Eur Spine J (2015) 24:905–918
DOI 10.1007/s00586-014-3424-6

REVIEW ARTICLE

Incidence of traumatic spinal cord injury worldwide: a systematic review

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Received: 25 March 2014 / Revised: 12 June 2014 / Accepted: 13 June 2014 / Published online: 21 June 2014

Abstract
Purpose Traumatic spinal cord injuries (TSCI) are among the most devastating conditions in developed and developing countries, which can be prevented. The situation of TSCI around the world is not well understood which complicates the preventive policy decision making in fight against TSCI. This study was aimed to gather the available information about incidence of TSCI around the world.
Methods A systematic search strategy was designed and run in Medline and EMBASE, along with extensive grey literature search, personal communications, website searching, and reference checking of related papers.
Results Overall, 133 resources including 101 papers, 17 trauma registries, 6 conference proceedings, 5 books, 2 theses and 2 personal communication data were retrieved. Data were found for 41 individual countries. The incidence of TSCI ranges from 3.6 to 195.4 patients per million around the world. Australia, Canada, US, and high-income European countries have various valuable reports of TSCI, while African and Asian countries lack the appropriate epidemiologic data on TSCI.
Conclusion Data of epidemiologic information in TSCI are available for 41 countries of the world, which are mostly European and high-income countries. Researches and efforts should be made to gather information in developing and low-income countries to plan appropriate cost-effective preventive strategies in fight against TSCI.

Keywords Traumatic spinal cord injury · Incidence · World · Epidemiology

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Introduction

Traumatic spinal cord injury (TSCI) is a catastrophic event worldwide often leading to permanent disabilities [1]. Patients with TSCI may suffer physically and emotionally as well as having financial difficulties after the injury [2–4]. Presently there is no available treatment enhancing functional recovery of the paraplegic/tetraplegic patients following a TSCI [5]. This demonstrates the importance of the development of preventing strategies worldwide. Most of the SCI are due to trauma; [6] commonly motor vehicle accidents, falls, violations, and sports injuries. Although there are publications on incidence and prevalence of TSCI from different countries of the world as well as systematic reviews on incidence and prevalence of TSCI in city(s) [7],

or at national [8], regional [5], and global level [9], yet the literature lacks an overview on the extent of SCI in single countries from parts of the world where data are of low quality or even not available. The present study aims to gather available data of the current situation of TSCI worldwide, through extensive systematic search strategies.

Methods

Data collection

In order to obtain all available information, different search methods including strategic searching, reference checking, searching for grey literatures, contacting registries, authors, and organisations requesting for unpublished data, and browsing-related websites and journals were employed. Details of following steps have been reported in "Appendix". In search process, there was no language, country, or date limitation for inclusion of the reports.

Development of search strategies

All abstracts from the bibliographic database used in the study by Rahimi-Movaghar et al. [1] on the epidemiology of spinal cord injury in developing countries including records up to July 16th 2012, were reviewed. The search included the terms 'spinal cord injury', 'incidence', 'prevalence', and 'epidemiology' [1]. A librarian performed monthly search from search the engine EMBASE via Ovid SP and PubMed (including MEDLINE and PubMed Central). All available full text papers from the search were obtained (April 29, 2013). During full-text screening, references of the related papers were checked manually for identifying other related papers. To retrieve non-indexed reports, we used Google search engine combining 'spinal cord' with 'incidence', 'prevalence', 'epidemiology', 'registry', or 'database'. Along with retrieval of relevant reports, we identified registries from different countries. The identified resources were added to the references list in the report of International Spinal Cord Society (ISCoS) team for global mapping of TSCI [9].

Websites/grey literature

By contacting authors of related websites identified through the links of registries and checking references manually we acquired more related information. The websites were checked by three members of the team. Data available to public were found from four registries: Australia, Germany, Israel, and USA. By searching the resources of grey literature, related reports and theses were found. Reports from the National Spinal Cord Injury Statistical Center (https://www.nscisc.uab.edu) and International Spinal Cord Society (https://www.iscos.org.uk) websites were also reviewed.

Communications for unpublished data

When data were not available online, we contacted the authors/websites/registries/organisations via available email addresses or contact forms from the websites. We included a list of registries provided by O'Reilly et al. [10, 11]. Potential authors, websites, and organisations were contacted by two members of the team using an email template. By communication with authors of related papers and authors of the book "Epidemiology of Spinal Cord Injuries" [12] we retrieved unpublished data. In total, 114 individual authors were contacted. Three researchers corresponded with the authors; the communications were focused on three requests:

1. Provision of raw data.
2. Access to any unpublished data in a local registry or locally published journal.
3. Translation of parts of non-English reports.

In case that no reply was received, we emailed a reminder 1 week later. This direct contact with authors led us to new information regarding TSCI in New Zealand, Austria, and Denmark.

Hand-searching of journals

The retrieved records were kept in a bibliographic database using EndNote X5. A list of highly focused journals on Spine, Injury and Trauma which published most of the papers was created. All issues of these journals were checked manually to obtain possible missed papers.

Resource selection and data extraction

A database containing the full-text papers, registry reports, conference proceeding and books were generated, including the following data: type of study, extent of study (national vs. subnational level), coverage years of study, extracting raw data of study if available, number of cases, age and incidence report, and type of SCI (traumatic vs. non-traumatic), to report incidence rate of TSCI in form of raw or age-adjusted rates or number of cases. Papers with unavailable incidence figures, cumulative report of traumatic and non-traumatic incidence rate without traumatic versus non-traumatic ratio, as well as reports of prevalence figures only, were excluded. A template of a uniform excel database was designed to enter data of available countries based on WHO classification of countries. In papers

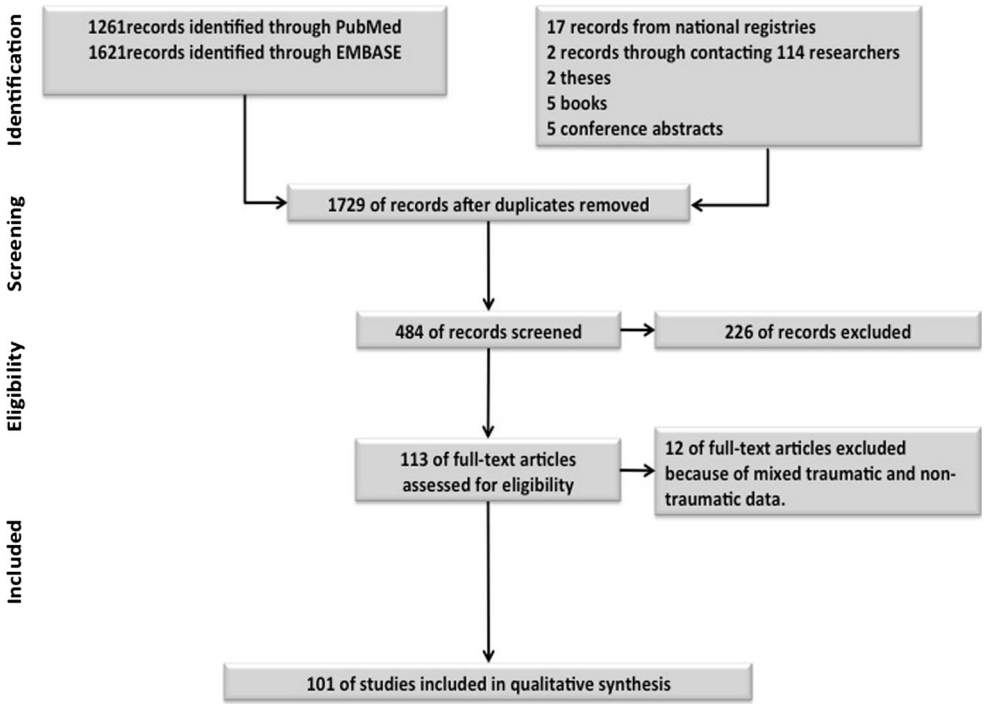

Fig. 1 Flow diagram of studies based on the PRISMA statement

reporting average incidence in timespans of more than one year, data in the paper were used to compute/estimate incidence rate for single years of the study, when available.

Results

A total of 1,261 records from PubMed and 1,621 records from EMBASE were identified and included in the End-Note X5 database. After excluding 1,153 duplicate records, titles and abstracts of 1,729 records were screened by two members of the team. After exclusion of 1,245 irrelevant records, 484 papers were screened and assessed using the inclusion criteria. This process limited the numbers to 258 papers of which 145 were excluded due to unavailable records of raw data or specific reports on incidence figures and full texts of 113 papers were retrieved. After assessing the full text, 101 papers [1, 7, 8, 13–110] were selected (Fig. 1). We identified 17 reports from national registries [111–127], five books [12, 128–131], five conference abstracts [132–136], two theses [137, 138] as well as data from New Zealand and Austria through personal communications [139, 140]. The trauma registries from Germany [125], Israel [127] and Ontario (Canada) [124] were excluded due to lack of detailed data on SCI. Two of the papers contained valuable information regarding the incidence of TSCI in Ireland [91] and USA [37], but lacked information on the precise years of the study. Data of TSCI incidence in Iceland were reported by Knutsdottir et al. [56, 57, 134] in a period between 1975 and 2009 in three separated resources. Overall, we identified incidence data for 41 countries worldwide, from current literature of 2013. Extracted data of incidence rates are shown in Table 1.

American region (AMR)

American region includes 28 countries within two sub regions of AMR A and AMR B. There were 36 reports on TSCI incidence from US, Canada and Brazil [7, 13, 18–20, 23, 29, 34, 37, 38, 43, 45–47, 52, 69, 73, 77, 82–85, 97–100, 106, 111, 122–124, 126, 128–130, 138], mainly from US and Canada (35 out of 36 records). Although there are incidence data of TSCI in the US since 1935 [46], the reports are mainly limited to registries of single or multiple states [7, 13, 18, 20, 23, 37, 43, 46, 52, 77, 85, 97, 98, 100, 105, 106, 122, 123, 126, 128] and there are no cumulative data regarding the incidence of TSCI. In Canada there are multiple reports at subnational levels [29, 34, 38, 69, 82–84, 99, 111, 129, 130, 138]. The incidence of TSCI in Canadian ranges from 3.6 to 52.5 cases per million in different years and regions. TSCIs in geriatrics has decreased over time from 83.2 to 30.0 cases per million during 1991–2001 as noted in a thesis by Aditya Sharma [138]. However, the recent survey in Canada has estimated about 53.0 cases of TSCI per million [73].

Brazil is the only country with available data of TSCI in AMR B. Incidence of SCI ranges from 17.0 to 71.0 cases per million, with a mean of 17.3 cases per million in the period 1986–2007 [45].

Table 1 Data of traumatic spinal cord injuries retrieved from search strategies of the study

WHO region	County	Study	Years of study	Type	Extend	No. of patients	Incidence per million	Age range
AFR D	Sierra Leone	Gosselin and Coppotelli [44]	2002–2004	Survey	Subnational	24	3.4	0–99
AFR E	South Africa	Velmahos et al. [103]	1988–1992	Survey	Subnational	551	48.5	0–99
	Zimbabwe	Levy et al. [62]	1988–1994	Survey	National	136	11.7	0–99
AMR A	Canada	Couris et al. [29]	2003–2006	Survey	Subnational	936	24	18–99
		Dryden [129]	1997–2000	Survey	Subnational		44.3	0–99
		Dryden et al. [34]	1997–2000	Registry	Subnational	450	52.5	0–99
		Farry and Baxter [130]	2010	Registry	Subnational	1,785	52.3	0–99
		Furlan et al. [38]	2007	Survey	Subnational	485	38	0–99
		Noonan et al. [73]	2010	Survey	National	1,785	53	0–99
		McCammon and Ethans [69]	1981–1985	Survey	Subnational	553	N/A	0–99
			1998–2007					
			1981–1985	Survey	Subnational	N/A	17.1	0–99
			1998–2002	Survey	Subnational	N/A	19.5	0–99
			2003–2007	Survey	Subnational	N/A	25.6	0–99
		Pickett et al. [82]	1997	Survey	Subnational	N/A	20.1	15–99
			1998	Survey	Subnational	N/A	20.5	15–99
			1999	Survey	Subnational	N/A	40.35	15–99
			2000	Survey	Subnational	N/A	50	15–99
		Pickett et al. [83]	1994	Registry	Subnational	N/A	46.2	0–99
			1999	Registry	Subnational	N/A	37.2	0–99
		Pirouzmand [84]	1986–2006	Registry	Subnational	658	N/A	0–99
		Rick Hansen Spinal Cord Injury Register [111]	2001	Registry	Subnational	N/A	35	0–99
		Guilcher et al. [47]	2003–2006	Survey	Subnational	931	N/A	18–99
		Sharma [138]	1991	Registry	Subnational	35	83.2	65–99
			1992	Registry	Subnational	47	108.2	65–99
			1993	Registry	Subnational	47	106	65–99
			1994	Registry	Subnational	50	109.3	65–99
			1995	Registry	Subnational	51	108.6	65–99
			1996	Registry	Subnational	42	86.4	65–99
			1997	Registry	Subnational	42	84.9	65–99
			1998	Registry	Subnational	38	75.3	65–99
			1999	Registry	Subnational	35	68.2	65–99
			2000	Registry	Subnational	38	72.5	65–99
			2001	Registry	Subnational	16	30	65–99
			1991–2001	Registry	Subnational	441	84	65–99
		Tator et al. [99]	1947–1973	Survey	Subnational	351	N/A	0–99
			1974–1981	Survey	Subnational	201	3.6	0–99
	USA	Acton et al. [13]	1980–1989	Registry	Subnational	N/A	27	0–99
		Bayakly et al. [128]	1991	Registry	Subnational	N/A	46	0–99
		Bracken et al. [18]	1970	Survey	National	N/A	29.1	0–99
			1971	Survey	National	N/A	33.7	0–99
			1972	Survey	National	N/A	40.7	0–99
			1973	Survey	National	N/A	45.6	0–99
			1974	Survey	National	N/A	47.6	0–99
			1975	Survey	National	N/A	43.8	0–99
			1976	Survey	National	N/A	43.1	0–99
			1977	Survey	National	N/A	42.8	0–99
			1970–1977	Survey	National	N/A	40.1	0–99
		Buechner et al. [19]	1994–1998	Survey	Subnational	277	56	0–99
		Burke et al. [20]	1993–1998	Registry	Subnational	161	27.1	0–99

Table 1 continued

WHO region	County	Study	Years of study	Type	Extend	No. of patients	Incidence per million	Age range
		Carroll [23]	1980–1989	Registry	Subnational	902	38	0–99
		1996 Annual Report of the Traumatic Spinal Cord Injury Early Notification System, Denver [123]	1989–1996	Registry	Subnational	N/A	43	0–99
		Fine et al. [37]	1973–N/A	Registry	Subnational	359	29.4	0–99
		Goebert et al. [43]	1987–1989	Survey	Subnational	59	23.7	0–99
		Griffin et al. [46]	1935–1981	Survey	Subnational	154	54.8	0–99
			1935–1944	Survey	Subnational	N/A	22.2	0–99
			1945–1954	Survey	Subnational	N/A	48.8	0–99
			1955–1964	Survey	Subnational	N/A	49	0–99
			1965–1974	Survey	Subnational	N/A	67	0–99
			1975–1981	Survey	Subnational	N/A	70.8	0–99
		Johnson et al. [52]	1994	Registry	Subnational	N/A	45.7	0–99
		Johnson [126]	1991–1992	Registry	Subnational	N/A	46	0–99
		Oliver et al. [77]	1996–2008	Registry	Subnational	557	N/A	0–99
		Price et al. [85]	1988–1990	Survey	Subnational	376	40	0–99
		Surkin et al. [98]	1993	Registry	Subnational	227	62	0–99
		Surkin et al. [97]	1992–1994	Registry	Subnational	359	76.8	0–99
		Thurman et al. [100]	1989–1991	Registry	Subnational	223	43	0–99
		Current Trends Trends in Traumatic Spinal Cord Injury: New York, 1982–1988 [7]	1982–1988	Registry	Subnational	5,384	43	0–99
		Spinal Cord Injury in Virginia: a Statistical Fact Sheet [122]	1990–1992	Registry	Subnational	N/A	30	0–99
		Warren et al. [105]	1991–1993	Registry	Subnational	139	83	0–99
		Woodruff and Baron [106]	1985–1988	Registry	Subnational		25	0–99
AMR B	Brazil	Greve [45]	1986–2007	Survey	National	3,289	17.3	0–99
		Barros Filho et al. [16]	1982–1987	Survey	Subnational	428	10.1	0–99
		Massini [68]	1997–1998	Survey	National	93	71	0–99
	Chile	Correa et al. [28]	1986–2005	Survey	Subnational	173	7.8 ± 3.6	0–99
EMR B	Iran	Rahimi-Movaghar et al. [1]	2007–2008	Survey	Subnational	496	72.4	0–99
		Fakharian et al. [108]	1995–1999	Survey	Subnational	39	30	0–99
	Jordan	Otom et al. [78]	1988–1993	Survey	National	151	18	0–99
	Kuwait	Raibulet [110]	1991–1999	Survey	Subnational	90	7.8	0–99
	Qatar	Quinones et al. [87]	1987–1996	Survey	National	262	12.5	0–99
	Saudi Arabia	Abo-Abat [137]	1990	Survey	Subnational	N/A	27	0–99
			1991	Survey	Subnational	N/A	23	0–99
			1992	Survey	Subnational	N/A	49	0–99
			1993	Survey	Subnational	N/A	47	0–99
			1994	Survey	Subnational	N/A	63	0–99
EMR D	Pakistan	Raja et al. [90]	1995–1999	Survey	National	2,654	5.1	0–99
EUA A	Austria	Prof. Walter Mauritz, (Personal Communication 2013)	2009	Registry	Subnational	149	17.7	0–99
			2010	Registry	Subnational	135	16	0–99
			2011	Registry	Subnational	133	15.8	0–99
	Denmark	Biering-Sørensen et al. [17]	1975–1984	Survey	National	268	9.2	0–99
		Pedersen et al. [80]	1965–1986	Survey	Subnational	29	26	0–99
	Finland	Ahoniemi et al. [8]	1976–2005	Registry	National	1,647	13.8	16–99
		Alaranta et al. [132]	1978–1997	Registry	National	N/A	10	0–99
		Puisto et al. [86]	1997–2006	Registry	National	749	66	0–18
	France	Albert and Ravaud [14]	2000	Survey	National	934	19.4	15–99
		Lieutaud et al. [64]	1997–2006	Registry	Subnational	144	8.9	0–99
		Lieutaud et al. [65]	1996–2001	Registry	Subnational	83	8.8	0–79

Table 1 continued

WHO region	County	Study	Years of study	Type	Extend	No. of patients	Incidence per million	Age range
			2003–2008	Registry	Subnational	82	8.2	0–79
		Minaire et al. [71]	1970–1975	Registry	Subnational	351	12.7	0–99
	Germany	Exner and Meinecke [36]	1976–1996	Registry	Subnational	16,559	10.65	0–99
		Koning and Frowein [59]	1983	Survey	National	N/A	36	0–99
	Greece	Divanoglou and Levi [32]	2006	Survey	Subnational	81	33.6	16–99
	Iceland	Knutsdottir et al. [57]	1975–1979	Survey	Subnational	33	30	4–99
			1980–1984	Survey	Subnational	21	18	4–99
			1985–1989	Survey	Subnational	28	23	4–99
			1990–1994	Survey	Subnational	26	20	4–99
			1995–1999	Survey	Subnational	17	12.5	4–99
			2000–2004	Survey	Subnational	30	21	4–99
			2005–2009	Survey	Subnational	52	33.5	4–99
	Ireland	Gregg [131]	1969–1988	Survey	National	750	11.4	0–99
		O'Connor and Murray [75]	2000	Registry	Subnational	46	13.1	0–89
		Roche et al. [91]	4 year data	Survey	Subnational	285	195.4	0–99
	Israel	Catz et al. [24]	1959–1992	Survey	Subnational	250	15.9	0–99
	Italy	Caldana and Lucca [22]	1994	Survey	Subnational	N/A	14.3	0–99
		Pagliacci et al. [79]	1997–1998	Survey	National	684	19	0–99
	Netherlands	van Asbeck et al. [101]	1994	Survey	National	126	7.5	0–99
	Norway	Gjone and Nordlie [42]	1974–1975	Survey	National	131	16.5	0–99
		Hagen et al. [49]	1952–1956	Survey	Subnational	13	6.2	0–99
			1957–1961	Survey	Subnational	12	5.5	0–99
			1962–1966	Survey	Subnational	18	8	0–99
			1967–1971	Survey	Subnational	29	12.4	0–99
			1972–1976	Survey	Subnational	33	13.6	0–99
			1977–1981	Survey	Subnational	40	16.2	0–99
			1982–1986	Survey	Subnational	45	17.9	0–99
			1987–1991	Survey	Subnational	33	12.9	0–99
			1992–1996	Survey	Subnational	42	15.9	0–99
			1997–2001	Survey	Subnational	71	26.3	0–99
	Portugal	Martins et al. [67]	1989–1992	Survey	Subnational	398	57.8	0–99
	Spain	Garcia-Reneses et al. [40]	1984	Survey	Subnational	320	8.3	0–99
			1985	Survey	Subnational	296	7.7	0–99
		Pérez and Novoa [81]	2000–2008	Registry	National	N/A	17.6	0–99
		Van Den Berg et al. [102]	1972–1980	Survey	Subnational	87	8.2	0–99
			1972–2008	Survey	Subnational	540	12.1	0–99
			1981–1990	Survey	Subnational	165	13.8	0–99
			1991–2000	Survey	Subnational	154	12.9	0–99
			2001–2008	Survey	Subnational	134	13.4	0–99
	Sweden	Divanoglou and Levi [32]	2006	Registry	Subnational	47	19.6	16–99
	Switzerland	Gehrig [41]	1960–1967	Survey	National	584	15	0–99
	United Kingdome	Aung and El Masry [15]	1985–1988	Survey	Subnational	219	7.3	0–99
EUR B	Bulgaria	Stavrev et al. [96]	1983–1992	Survey	Subnational	980	130.7	
	Romania	Soopramanien [95]	1975–1991	Survey	Subnational	3,854	28.5	0–99
	Turkey	Erdoğan et al. [35]	2007–2011	Survey	Subnational	409		0–99
		Gur et al. [48]	1990	Survey	Subnational	51	16.65	0–99
			1991	Survey	Subnational	60	14.54	0–99
			1992	Survey	Subnational	58	13.74	0–99
			1993	Survey	Subnational	63	14.59	0–99
			1994	Survey	Subnational	75	15.98	0–99
			1995	Survey	Subnational	56	12.39	0–99

Table 1 continued

WHO region	County	Study	Years of study	Type	Extend	No. of patients	Incidence per million	Age range
			1996	Survey	Subnational	50	10.82	0–99
			1997	Survey	Subnational	41	8.59	0–99
			1998	Survey	Subnational	45	9.38	0–99
			1999	Survey	Subnational	40	8.29	0–99
		Karacan et al. [53]	1992	Survey	National	581	12.7	0–99
		Karamehmetoğlu et al. [54]	1992	Survey	Subnational	152	12.06	0–99
			1994	Survey	Subnational	75	16.9	0–99
EUR C	Estonia	Sabre et al. [135]	2003–2007	Survey	Subnational	191	27.9	0–99
	Russia	Kondakov et al. [58]	1994	Survey	Subnational	26	30	0–99
			1995	Survey	Subnational	31	36	0–99
			1996	Survey	Subnational	48	56	0–99
		Silberstein and Rabinovich [94]	1989–1993	Survey	Subnational	196	29.7	0–99
SEAR B	Thailand	Kovinpha [60]	1985–1991	Survey	National	398	23	0–99
		Pajareya [109]	1989–1994	Survey	National	219	5.8	0–99
WPR A	Australia	O'Connor [120]	1986	Registry	National	255	20.7	15–99
			1987	Registry	National	230	18.3	15–99
			1988	Registry	National	259	14.8	15–99
			1989	Registry	National	243	18.6	15–99
			1990	Registry	National	238	17.9	15–99
			1991	Registry	National	244	18.1	15–99
			1992	Registry	National	229	16.7	15–99
			1993	Registry	National	246	17.8	15–99
			1994	Registry	National	247	17.6	15–99
			1995	Registry	National	256	13.4	15–99
			1996	Registry	National	259	13.2	15–99
			1997	Registry	National	253	15.2	15–99
		O'Connor [76]	1998	Registry	National	302	14.5	15–99
		O'Connor [121]	2000	Registry	National	259	13.6	15–99
		Cripps [112]	2001	Registry	National	239	12.2	15–99
		Cripps [113]	2002	Registry	National	245	12.4	15–99
		Cripps [114]	2003	Registry	National	289	15.3	15–99
		Cripps [115]	2004	Registry	National	280	15.4	15–99
		Cripps [116]	2005	Registry	National	284	15.7	15–99
		Cripps [117]	2006	Registry	National	272	14.9	15–99
		Norton [119]	2007	Registry	National	285	15	15–99
		Middleton et al. [70]	2004-2008	Survey	Subnational	324	46.2	16-99
	Japan	Shingu et al. [93]	1990–1992	Survey	National	9,752	40.2	0–99
		Shingu et al. [92]	1990	Survey	National	3,465	39.4	0–99
		Ide et al. [51]	1988	Survey	Subnational	330	28.6	0–99
	New Zealand	Derrett et al. [31]	2007–2009	Survey	National	238	30	16–64
		Dixon et al. [33]	1988	Survey	National	N/A	49.1	0–99
			1979–1988	Survey	National	N/A	43.3	0–99
		Hamilton [139]	2012	Survey	National	100	22.5	0–99
WPR B	China	Ning et al. [72]	2004–2008	Survey	Subnational	868	23.7	15–99
		Li et al. [63]	2002	Survey	Subnational	1,079	60.6	0–99
		Wang et al. [104]	2007–2010	Survey	Subnational	761	N/A	0–99
	Fiji	Maharaj [66]	1985–1994	Survey	National	75	10	0–99
	Malaysia	Ibrahim et al. [50]	2006–2009	Survey	Subnational	167	N/A	0–99
	Vietnam	Weerts [136]	2006–2007	Survey	Subnational	N/A	13.9	0–99

Table 1 continued

WHO region	County	Study	Years of study	Type	Extend	No. of patients	Incidence per million	Age range
N/A	Taiwan	Chen et al. [26]	1992–1996	Survey	National	1,586	18.8	0–99
		Chen and Lien [25]	1978–1981	Survey	Subnational	123	14.6	0–99
		Yang et al. [107]	2000	Survey	National	13,371	62.1	0–99
			2001	Survey	National	13,800	63.28	0–99
			2002	Survey	National	13,728	62.52	0–99
			2003	Survey	National	13,585	61.41	0–99
		Lan et al. [61]	1986–1990	Survey	Subnational	135	56.1	0–99

African region (AFR)

Three papers were identified from Africa: Sierra Leone, South Africa and Zimbabwe [44, 62, 103]. Only two papers reported data on incidence of TSCI [62, 103]: one paper from late 80 s and early 90 s and one paper from early 2000 [44]. The incidence of 11.7 cases per million is estimated from national rehabilitation centre of trauma patients between 1988 and 1994 in Zimbabwe. Estimates of 48.5 cases of TSCIs in South Africa are based on a single-centre report of patients with traumatic spine injuries between 1988 and 1992 in Johannesburg [103]. The only available study in Sierra Leone is a follow-up study of treated patients of a single hospital. The incidence in Sierra Leone is estimated around 3.4 cases per million.

East-Midland region (EMR)

Six papers from countries in East-Midland region (EMR) including Iran, Jordan, Kuwait, Qatar, Saudi Arabia and Pakistan were identified [78, 87–90, 108, 137]. The incidence figure from Pakistan (5.1 per million) is based on a national survey of medical records of patients with head and spine trauma hospitalised between 1995 and 1999 [90]. Jordan, Kuwait and Qatar figures are estimated from single centres while Iran and Saudi Arabia figures are from population-based studies [88, 137]. The incidence in these countries ranges from 5.1 cases per million in Pakistan to 72.4 cases per million in Iran. None of the countries in this region have available reports from trauma registries, though most cases of TSCI in these countries are believed to be due to traffic accidents.

Europe region (EUR)

Data are available for 22 of these countries. European countries including Austria, Bulgaria, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, England, Romania, Turkey, Estonia, and Russia have published the major part of available data in literature with 40 separate records [8, 14, 15, 17, 22, 24, 32, 36, 40–42, 48, 49, 53–59, 64, 65, 67, 71, 75, 79–81, 86, 91, 94–96, 101, 102, 131, 132, 134, 135, 140]. The incidence of TSCI in Europe ranges from 5.5 to 195.4 cases per million in Norway and Ireland, respectively.

Western pacific region (WPR)

A total of 23 papers from Australia, Japan, New Zealand, China, Fiji Islands, Malaysia, Vietnam and Taiwan were found on TSCI incidence [33, 50, 51, 61, 63, 66, 70, 72, 76, 92, 93, 104, 112–121, 136]. However, there are 20 countries in this region without publications on the epidemiology of SCI. The incidence in WPR ranges from 10.0 to 60.6 cases per million in Fiji Islands and China, respectively. Australia is the leading country worldwide in registration of SCI. Annual reports of SCI in Australia have been published since 1986 and the registry is updated each year. The incidence of TSCI in Australia has decreased from 20.7 in 1986 to 15.0 cases per million in 2007.

South East Asia (SEAR) and Taiwan

The only available data for SEAR are the reports of TSCI in Thailand. In Thailand one paper estimated the incidence of TSCI between 1985 and 1991 to be 23 cases per million [60]. A paper from a single hospital reported 219 patients with TSCI were hospitalised in Thailand (incidence 5.8 per million) in the period 1989–1994 [109]. Taiwan is not classified in WHO regional distribution of countries; however, there are 3 papers which include the incidence of TSCI in Taiwan, between 14.6 and 63.2 cases per million [25–27, 61, 107].

Discussion

Spinal cord injury is a rare but debilitating health condition worldwide. Most of the SCI cases are due to trauma including traffic accidents and falls. Epidemiological data on TSCI have not been studied in many countries

worldwide. In this review an extensive search was made to retrieve and access all available information regarding the incidence of TSCI in every country of the world. The searches resulted in finding of TSCI incidence data of 41 countries. Most of the available data are found in developed countries, where the incidence of TSCI in recent years has decreased or been stable due to preventive strategies probably based on knowledge of epidemiology of SCI [9]. However, SCIs are increasing in developing and middle to low-income countries, where there is lack of information regarding the epidemiology of SCI. Although SCI is not a common condition with an estimated overall incidence of 23.0 cases per million worldwide [9], the results of SCI as well as the costs, have made a growing concern in both developed and developing countries around the world.

The incidence of TSCI in this review ranged from 3.6 per million in Canada [99] to 195.4 per million in Ireland [91]. A decreasing/stable incidence of TSCI is seen in Australia, Austria, Canada, France, Iceland, New Zealand, Turkey, and US. Nevertheless, the incidence of TSCI increases in Ireland, Italy, Norway, Russia, Saudi Arabia, Spain, and Taiwan. The increase in incidence of TSCI may be due to improved recognition, registration, and health care system in these countries. However, there is insufficient evidence from other countries around the world to define trends of spinal cord injury.

According to registries across the US, the incidence of SCI is estimated to be 30.0–40.0 cases per million in the US [141]. Nonetheless, this incidence number includes 8.5 % of cases with unknown origin, which might be due to non-traumatic etiologies like tumours and infections. TSCI data in different states of Canada are available [3, 29, 34, 73, 82–84, 99, 111, 124, 130, 138]. Rick Hansen Spinal Cord Injury Register data are soon becoming public and these data are the most up-to-date data on TSCI in Canada. In Brazil, the incidence of 17.3 cases per million of TSCI based on retrospective surveys might be an underestimation in a country with more than 200 million residents and a growing concern about traffic accidents [12]. Data are not available for other 25 countries in AMR. There are 52 European countries, and seven (Austria, Finland, France, Germany, Ireland, Spain and Sweden) have published data on SCI from trauma registries. Although there might be more trauma registries across the Europe, e.g. in Norway, no publication on SCI is available through public access websites. Data are available for 22 countries across Europe. Publications from high-income countries (EUR A) form the major part of the present available data.

The African continent has yet the least available information on SCI epidemiology. There are 46 countries in African region according to WHO classification of countries. However, data are available only for three countries (Sierra Leone, South Africa, Zimbabwe). Moreover, the incidence figures reported in African region are inconclusive; they are mostly derived from single hospital-based or follow-up studies of treated patients.

Today developed countries are better informed and have effectively gathered data on TSCI; however, the definition of SCI is used differently or broadly. The reporting of those who die at the scene of the injury is included in some studies or data collection and excluded in others. These discrepancies in data collection have made it difficult to identify the cases and estimate the incidence of TSCI globally. There is an ongoing global effort to standardise registries and data management as well as effectively utilise the timing of surgical intervention to drive the translation of clinical practice on early intervention to prevent neurological damage, reduce secondary complications and improve outcomes resulting in better HRQOL in the community [142–144].

The new evidence will enable us to collaborate with policy makers to introduce new measures of prevention strategies for motor vehicle accidents and falls and regulations on safety for prevention of TSCI.

Due to the poor reporting and recording of TSCI in developing countries, there is no real urgency to drive the policy decision for prevention programmes. The obligation lies on the developing countries to prioritise care, bring awareness and look to developing countries for knowledge translation from their best practice programmes.

Conclusion

In this review the data retrieved from available data, both published and unpublished, demonstrate large variations in classification of age and aetiology of TSCI as well as the computation of incidence. The literature still lacks accurate epidemiological data on TSCI in many countries, most prominently in Africa. An extensive work is done by ISCoS-WHO collaboration to standardise the reporting of TSCI. This will improve future epidemiological studies on TSCI and promote the establishment of preventive strategies worldwide.

Acknowledgments In addition to the list in Appendix of websites/organisations/people that helped us retrieving unpublished data, we would like to thank the authors of included papers in this publication as well as the following researchers: Dr. Walter Mauritz, who kindly shared his knowledge of TSCI data in Austria. Topsy Neher Smally, a Research Librarian at Santa Cruz, CA 95065 USA: She provided the full texts of two papers which were not accessible to us, and also she provided the extracted data of a Russian paper by contacting B. B. Lee (Spinal Medicine Department, Prince of Wales Hospital, Sydney, New South Wales, Australia).

Conflict of interest None.

Appendix

Lists are based on alphabetical order.

Contacts

- Austria: Dr. Walter Mauritz,
- Canada: Rick Hansen Institute available at http://www.rickhanseninstitute.org/ (The contact person of the site provided us with 6 related papers).
- Cyprus: Cyprus Trauma Registry, contact person: Anna Pharmaka at a.farmaka@traumangh.com.
- Denmark: Dr. Ellen Merete Hagen.
- European Spinal Cord Injury Federation at http://www.escif.org/ (on the website, there were several links to affiliated institutes located in different countries across the EUROPE and we made inquiry to all the available addresses).
- Eurotrauma: List of European Trauma Registries at http://www.eurotrauma.net/site2/index.php?option=com_content&view=article&id=46&Itemid=55.
- Nordic Spinal Cord Council at http://www.nscic.se/nscic/Contacts.aspx.
- The Netherlands: Dutch Trauma Registry, Contact Person: Leontien Sturms at l.sturms@lnaz.nl.
- Nordic Spinal Cord Injury Registry:
- Norway: Norwegian Spinal Cord Injury Registry at nhf@nhf.no.
- Sweden: The Spinal Injury Registry of Sweden:
- UK: EuroTARN (The Trauma Audit and Research Network) at http://eurotarn.man.ac.uk/. Contact Person: Antoinette Edwards, the Projects & Research Manager, at antoinette.edwards@tarn.ac.uk (he sent 2 related papers to us).
- USA: National Spinal Cord Injury Association at http://www.spinalcord.org/ (Under resource centre tab and then at international resource section, there are registered names and contact addresses of organisations of 105 countries).
- USA: National Spinal Cord Injury Statistical Center (NSCISC) at http://www.nscic.se/nscic/Contacts.aspx.
- Vietnam: Vietnam Registry for Head and Spinal Cord Injury (Vietnam Head and Spinal Cord Injury Registry): Vietnam Veterans Spinal Cord Injury Registry:

Grey literature resources

- BioLine at http://www.bioline.org.br/.
- British Theses at http://ethos.bl.uk/Home.do.
- DAEDALUS—A JISC FAIR Project at http://www.lib.gla.ac.uk/daedalus/.
- DART (Europe E-theses Portal) at http://www.dart-europe.eu/basic-search.php.
- Helsinki Theses at http://ethesis.helsinki.fi/en/.
- Karolinska Institute Thesis at http://diss.kib.ki.se/index_en.cfm.
- Lenus: the Irish Health Repository at http://www.lenus.ie/hse/.
- List at http://hlwiki.slais.ubc.ca/index.php/Grey_literature.
- List at http://hlwiki.slais.ubc.ca/index.php/Grey_literature_-_part_II.
- NARCIS at http://www.narcis.nl/.
- OhioLink Theses at http://etd.ohiolink.edu/.
- OpenGrey Repository at http://www.opengrey.eu/.
- ProQuest Theses and Dissertations Database at http://search.proquest.com/index.

Browsed websites

- Australia: Research Center for Injury Studies at http://www.nisu.flinders.edu.au/pubs/reports/2010/injcat128.php.
- Canada: Canadian Institute of Health Information at https://secure.cihi.ca/estore/productbrowse.htm?locale=en&Lang=en-US#N and at http://www.cihi.ca/CIHI-ext-portal/internet/en/document/types+of+care/specialized+services/trauma+and+injuries/services_otr.
- Finland: Käpylä Rehabilitation Centre, Helsink at http://www.hur.fi/index.asp?page=ref-kapyla.
- Germany: Deutsches Trauma-Register or German Trauma Registry, Annual Reports at http://www.traumaregister.de/index.php?option=com_content&view=article&id=49&Itemid=55&lang=en.
- International Spinal Cord Society (ISCoS) at http://www.iscos.org.uk/sci-global-mapping.
- Israel: Israel Trauma Registry Reports at http://www.gertnerinst.org.il/e/health_policy_e/trauma/trauma_publications/100.htm.
- USA: Center for Disease Control and Prevention (CDC) at http://www.cdc.gov/datastatistics/.
- USA: National Institute on Disability and Rehabilitation Research at http://www2.ed.gov/about/offices/list/osers/nidrr/.
- USA: National Institute on Neurological Disorders and Stroke at http://www.ninds.nih.gov/.
- USA: National Spinal Cord Injury Association at http://www.spinalcord.org/.
- USA: National Spinal Cord Injury Statistical Center (NSCISC) at https://www.nscisc.uab.edu/reports.aspx.
- USA: The Christopher and Dana Reeve Foundation at http://www.christopherreeve.org/.
- World Bank at http://www.worldbank.org/.

- World Health Organization (WHO) at http://www.who.int/en/.

Browsed journals

- Central Nervous System Trauma (ISSN 0737-5999).
- European Spine Journal (ISSN 1432-0932).
- Injury (ISSN 0020-1383).
- Injury Research and Statistics Series (ISSN 1444-3791).
- The Journal of Trauma (ISSN 0022-5282).
- Neuroepidemiology (ISSN 0251-5350).
- Neurotrauma (ISSN 0897-7151).
- Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine (ISSN 1757-7241).
- Spinal Cord (ISSN 1362-4393).
- The Spine Journal (ISSN 1529-9430).
- Spine (ISSN 0362-2436).
- The Journal of Spinal Cord Medicine (ISSN 1079-0268).

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