td>
<td>37.2/million/year (1994/95)</td>
</tr>
<tr>
<td>(12) N=151</td>
<td>London, Ontario, Canada</td>
<td>1997-2006 Admissions to hospital with SCI. Exclusion Criteria: Spine fracture without SCI. SCI unrelated to trauma; neurological deficit caused by peripheral nerve lesion; trauma occurring out of defined time.</td>
<td>40.8/million/year (1997-2000)</td>
</tr>
<tr>
<td>(13) N=936</td>
<td>Ontario, Canada</td>
<td>2003-2007 Data from Statistics Canada and the Canadian Institute for Health Information. All patients aged 18 years or older living in Ontario with SCI.</td>
<td>21.0/million/year (1997)</td>
</tr>
<tr>
<td>(15) N=553</td>
<td>Manitoba, Canada</td>
<td>1981-2006 Admission to hospital with SCI, or outpatient referral to an SCI rehabilitation specialist. Exclusion Criteria: congenital causes of paralysis such as spina bifida or cerebral palsy as well as acquired paralysis from multiple sclerosis or Guillain-Barre syndrome.</td>
<td>44.0/million/year (1999)</td>
</tr>
<tr>
<td>(16) N=450</td>
<td>Alberta, Canada</td>
<td>1997-2000 Data from the Alberta Ministry of Health and Wellness; records from the Alberta Trauma Registry, and death certificates from the Office of the Medical Examiner</td>
<td>49.0/million/year (2000)</td>
</tr>
<tr>
<td>(22) N=376</td>
<td>Oklahoma, USA</td>
<td>1988-1990 Oklahoma residents with SCI in Oklahoma statewide multilevel surveillance system. Exclusion Criteria: People who died at scene of injury; Injuries to nerve roots or spinal plexus.</td>
<td>23.9/million/year (1986)</td>
</tr>
<tr>
<td>(23) N=223</td>
<td>Utah, USA</td>
<td>1989-1991 Statewide injury reporting system obtaining SCI cases from all state hospital and inpatient rehabilitation units and state death certificates.</td>
<td>24.7/million/year (1988)</td>
</tr>
<tr>
<td>(24) N=66,204</td>
<td>USA</td>
<td>1970-1977 Data from National Center for Health Statistics Hospital Discharge Survey</td>
<td>23.9/million/year (1987)</td>
</tr>
<tr>
<td>(25) N=161</td>
<td>Kentucky and Indiana, USA</td>
<td>1993-1998 University of Louisville Hospital SCI Trauma Registry and patient medical records</td>
<td>35.9/million/year (1989)</td>
</tr>
<tr>
<td>(26) N=395</td>
<td>Mississippi USA</td>
<td>1992-1994 All SCI cases that occurred in the state of Mississippi and to state residents.</td>
<td>38.8/million/year (1990)</td>
</tr>
<tr>
<td>(27) N=106</td>
<td>San Diego, California, USA</td>
<td>1992-1997 Data from San Diego County Trauma Injury</td>
<td>47.0/million/year (age adjusted to 1980)</td>
</tr>
<tr>
<td>(29) N=12,000</td>
<td>Olmsted, Minnesota, USA</td>
<td>1935-1981 Medical records-linkage system of the Rochester Project at the Mayo Clinic, periodic multi-center surveys</td>
<td>40.0/million/year (1997)</td>
</tr>
</tbody>
</table>

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Table 1: Incidence of traumatic spinal cord injury (SCI) in Americas by country
The literature search included publications from 1950 (MEDLINE) or 1980 (the other databases) to December 1, 2012. The search strategy included the following specific words: “incidence”, “prevalence”, “epidemiology” and “etiology”. Those specific key words were paired with the following Medical Subject Headings (MeSHs): “spinal cord injury”, “tetraplegia”, “quadriplegia” and “paraplegia”. The literature search was limited to peer-reviewed publications written in English only.

**Selection Process and Data Extraction**

All titles and abstracts resulting from the literature searches were reviewed. The reference of any publication that referred to SCI, epidemiology, incidence, and/or prevalence in the title or abstract was imported into RefWorks. The lead author then extracted relevant data from each paper. Subsequent to finalizing the list of papers for review, trained research assistants from the Spinal Cord Injury Rehabilitation Evidence (SCIRE) reviews extracted relevant data from each paper.

### Table 2: Incidence of traumatic spinal cord injury (SCI) in Europe by country

<table>
<thead>
<tr>
<th>Reference (N)</th>
<th>Geographic Area</th>
<th>Inclusion and exclusion criteria</th>
<th>Incidence rates by year</th>
</tr>
</thead>
<tbody>
<tr>
<td>(33) N=29</td>
<td>Greenland</td>
<td>1965-1986 Admissions to rehabilitation hospital in Hornback with traumatic SCI</td>
<td>26/million/year</td>
</tr>
<tr>
<td>(34) N=360</td>
<td>Kingdom of Denmark</td>
<td>1975-1994 Admission to national specialized rehabilitation hospitals.</td>
<td>9.2/million/year</td>
</tr>
<tr>
<td>(36) N=207</td>
<td>Iceland</td>
<td>1975-2009 Landspital University Hospital, the single referral center for SCIs in Iceland</td>
<td>18/million/year (1983-1989)</td>
</tr>
<tr>
<td>(38) N=980</td>
<td>Plovdiv region, Bulgaria</td>
<td>1982-1992 Treatment for SCI at 2 clinics in Plovdiv region.</td>
<td>110.6/million/year</td>
</tr>
<tr>
<td>(39) N=46</td>
<td>Ireland</td>
<td>2000 Patients admitted to National Rehabilitation Hospital.</td>
<td>13.1/million/year</td>
</tr>
<tr>
<td>(40) N=126</td>
<td>Netherlands</td>
<td>1994 Defined SCI cases within national registration system</td>
<td>12.1/million/year</td>
</tr>
<tr>
<td>(41) N=519</td>
<td>Anatolia, Turkey</td>
<td>1990-1999 Four hospitals that were major referral centers for trauma in South-eastern Anatolia.</td>
<td>12.1/million/year</td>
</tr>
<tr>
<td>(42) N=75</td>
<td>Southeast Turkey</td>
<td>1994 Traumatic SCI in Southeast Turkey.</td>
<td>16.9/million/year</td>
</tr>
<tr>
<td>(43) N=152</td>
<td>Istanbul, Turkey</td>
<td>1992 All new patients with SCI, including pediatrics.</td>
<td>20.8/million/year</td>
</tr>
<tr>
<td>(44) N=581</td>
<td>Turkey</td>
<td>1992 Nation-wide survey of SCI admissions to medical institutions.</td>
<td>12.7/million/year</td>
</tr>
<tr>
<td>(45) N=398</td>
<td>Central Region of Portugal</td>
<td>1989-1992 Two hospitals that treat all SCI in the central region of Portugal. Including pediatric cases.</td>
<td>57.8/million/year</td>
</tr>
<tr>
<td>(48) 1970 N=29</td>
<td>Finland</td>
<td>1970-2004 All persons aged 50 or older admitted to Finnish hospitals for treatment of a fall induced severe cervical spine injury.</td>
<td>52.0/million/year (1970)</td>
</tr>
<tr>
<td>(49) N=1647</td>
<td>Finland</td>
<td>1976-2005 Kaplyivam Rehabilitation Centre database.</td>
<td>33.3/million/year (2002)</td>
</tr>
<tr>
<td>(50) N=412</td>
<td>Bucharest, Romania</td>
<td>1992-1995 SCI patients admitted to Dr Gh. Marinescu Hospital.</td>
<td>28.5/million/year</td>
</tr>
<tr>
<td>(51) N=4431</td>
<td>Federal Republic of Germany</td>
<td>1983 Hospitalizations, Hamburg’s Central Office for Paraplegic Patients, German Workmen’s compensation, and General Local Health Insurance Co.</td>
<td>36.0/million/year</td>
</tr>
<tr>
<td>(53) N=1010</td>
<td>Spain</td>
<td>1984-1985 (Every traumatic and non-traumatic SCI patient in specialized Spanish hospitals)</td>
<td>8.0/million/year</td>
</tr>
<tr>
<td>(54) N=540</td>
<td>Aragon, Spain</td>
<td>1972-2008 Hospital admission in Aragon.</td>
<td>8.2/million/year (1972-1980)</td>
</tr>
<tr>
<td>(56) N=934</td>
<td>France</td>
<td>2000 (Survey of rehab units in France patients with SCI (≥ 15 yo) admitted for first stay.</td>
<td>19.4/million/year</td>
</tr>
</tbody>
</table>

Age-adjusted incidence of traumatic spinal cord injury

Given the potential effects of differences in age distribution among the countries, we estimated the age-adjusted incidences of traumatic SCI for every study that provided data on age distribution as per the census standards. The age distribution for each country at a particular year was obtained from the U.S. Census Bureau International Data Base.

**RESULTS**

The primary search yielded 1,871 article titles of which 111 were selected for a full article review. The secondary search captured 15 additional articles. Of those 126 studies, 64 articles fulfilled the inclusion and exclusion criteria for incidence studies (Tables 1 to 4) and 13 articles were selected as adequate prevalence studies (Table 5).

**Incidence of traumatic SCI by continent**

In the Americas, the incidence rate of traumatic SCI varied from 20.7 to 83.0 people per million inhabitants a year in the most recent studies (Table 1). All of the studies are based on Canadian (n=8) or American data (n=14).11-32

In Europe, the estimated incidence rate varied from 8.0 in Spain to 130.6 individuals with traumatic SCI per million
inhabitants a year in Bulgaria. This reflects the experience of several countries including Bulgaria, Denmark, Estonia, Finland, France, Germany, Iceland, Ireland, Italy, Norway, Portugal, Romania, Spain, the Netherlands and Turkey (Table 2)33-56.

In Asia and the Middle East, the incidence rate of traumatic SCI was reported between 14.6 in Taipei, Taiwan, and 246.0 people per million inhabitants a year in all of Taiwan57-69. There were five Taiwanese studies, three Japanese studies, two Chinese studies, and one study from each of Russia, Jordan, and Iran (Table 3).

In Oceania, the estimated incidence rate varied from 10.0 to 77.0 individuals with traumatic SCI per million inhabitants a year, from Fiji and New Zealand respectively70-75. There were three Australian studies, two articles from New Zealand, and one from Fiji (Table 4).

Of note, our search did not capture any study focused on incidence or prevalence in an African country.

The age-adjusted incidences were estimated based on data from seven population-based studies19,24,34,45,55,63,65,71. There were considerable differences among the studies from distinct countries with regard to their age-adjusted incidences (Figure).

**Time-related trends of incidence of traumatic SCI**

Of the 60 articles on incidence of traumatic SCI, 14 studies provided estimated incidence rates in at least two different periods of time. While most of those studies suggest increasing incidence rates of traumatic SCI over the last decades, four articles reported decreasing incidence rates in regions within Canada, Taiwan and Australia.

Pickett et al found that the incidence rate of traumatic SCI in London (Ontario, Canada) increased from 21.0 to 49.0 people per million inhabitants a year between 1997 and 200012. Also, McCammon and Ethans reported an increase in the incidence

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### Table 3: Incidence of traumatic spinal cord injury (SCI) in Asia by country

<table>
<thead>
<tr>
<th>Reference (N)</th>
<th>Geographic Area</th>
<th>Inclusion and exclusion criteria</th>
<th>Incidence rates by year</th>
</tr>
</thead>
<tbody>
<tr>
<td>(57) N=151</td>
<td>Jordan</td>
<td>1988-1993 Patient with traumatic SCI admitted to spinal unit of hospital in Amman.</td>
<td>18.0/million/year</td>
</tr>
<tr>
<td>(58) N=9006</td>
<td>Tehran, Iran</td>
<td>2007 Random cluster sampling of 100 out of a possible 2,148,000 postal addresses in Tehran.</td>
<td>44.0/million/year</td>
</tr>
<tr>
<td>(59) N=196</td>
<td>Novosibirsk, Russia</td>
<td>1989-1993 All in patients with SCI admitted to the Department of SCI.</td>
<td>29.7/million/year</td>
</tr>
<tr>
<td>(60) N=3465</td>
<td>Japan</td>
<td>1990 Survey of nationwide institutions that accept SCI patients.</td>
<td>39.4/million/year</td>
</tr>
<tr>
<td>(61) N=9752</td>
<td>Japan</td>
<td>1990-1992 Survey of nationwide institutions that accept SCI patients.</td>
<td>40.2/million/year</td>
</tr>
<tr>
<td>(63) N=54,484</td>
<td>Taiwan</td>
<td>2000-2003 Cases of acute spinal trauma included in the National Health Insurance database.</td>
<td>174.0/million/year</td>
</tr>
<tr>
<td>(64) N=560</td>
<td>Taipei, Taiwan</td>
<td>1978-1981 All record from general hospitals in Taipei. Included all spinal cord lesions.</td>
<td>14.6/million/year</td>
</tr>
<tr>
<td>(65) N=1,586</td>
<td>Taiwan</td>
<td>1992-1996 Admissions in one of the 113 hospitals (including 11 medical centers, 50 regional general hospitals, 52 local general hospitals).</td>
<td>18.8/million/year (1992-1996)</td>
</tr>
<tr>
<td>(66) N=99</td>
<td>Hualien county, Taiwan</td>
<td>1986-1990 Traumatic SCI in 4 hospitals in Hualien county. Exclusion Criteria: People who died before hospitalization; non-traumatic SCI; patients with transient paralysis; non-residents of Hualien.</td>
<td>56.1/million/year</td>
</tr>
<tr>
<td>(67) N=41,586</td>
<td>Taiwan</td>
<td>1998-2008 SCI patients at least 20 years of age in the National Health Insurance Research Database of Taiwan.</td>
<td>246.0/million/year</td>
</tr>
<tr>
<td>(68) N=1,079</td>
<td>Beijing, China</td>
<td>2002 Admission to civilian or military hospital with SCI.</td>
<td>60.6/million/year (2002)</td>
</tr>
<tr>
<td>(69) N=869</td>
<td>Tianjin, China</td>
<td>2004-2008 SCI patients at least 15 years of age, admitted to a tertiary hospital in Tianjin.</td>
<td>23.7/million/year</td>
</tr>
</tbody>
</table>
From 17.1 to 25.6 people per million inhabitants a year between 1981 and 2007 in Manitoba, Canada\textsuperscript{15}. Similarly, Starr-Bocian et al. reported that the SCI incidence in Colorado (USA) increased from 26.5 to 38.8 individuals per million inhabitants a year between 1986 and 1990\textsuperscript{31}. Based on a broader time series from Olmsted County (Minnesota, USA), Griffin et al also showed a considerable increase of the SCI incidence rate from 22.2 people per million inhabitants a year between 1935 and 1994 to 70.8 people per million inhabitants a year between 1975 and 1981\textsuperscript{29}. In a Finnish study, the incidence rate of traumatic SCI more than doubled, from 52.0 to 120.0 individuals per million inhabitants, between 1970 and 2004\textsuperscript{48}. Similarly, Maharaj and Cameron documented a significant increase in the incidence rate of SCI in Fiji from 5.6 to 17.9 people per million inhabitants a year between 1986 and 1991\textsuperscript{75}. In the more recent studies, Hagen et al documented an increase in the incidence rate of traumatic SCI from 6.2 to 26.3 individuals per million a year from the 1950s to the 1990s in the Western Norway\textsuperscript{46}, and Van den Berg et al reported an increase from 8.2 million a year in 1972 to 13.4 in 2008\textsuperscript{44}.

In contrast, Ahoniemi et al. found no considerable change in the incidence rates of SCI among three decades from 1976 and 2005 in Finland\textsuperscript{42}. Chen et al reported a reduction in the incidence rate of SCI in Taiwan from a high of 24.5 to 17.2 individuals per million a year between 1993 and 1996\textsuperscript{65}. Yeo also found a decreasing incidence rate of traumatic SCI in New South Wales (Australia) from 21.6 people per million inhabitants a year in 1987 to 15.6 individuals per million inhabitants a year in 1992\textsuperscript{72}. Similarly, Knutsdottir reported a decrease in the incidence rate of traumatic SCI from 24 (in the 1970s) to 18 people per million a year (in the 1980s) in Iceland\textsuperscript{35}. In a more recent report from the same author, the incidence rate in Iceland

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### Table 4: Incidence of traumatic spinal cord injury (SCI) in Oceania by country

<table>
<thead>
<tr>
<th>Reference (N)</th>
<th>Geographic Area</th>
<th>Inclusion and exclusion criteria</th>
<th>Incidence rates by year</th>
</tr>
</thead>
<tbody>
<tr>
<td>(70) N=253</td>
<td>Australia</td>
<td>1986-1997 Australian SCI Register for persons 15 years and older</td>
<td>17.31/million/year (1997)</td>
</tr>
<tr>
<td>(72) N=772</td>
<td>New South Wales, Australia</td>
<td>1986-1992 Admissions to 2 spinal units in Sydney with significant loss of motor power and sensation associated with SCI.</td>
<td>19.2/million/year (1986)</td>
</tr>
<tr>
<td>(73)</td>
<td>New Zealand</td>
<td>1988</td>
<td>77.0/million/year</td>
</tr>
<tr>
<td>(75) N=75</td>
<td>Fiji</td>
<td>1985-1994 Medical Rehabilitation Unit at Tamavua Hospital.</td>
<td>5.6/million/year (1986)</td>
</tr>
</tbody>
</table>

### Table 5: Prevalence of traumatic spinal cord injury (SCI) by country

<table>
<thead>
<tr>
<th>Reference (N)</th>
<th>Geographic Area</th>
<th>Inclusion and exclusion criteria</th>
<th>Prevalence rates (year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(17) N=1,785</td>
<td>Canada</td>
<td>2010 Canadian discharge incidence rates on historical demographics using a cohort survival model and age-specific mortality rates.</td>
<td>1,298/million population (2010)</td>
</tr>
<tr>
<td>(28)</td>
<td>USA</td>
<td>National Model Spinal Cord Injury Data Base</td>
<td>906/million population</td>
</tr>
<tr>
<td>(76) N=154</td>
<td>Olmsted County, Minnesota, USA</td>
<td>1935-1981 Medical records-linkage system of the Rochester Project at the Mayo Clinic, periodic multi-center surveys.</td>
<td>197/million population (1950)</td>
</tr>
<tr>
<td>(77)</td>
<td>USA</td>
<td>1988 Traumatic SCI survey specifically designed to identify the SCI population in both institutional and non-institutional settings.</td>
<td>721/million population (1988)</td>
</tr>
<tr>
<td>(78) N=353</td>
<td>Stockholm, Sweden</td>
<td>Survey of the regional Stockholm SCI population.</td>
<td>227/million population</td>
</tr>
<tr>
<td>(36) N=207</td>
<td>Iceland</td>
<td>1975-2009 Landspitali University Hospital, the single referral center for SCIs in Iceland</td>
<td>526/million population (2009)</td>
</tr>
<tr>
<td>(79) N=152</td>
<td>Helsinki, Finland</td>
<td>Adult citizens of Helsinki who had permanent sensory or motor deficits because of traumatic SCI</td>
<td>280/million population (1999)</td>
</tr>
<tr>
<td>(81) N=63,645</td>
<td>Kashmir, India</td>
<td>1986 Complete rural population of 63,645</td>
<td>236.0/million population (1986)</td>
</tr>
<tr>
<td>(58) N=9006</td>
<td>Tehran, Iran</td>
<td>2007 Random cluster sampling of 100 out of a possible 2,148,000 postal addresses in Tehran</td>
<td>440.0/million population (2007)</td>
</tr>
<tr>
<td>(70) N=2959</td>
<td>Australia</td>
<td>1986-1997 Australian Spinal Cord Injury Register (ASCIR) for persons 15 years and older.</td>
<td>681.0/million population</td>
</tr>
</tbody>
</table>
reached a low of 12.5 in the 1990s, however, subsequently increased to 33.5 cases per million population from 2005 to 2009.

Prevalence of traumatic SCI by country

In our systematic review, 13 studies focused on prevalence of traumatic SCI documented rates from 50 to 1,298 cases per million population worldwide (Table 5). In the Americas, reports from the United States estimate the prevalence rates to vary from 50 to 906 individuals with traumatic SCI per million population, and one study from Canada estimates the prevalence to be 1,298 per million population. In Sweden, Finland, Norway, and Iceland, the prevalence rates of traumatic SCI were estimated to be 227, 280, 351 to 419, and 526 individuals per million population, respectively. Based on data from Nepal and India, two Asian studies reported prevalence rates of traumatic SCI as 849.8 cases per million population in Nepal, and 236 cases per million population in India. In Iran, a prevalence rate of 440 per million population was estimated. Finally, in Australia, O’Connor et al. recently documented a prevalence rate of 681 individuals with traumatic SCI per million population.

Time-related trends of prevalence of traumatic SCI

In addition to regional differences with regard to the prevalence rates of traumatic SCI across the globe, there has been a trend towards increasing prevalence rates over the last decades according to three different studies. Griffin et al. reported an increase in the prevalence rate of traumatic SCI in Olmsted County (Minnesota, USA) from 197 to 473 cases per million population between the 50s and 80s. Likewise, Lakhey et al. found an increase in the prevalence rates from 92.5 to 849.8 individuals with traumatic SCI per million population in Dharan (Nepal) between 1997 and 2001.

Discussion

The results of this systematic review indicate that the global incidence of traumatic SCI varies from 9.2 to 246.0 cases per million inhabitants a year. The estimated incidence varied considerably according to the geographic region as follows: (i) the Americas: 20.7 to 83.0 per million inhabitants a year; (ii) Europe: 8.0 to 130.6; (iii) Asia and the Middle East: 14.6 to 246; and (iv) Oceania: 10.0 to 77.0. There were considerable differences among the studies from distinct countries regarding their age-adjusted incidences. The global prevalence varied from 236 to 1,298 per million inhabitants. In addition to regional differences with regard to the prevalence rates of traumatic SCI across the globe, there has been a trend towards increasing prevalence rates over the last three decades. There was no publication on the incidence or prevalence of SCI in Africa.

Incidence of traumatic SCI by continent and by time period

In this review, the European and Asian continents showed a greater range of incidence rates than Oceania and the Americas, which are essentially represented by Australia, Canada and the United States. One may speculate that diversity of societies, economies, healthcare systems and public health policies in Europe and Asia amplifies differences regarding health status including traumatic SCI. In addition to this contextualization, there are potential methodological issues and limitations with regard to data collection and its quality assessment. For instance, underestimation of the numerator is a major methodological issue in studies focusing on incidence of any disease or clinical condition, including SCI. Therefore, due to the paucity of validation studies of SCI registries and databases, caution must be taken when comparing the results of any study reporting on the incidence of SCI.

Our review also indicates that the incidence rates of traumatic SCI increased in Canada, the United States, Finland, Fiji, Norway, and Iceland, whereas those incidence rates reduced in Taiwan, and New South Wales. Again, methodological considerations should be taken prior to interpreting these discrepancies. Further studies are required to confirm such trends and, more importantly, to determine the reasons for such differences which may be applied to improve the health status in other countries.

Finally, given that the age-adjusted incidence rates were found to broadly vary among countries, differences in age distribution cannot explain the discrepancies of the reported incidence rates of traumatic SCI. Although Chiu et al. observed differences in reported incidence rates between developed and developing countries, with developed countries generally having higher rates, more research is needed on why such differences exist. In addition, international standards and guidelines should be developed and used in the reporting of SCI.

Prevalence of traumatic SCI by country and by time period

Based on the findings of the studies included in this review, it can be concluded that the prevalence of SCI varies depending upon the geographic region, both among different countries and even within individual countries. Again, underestimation of the numerator and methodological differences are likely to have influenced the prevalence rates reported in the studies. Nonetheless, of the studies that provided time-related prevalence trends, it was observed that the prevalence of SCI is rising. Improvements in technology, means that more supportive health care, and our knowledge of SCI in general have contributed to an increased survival of persons with traumatic SCI. Therefore, a rise in prevalence rates due to longer life spans of individuals with a SCI is not surprising. Prevalence rates could also be amplified by a real increase in the incidence rate of traumatic SCI as determined in several studies.

Potential sources of the differences in the incidence and prevalence among studies

It is still uncertain the real reasons for the differences in the incidence and prevalence of traumatic SCI among those studies. Nonetheless, when comparing the results of those studies, it should be noted that the discrepancies among countries can be actual differences in the incidence and prevalence of traumatic SCI among the countries or, at least in part, the differences can be attributed to methodological shortcomings. The former includes incomplete identification of the incident and prevalent cases, unreliable boundaries of the study population, lack of adjustments for potential confounding effects such as age and sex distribution, inadequate quality control of the data collection, lack of validation of database or registry and other flaws. For
instance, a recent study of the National Trauma Registry reported concerns on the data collection for that Canadian SCI database due to miscoding and limitations when using International Classification of Diseases coding\textsuperscript{84}.

Regardless of the potential methodological discrepancies, there are several other reasons that can explain differences in the incidence and prevalence of traumatic SCI among countries. Using the same methodology, Sabre et al reported significant greater standardized incidence rate of traumatic SCI in two Norwegian counties when compared with Estonia\textsuperscript{85}. The authors concluded that those discrepancies are attributable to different socioeconomic conditions, injury preventive programs, geographical characteristics, extent of physical activity in all age-groups, and life expectancy\textsuperscript{85}. While Sabre et al. offer reasonable explanations for discrepancies between the two countries, even socioeconomic differences require in-depth analysis as a potential source of differences in the incidence and prevalence rates of disease. For instance, van Beeck et al reported that prosperity was protective against deaths related to motor vehicles accidents among industrialized countries only in the mid-1970s\textsuperscript{86}. At low prosperity, growing wealth favors increasing number of motor vehicles in the population. At a greater prosperity level, mortality rates of motor vehicles accidents tend to level off presumably as a result of several adaptations including improvement of traffic infrastructure and medical care for injury victims\textsuperscript{86}.

**Conclusions**

The results of this systematic review suggest a relatively broad variation of incidence and prevalence rates of traumatic SCI among distinctive geographic regions. There are also discrepancies among the studies regarding the trends on incidence of SCI. For example, many studies indicated an increasing incidence of traumatic SCI, however, a few reports demonstrated no change, and in some instances a reduction in incidence rates of SCI. While such discrepancies can be partially attributed to methodological differences, and in some cases limitations, they can also be attributed to country-related differences such as social-economic-cultural factors, public health policies, and healthcare systems. Despite consistent findings that prevalence rates are on the rise, such findings must also be interpreted with caution given the methodological and country-related differences, in addition to the fact that only two studies reported time-related prevalence trends. Finally, this comprehensive review of the literature emphasizes the need for further studies on incidence and prevalence of traumatic SCI, and for international standards and guidelines for reporting on SCI. By comprehensively understanding the reasons for the discrepancies in the incidence and prevalence rates among the geographic regions, more appropriate strategies could be developed favoring a reduction in the global burden of this clinical condition.

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**References**


