REVIEW ARTICLE

Global Incidence and Prevalence of Traumatic Spinal Cord Injury

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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.

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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 upmost 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 world[1-5]. 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 papers[2]. Their results suggested that countries with similar economic profile had alike incidence rates[2]. In 2006, Wyndaele and Wyndaele 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 prevalence[1]. 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, respectively[4]. 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 countries[3]. Recently, van den Berg et al. found incidence rates of SCI to vary between 12.1 and 57.8 cases per million in different countries[5]. 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

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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[6,7].

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 standardized 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 1: Incidence of traumatic spinal cord injury (SCI) in Americas by country

Reference (N)	Geographic Area	Inclusion and exclusion criteria	Incidence rates by year
(11) N=2385	Ontario, Canada	1994-1999 Hospital admissions for SCI in Ontario Trauma Registry.	37.2/million/year (1994/95) 46.2/million/year (1995/96)
(12) N=151	London, Ontario, Canada	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.	40.8/ million/year (1997-2000) 21.0/million/year (1997) 26.0/million/year (1998) 44.0/million/year (1999) 49.0/million/year (2000)
(13) N=936	Ontario, Canada	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.	24.2/million/year (2003) 23.1/million/year (2006)
(14) N=2063	Manitoba, Canada	1981-1984 Manitoba Health Services Insurance Plan database	40.0/million/year
(15) N=553	Manitoba, Canada	1981-2007 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-Barrè syndrome.	17.1/million/year (1981-1985) 19.5/million/year (1998-2002) 25.6/million/year (2003-2007)
(16) N=450	Alberta, Canada	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	52.5/million/year
(17) N=1,785	Canada	2010 Canadian population data multiplied by initial incidence rates previously published (16)	53/million/year (2010)
(18) N=930	British Columbia, Canada	1995-2004 Spinal Cord Unit at Vancouver General Hospital	35.7/million/year (1995-2004)
(19) N=139	Alaska, USA	1991-1993 SCI in Alaska Trauma Registry	83/million/year
(20) N=644	Arkansas, USA	1980-1989 Arkansas residents in Arkansas State Spinal Cord Commission registry.	28.5/million/year
(21) N=522	Colorado, USA	1986-1991 SCI cases in Colorado and Wyoming Spinal Cord Injury Early Notification System (ENS); SCI cases in Colorado; Cases identified using retrospective ICD-9 reporting in 1989-1990. Inclusion criteria not provided prior to this.	26.5/million/year (1986) 23.9/million/year (1987) 24.7/million/year (1988) 35.9/million/year (1989) 38.8/million/year (1990)
(22) N=376	Oklahoma, USA	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.	51.0/million/year
(23) N=223	Utah, USA	1989-1991Statewide injury reporting system obtaining SCI cases from all state hospital and inpatient rehabilitation units and state death certificates.	47.0/million/year (age adjusted to 1980) 43/million/year (crude)
(24) N=66,204	USA	1970-1977 Data from National Center for Health Statistics Hospital Discharge Survey	40.1/million/year
(25) N=161	Kentucky and Indiana, USA	1993-1998 University of Louisville Hospital SCI Trauma Registry and patient medical records	25.2/million/year
(26) N=395	Mississippi USA	1992-1994 All SCI cases that occurred in the state of Mississippi and to state residents.	77/million/year
(27) N=106	San Diego, California, USA	1992-1997 Data from San Diego County Trauma Injury	40/million/year (1992) 40/million/year (1997)
(28)	USA	National Model Spinal Cord Injury Data Base	30/million/year
(29) N=154	Olmsted, Minnesota, USA	1935-1981Medical records-linkage system of the Rochester Project at the Mayo Clinic, periodic multi-center surveys	54.8/million/year (1935-1981) 22.2/million/year (1935-1944) 70.8/million/year (1975-1981)
(30)	West Virginia, USA	1985-1988 West Virginia residents with SCI in Statewide reporting system. Data collected during the West Virginia SCI Registry, includes only injured patients surviving until hospitalization	25/million/year
(31) N=1,236	USA	1974 National Head and Spinal Cord Injury Survey	50/million/year (1974)
(32) N=5,384	New York State, USA	1982-1988 All hospital discharges from acute-care facilities in New York State	43/million/year

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

Reference (N)	Geographic Area	Inclusion and exclusion criteria	Incidence rates by year
(33) N=29	Greenland	1965-1986 Admissions to rehabilitation hospital in Hornback with traumatic SCI	26/million/year
(34) N=360	Kingdom of Denmark	1975-1984 Admission to national specialized rehabilitation hospitals.	9.2/million/year
(35) N=79	Iceland	1973-1989 Patients admitted to rehabilitation unit in Reykjavik.	24/million/year (1973-1982) 18/million/year (1983-1989)
(36) N=207	Iceland	1975-2009 Landspitali University Hospital, the single referral center for SCIs in Iceland	30/million/year (1975-1979) 12.5 million/year (1995-1999) 33.5/million/year (2005-2009)
(37) N=>3000	Estonia	1997-2007 Medical records from 22 Estonian hospitals	39.7/million/year (1997-2007)
(38) N=980	Plovdiv region, Bulgaria	1983-1992 Treatment for SCI at 2 clinics in Plovdiv region.	130.6/ million/year
(39) N=46	Ireland	2000 Patients admitted to National Rehabilitation Hospital.	13.1/ million/year
(40) N=126	Netherlands	1994 Defined SCI cases within national registration system Exclusion Criteria: Spinal contusions with no or temporary neurological symptoms.	12.1/million/year
(41) N=539	Anatolia, Turkey	1990-1999 Four hospitals that were major referral centers for trauma in South-eastern Anatolia.	12.1/million/year
(42) N=75	Southeast Turkey	1994 Traumatic SCI in Southeast Turkey.	16.9/million/year
(43) N=152	Istanbul, Turkey	1992 All new patients with SCI, including pediatrics.	20.8/million/year
(44) N=581	Turkey	1992 Nation-wide survey of SCI admissions to medical institutions. Exclusion Criteria: Patients who died before hospitalization.	12.7/million/year
(45) N= 398	Central Region of Portugal	1989-1992 Two hospitals that treat all SCI in the central region of Portugal. Including pediatric cases. Cases without neurological lesion, rehospitalization and vertebral lesions were excluded	57.8/million/year
(46) N=366	Western Norway	1952-2001 Discharges from 8 hospitals in region with SCI.	6.2/million/year (1952-1956) 26.3/million/year (1997-2001)
(47) N=336	Norway	1952-2001 Individuals with SCI in the Hordaland and Sogn og Fjordane counties	6.2/million/year (1952-1956) 13.6/million/year (1972-1976) 26.3/million/year (1997-2001)
(48) 1970 N=29 2004 N=228	Finland	1970-2004 All persons aged 50 or older admitted to Finnish hospitals for treatment of a fall induced severe cervical spine injury,	52.0/million/year (1970) 120.0/million/year (2004)
(49) N=1647	Finland	1976-2005 Käpylä Rehabilitation Centre database.	13.8/million/year (1976-2005)
(50) N=412	Bucharest, Romania	1992-1993 SCI patients admitted to Dr Gh. Marinescu Hospital.	28.5/million/year
(51) N=4431	Federal Republic of Germany	1983 Hospitalizations, Hamburg's Central Office for Paraplegic Patients, German Workmen's compensation, and General Local Health Insurance Cia.	36.0/million/year
(52) N=577	Veneto, Italy	1994-1995 New cases of traumatic SCI and non-traumatic spinal cord disease treated in regional hospitals.	14.3/million/year
(53) N=1010	Spain	1984-1985 (Every traumatic and non-traumatic SCI patient in specialized Spanish hospitals)	8.0/million/year
(54) N=540	Aragon, Spain	1972-2008 Hospital admission in Aragon.	8.2/million/year (1972-1980) 13.8/million/year (1981-1990) 12.9/million/year (1991-2000) 13.4/million/year (2001-2008)
(55) N=10,274	Spain	2000-2009 The National Hospital Discharge Register	23.5/million/year (2000-2009)
(56) N=934	France	2000 (Survey of rehab units in France Patients with SCI (≥ 15 yo) admitted for first stay. Exclusion Criteria: Non-traumatic SCI; neurological impairment due to peripheral nervous lesion; follow-up or readmissions to rehab unit)	19.4/million/year

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[8]. The lead author then reviewed all the references and selected papers of interest as per the inclusion and exclusion criteria. The papers of interest were then reviewed to ultimately determine their inclusion eligibility. 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[9].

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[10].

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

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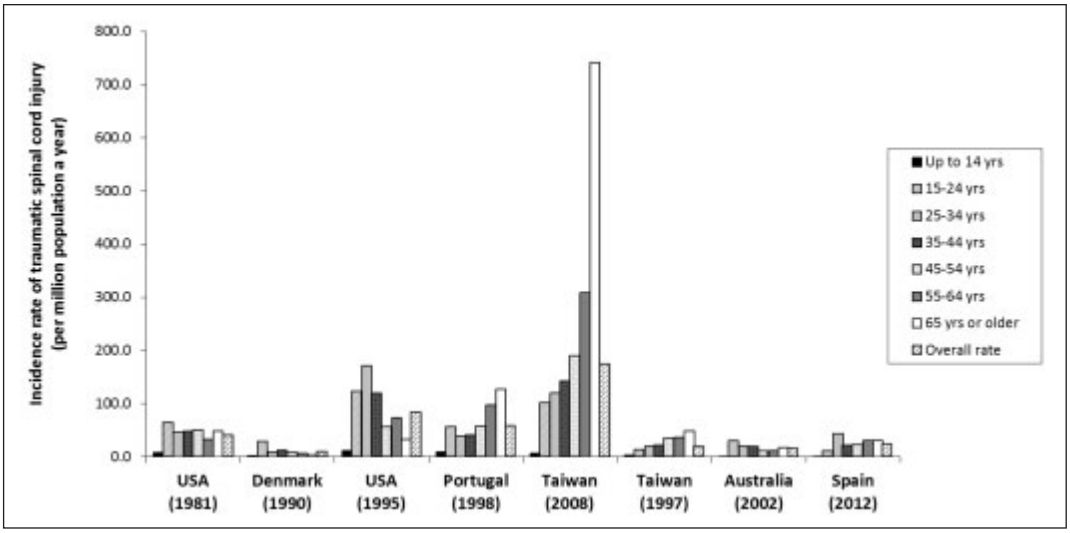

Figure: *Age-adjusted incidence rates of traumatic spinal cord injury among different countries.*

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 Taiwan[57-69]. 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 respectively[70-75]. 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 studies[19,24,34,45,55,63,65,71]. 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 2000[12]. Also, McCammon and Ethans reported an increase in the incidence

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

Reference (N)	Geographic Area	Inclusion and exclusion criteria	Incidence rates by year
(57) N=151	Jordan	1988-1993 Patients with traumatic SCI admitted to spinal unit of hospital in Amman.	18.0/million/year
(58) N=9006	Tehran, Iran	2007 Random cluster sampling of 100 out of a possible 2,148,000 postal addresses in Tehran	44.0/million/year
(59) N=196	Novosibirsk, Russia	1989-1993 All in patients with SCI admitted to the Department of SCI.	29.7/million/year
(60) N=3465	Japan	1990 Survey of nationwide institutions that accept SCI patients.	39.4/million/year
(61) N=9752	Japan	1990-1992 Survey of nationwide institutions that accept SCI inpatients.	40.2/million/year
(62) N=92	Okayama, Japan	1988-1989 Handicapped registration system "Law for the Welfare of the Physically Disabled".	28.6/million/year
(63) N=54,484	Taiwan	2000-2003 Cases of acute spinal trauma included in the National Health Insurance database.	174.0/million/year
(64) N=560	Taipei, Taiwan	1978-1981 All record from general hospitals in Taipei. Included all spinal cord lesions.	14.6/million/year
(65) N=1,586	Taiwan	1992-1996 Admissions in one the 113 hospitals (including 11 medical centers, 50 regional general hospitals, 52 local general hospitals).	18.8/million/year (1992-1996) 24.5/million/year (1993) 19.6/million/year (1994) 18.2/million/year (1995) 17.2/million/year (1996)
(66) N=99	Hualien county, Taiwan	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.	56.1/million/year
(67) N=41,586	Taiwan	1998-2008 SCI patients at least 20 years of age in the National Health Insurance Research Database of Taiwan.	246.0/million/year
(68) N=1,079	Beijing, China	2002 Admission to civilian or military hospital with SCI.	60.6/million/year (2002)
(69) N=869	Tianjin, China	2004-2008 SCI patients at least 15 years of age, admitted to a tertiary hospital in Tianjin.	23.7/million/year

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

Reference (N)	Geographic Area	Inclusion and exclusion criteria	Incidence rates by year
(70) N=253	Australia	1986-1997 Australian SCI Register	17.31/million/year (1997)
(71) N=265	Australia	1998-1999 Australian Spinal Cord Injury Register for persons 15 years and older.	14.5/million/year
(72) N=772	New South Wales, Australia	1986-1992 Admissions to 2 spinal units in Sydney with significant loss of motor power and sensation associated with SCI.	19.2/million/year (1986) 21.6/million/year (1987) 20.3/million/year (1988) 18.5/million/year (1989) 18.8/million/year (1990) 14.4/million/year (1991) 15.6/million/year (1992)
(73)	New Zealand	1988	77.0/million/year
(74) N=164	New Zealand	1979-1988 SCI cases in Health Statistics Services files.	49.1/million/year (1988) 43.3/million/year (1979-1988)
(75) N=75	Fiji	1985-1994 Medical Rehabilitation Unit at Tamavua Hospital.	5.6/million/year (1986) 17.9/million/year (1991) 10.0/million/year (1986-1991)

from 17.1 to 25.6 people per million inhabitants a year between 1981 and 2007 in Manitoba, Canada[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[21]. 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[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[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[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[46], and Van den Berg et al reported an increase from 8.2 million a year in 1972 to 13.4 in 2008[54].

In contrast, Ahoniemi et al. found no considerable change in the incidence rates of SCI among three decades from 1976 and 2005 in Finland[49]. 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[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[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[35]. In a more recent report from the same author, the incidence rate in Iceland

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

Reference (N)	Geographic Area	Inclusion and exclusion criteria	Prevalence rates (year)
(17) N=1,785	Canada	2010 Canadian discharge incidence rates on historical demographics using a cohort survival model and age-specific mortality rates.	1,298/million population (2010)
(28)	USA	National Model Spinal Cord Injury Data Base	906/million population
(76) N=154	Olmsted County, Minnesota, USA	1935-1981 Medical records-linkage system of the Rochester Project at the Mayo Clinic, periodic multi-center surveys.	197/million population (1950) 211/million population (1960) 356/million population (1970) 473/million population (1980)
(31) N=1,236	USA	1974 National Head and Spinal Cord Injury Survey.	50/million population (1974)
(77)	USA	1988 Traumatic SCI survey specifically designed to identify the SCI population in both institutional and non-institutional settings.	721/million population (1988)
(78) N=353	Stockholm, Sweden	Survey of the regional Stockholm SCI population.	227/million population
(36) N=207	Iceland	1975-2009 Landspitali University Hospital, the single referral center for SCIs in Iceland	526/million population (2009)
(79) N=152	Helsinki, Finland	January 1, 1999 cross-section date Adult citizens of Helsinki who had permanent sensory or motor deficits because of traumatic SCI.	280/million population (1999)
(47) N=336	Norway	1952-2001 Individuals with SCI in the Hordaland and Sogn og Fjordane counties	351.0/million population in Hordaland (2002) 419.0/million population in Sogn og Fjordane (2002)
(80) N=233	Dharan, Nepal	May 1997- April 2001. Admissions to BP Koirala Institute of Health Sciences orthopedic ward.	92.5/million population (1997) 172.2/million population (1998) 364.4/million population (1999) 557.6/million population (2000) 849.8/million population (2001)
(81) N=63,645	Kashmir, India	1986 Complete rural population of 63,645	236.0/million population (1986)
(58) N=9006	Tehran, Iran	2007 Random cluster sampling of 100 out of a possible 2,148,000 postal addresses in Tehran	440.0/million population (2007)
(70) N=2959	Australia	1986-1997 Australian Spinal Cord Injury Register (ASCIR) for persons 15 years and older.	681.0/million population

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reached a low of 12.5 in the 1990s, however, subsequently increased to 33.5 cases per million population from 2005 to 2009[36].

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)[17,28,31,36,47,58,70,76-81].

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[28,31,76,77], and one study from Canada estimates the prevalence to be 1,298 per million population[17]. 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[78,79]. 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[80,81]. In Iran, a prevalence rate of 440 per million population was estimated[58]. Finally, in Australia, O'Connor et al. recently documented a prevalence rate of 681 individuals with traumatic SCI per million population[70].

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[76]. 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[80].

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[3].

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[82,83]. 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

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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[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[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[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[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[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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