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Incidence of traumatic spinal cord injury worldwide: A systematic review, data integration, and update

Seyed Behnam Jazayeri [a,b], Seyed Farzad Maroufi [a,b], Esmaeil Mohammadi [a], Mohammad Amin Dabbagh Ohadi [a,b], Ellen-Merete Hagen [c,d,e], Maryam Chalangari [a], Seyed Behzad Jazayeri [a], Mahdi Safdarian [a,k], Shayan Abdollah Zadegan [a,l], Zahra Ghodsi [a], Vafa Rahimi-Movaghar [a,f,g,h,i,j,*]

[a] Sina Trauma and Surgery Research Center (STSRC), Tehran University of Medical Sciences (TUMS), Tehran, Iran
[b] Students' Scientific Research Center, Tehran University of Medical Sciences, Tehran, Iran
[c] Autonomic Unit, National Hospital for Neurology & Neurosurgery, UCLH, UK
[d] Department of Brain Repair and Rehabilitation, Queen Square Institute of Neurology, UCL, UK
[e] Department of Clinical Medicine, Aarhus University, Denmark
[f] Brain and Spinal Cord Injury Research Center, Neuroscience Institute, Tehran University of Medical Sciences, Tehran, Iran
[g] Department of Neurosurgery, Shariati Hospital, Tehran University of Medical Sciences, Tehran, Iran
[h] Universal Scientific Education and Research Network (USERN), Tehran, Iran
[i] Institute of Biochemistry and Biophysics, University of Tehran, Tehran, Iran
[j] Spine Program, University of Toronto, Toronto, Canada
[k] Department of Neurology, Christian Doppler Medical Center, University Hospital Salzburg, Austria
[l] Department of Neurology, McGovern Medical School, The University of Texas Health Science Center at Houston (UTHealth), Houston, TX, USA

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ABSTRACT

Objectives: This review was designed to update our earlier systematic review which evaluated both published and unpublished evidence on the incidence of traumatic spinal cord injury (TSCI) worldwide.
Methods: We used various search methods including strategic searching, reference checking, searching for grey literature, contacting registries, authors, and organizations requesting unpublished data, browsing related websites, and hand searching key journals. The quality of included studies was evaluated by Joanna Briggs Institute Critical Appraisal Tools. Records published between April 2013 and May 2020 were added to the original systematic review.
Results: Overall, 58 resources including 45 papers, 10 SCI registry reports, 1 book, and 2 theses were retrieved. We found TSCI incidence data for eight new countries, which overall shapes our knowledge of TSCI incidence for 49 countries. The incidence of TSCI ranges from 3.3 to 195.4 cases per million (cpm) based on subnational studies and from 5.1 to 150.48 cpm based on national studies. Most of the studies were low quality, lacked consistent case selection due to unclear definition of TSCI and unclear ascertainment methods.
Conclusions: There is an increasing number of publications in the literature focusing on the epidemiologic data of TSCI. The absence of a standard form of reporting TSCI hinders the comparability of data across different data sources. Use of various definitions for TSCI may lead to heterogeneity in reports. Use of sensitivity analyses based on reasonable classification criteria can aid in offering a uniform set of case identification and ascertainment criteria for TSCI.

Abbreviations: TSCI, Traumatic Spinal Cord Injury; CPM, Cases Per Million; InSCI, The International Spinal Cord Injury; PICO, Population, Intervention, Comparator, and Outcome; CoCoPop, Condition, Context, and Population; TSI, Traumatic spinal injuries; PHM, Prehospital mortality; JBI, Joanna Briggs Institute; ASCIR, Australian Spinal Cord Injury Register; AMR, American region; EMR, Eastern Mediterranean region; EUR, European Region; WPR, Western Pacific Region; SEAR, South East Asia Region; ISCoS, International Spinal Cord Society; ICD, International Codes of Disease; SwiSCI, Swiss Spinal Cord Injury.

* Corresponding author. Sina Trauma and Surgery Research Center, Sina Hospital, Hassan Abad Square, Imam Khomeini Avenue, Tehran, Iran.
E-mail addresses: v_rahimi@sina.tums.ac.ir, v_rahimi@yahoo.com (V. Rahimi-Movaghar).

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1. Introduction

Rationale: Traumatic Spinal Cord Injury (TSCI) is a devastating but preventable condition with high morbidity and mortality. The lack of curative treatment for TSCI necessitates to understand epidemiology and etiologies of this condition to promote practical preventive strategies. Reports of SCI have been heterogeneous in previous publications among countries and SCI centers mainly because of different data-gathering methods, case defining approaches, and the various socio-economic structures of the countries.[1,2] Recently, efforts have been undertaken to homogenously describe the true epidemiology of SCI.[3] The International Spinal Cord Injury (InSCI) study is a good example in this regard. This study was conducted in all six WHO regions with a uniform sampling strategy to improve health and function of patients with SCI; however, the impact of this study on the healthcare system of the participating countries is not available yet.

In a previous systematic review, our team addressed the worldwide incidence of TSCI up to April 29th, 2013.[4] In that review, after searching the published and grey literature, data was limited to forty-one countries regarding the incidence of TSCI, which are representative of about 20% of countries in the world. Moreover, most of the available literature had evaluated the epidemiologic aspects of TSCI in high-income developed countries.

Objectives: Considering the newly recommended protocols for conduction of SCI epidemiologic assessment,[5] we aimed to assess reported publications in compliance with guidelines and update the knowledge on TSCI incidence worldwide.[5,6]

2. Material and methods

This systematic review has been conducted utilizing methodological guidance for systematic reviews of observational epidemiological studies reporting prevalence and cumulative incidence data.[7]

3. Eligibility criteria

3.1. Inclusion criteria

Instead of applying conventional population, intervention, comparator, and outcome (PICO) structure as inclusion criteria we used CoCoPop model (condition, context, and population) as suggested by Munn et al.[7]

3.2. Condition

Spinal cord injury has been defined as "*an acute, traumatic lesion of neural elements in the spinal canal (spinal cord and cauda equina) resulting in temporary or permanent sensory deficit, motor deficit, or bladder/bowel dysfunction.*[8]" Such damage can be result of an internal non-traumatic etiology (e.g. tumor or disease), or external etiology (e.g. transport-related injuries, fall, or violence). Therefore, SCI is often described in terms of traumatic or non-traumatic. In this review, we excluded studies of non-traumatic or mixed SCI if they were indistinguishable. Another point to consider is the injury to the spinal cord. We separated Traumatic spinal injuries (TSI) from TSCI. Studies of TSI without mentioning the cord injury were excluded. Studies focusing on a certain injury level (e.g. cervical SCI), specific etiology (e.g. sports-related SCI), or specific target population (e.g. workers) were also excluded.

3.3. Context

We included both national and subnational studies if they reported the incidence rate of TSCI or provided enough information regarding their catchment area and population at risk in order to estimate the incidence. Studies that reported the epidemiology of TSCI in a region within a country such as a state, city, etc. were considered subnational. In contrast those studies that considered the whole population of a country were considered national. Studies reporting only prevalence figures were excluded.

3.4. Population

In the current review we excluded studies of pediatric-onset (<16 years) TSCI.

One major source of heterogeneity among study rates of TSCI is believed to stem from inclusion or exclusion of prehospital mortality (PHM).[9] In Order to homogenize the incidence rates, we examined the inclusion of PHM in all studies. There was no restriction for data sources or study designs. All observational epidemiological studies containing relevant information, either survey or registry-based studies were eligible to include.

4. Information sources

We searched EMBASE via Ovid SP and PubMed (including MEDLINE and PubMed Central). We also reviewed the references of our retrieved eligible studies in order to find additional relevant articles that may have been missed from database searching. Relevant abstracts from conference proceedings were also collected and checked for full-text availability. The grey literature was searched manually as previously described.[4] In brief, we used 13 grey literature resources and 14 websites, and emailed 306 investigators. The search was performed on 5th may 2020.

5. Search strategy

We adopted our previous search strategy, which is described in details elsewhere.[4] In short, for optimal retrieval of available information, we used different search methods including strategic searching, reference checking, searching for grey literature, contacting registries, authors, and organizations requesting for unpublished data, browsing related websites, and hand searching key journals.

We used the terms 'Spinal cord injury', 'incidence', 'prevalence' and 'epidemiology' as keywords (Appendix A). In this review, our search was primarily aimed to gather all published and unpublished papers after April 29th, 2013 (last date of the previous search), therefore we restricted the date of search to those records entered into databases (entry date) after April 29th, 2013. However, we checked reference lists of systematic reviews as of 2010[1,10–15] to avoid losing any potentially missed paper before 2013. There were no language or country limitation in the search process in all resources.

6. Selection process, data collection process and data items

Two independent reviewers (S.F.M and M.A.D.O) screened the titles and then the abstracts of each retrieved record from the literature. Then the full-texts of selected records were assessed for inclusion based on eligibility criteria. The disagreements between two researchers were resolved either by consensus or the third reviewer (S.B.J) made the final decision. After inclusion of relevant full-texts, two independent authors (M.A.D.O and S.F.M) extracted the following information from each record: type of study (registry-based or survey-based), extent of study (national vs. subnational level), coverage years, raw data of study (if available), number of cases, age and incidence report, type of SCI (traumatic vs. non-traumatic), inclusion or exclusion of PHM, timing of data collection (prospective or retrospective), study design, and study scale (population-based, hospital-based, rehabilitation-based, etc.). The third author (S.B.J) double-checked the extracted data for accuracy and completeness.

7. Critical appraisal

The quality of included studies was evaluated by appropriate Joanna Briggs Institute (JBI) Critical Appraisal Tools based on study design.[16] For the aims of this study we used the checklist for case-series. This checklist contains 10 questions which are related to areas of risk of bias assessment including adequate reporting, statistical analysis. Each question in the checklist can be answered as "yes, no, unclear or not applicable". Each study was assessed by two independent researchers (S.F.M and M.A.D.O). Disagreements between individual judgments were resolved by discussion or decision of a third researcher (S.B.J) whenever needed. We calculated the total score for methodological quality of studies by adding up the "Yes" answers to each question of the quality appraisal tool. Our criteria for answering each question of the described checklist can be found in Appendix B.

Although we did not exclude any study based on critical appraisal, we qualified all papers to identify the areas of potential bias.

8. Data synthesis

Data synthesis was performed by tabular summary approach.[7]

9. Results

9.1. Study inclusion

A total of 858 records from Medline and 1115 records from EMBASE were identified and included in the EndNote X8 database. After excluding 752 duplicate records, titles and abstracts of 1221 records were screened by two members of the team (M.C and M.S). After exclusion of 797 irrelevant records, 424 papers were screened and assessed using the inclusion criteria. This process limited the number of papers to 128, of which 70 were excluded: 23 did not mention any incidence rate, 16 reported non-traumatic or mixed injuries, 22 records were either review articles or conference abstracts, five papers only reported cervical SCI, and four were prevalence study. We identified 10 reports from national registries,[17–26] one book,[27] as well as data from New Zealand and Russia through personal communications. Overall, we identified 58 reports[2,9,14,17–26,28–71] for 31 countries worldwide as of 2013 (Fig. 1).

9.2. Methodological quality

The included studies were critically appraised as described in critical appraisal section of methods. The methodology utilized in nine reports from national registry of Australia were similar, therefore we grouped them to one record under "Australian Spinal Cord Injury Register (ASCIR) reports" title.

There were nine relevant items in the questionnaire, thus the maximum score was 9. The-included studies' scores ranged from four to nine. The highest risk of bias was attributed to the process of case selection due to unclear definition of TSCI and ascertainment methods. Results of the methodological quality evaluation are shown in Table 1.

9.3. Review findings

Similar to our previous study[4] we categorized incidence data based on WHO classification of countries. Extracted data of incidence rates are shown in Table 2.

10. American region (AMR)

In our previous systematic review[4] we could find 36 reports on TSCI from the United States (US), Canada, and Brazil in this region. In the current review, five studies were available including three studies from US[33,37,72] and two from Canada.[31,32] Three studies of US were all registry-based and sourced information from different data repositories such as Nationwide Emergency Department Sample database,[33] Nationwide Inpatient Sample database,[72] and Spinal Cord Injury Surveillance Registry.[37] The Canadian studies were subnational studies from a single hospitals in Quebec[31] and the British Colombia Trauma Registry.[32]

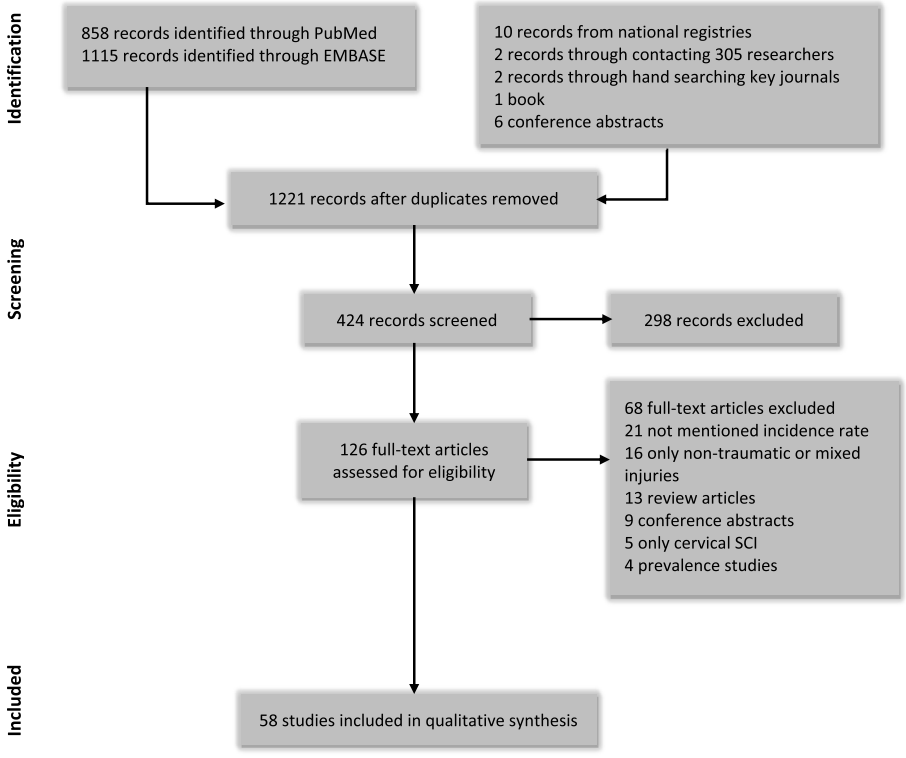

Fig. 1. Flow diagram of studies based on PRISMA statement.

Table 1
Methodological assessment scores of included studies.

Country	Source	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total Score
Australia	ASCIR reports	Y	U	Y	Y	Y	Y	Y	NA	Y	Y	8
	Moorin et al	Y	U	Y	Y	Y	N	Y	NA	Y	Y	7
	Beck et al	Y	U	Y	U	Y	Y	Y	NA	Y	Y	7
	New et al	Y	U	Y	U	U	Y	Y	NA	Y	U	5
Austria	Majdan et al	Y	U	Y	Y	Y	N	Y	NA	Y	Y	7
Botswana	Löfvenmark et al	U	U	U	U	N	Y	Y	NA	Y	Y	4
Canada	Thompson et al	Y	U	Y	Y	Y	Y	Y	NA	Y	Y	8
	Lenehan et al	Y	U	Y	Y	Y	Y	Y	NA	Y	Y	8
Czech Republic	Kriz et al	Y	U	U	Y	Y	Y	Y	NA	Y	Y	7
Denmark	Noe et al	Y	U	U	Y	Y	N	Y	NA	Y	Y	6
Estonia	Sabre et al	Y	U	Y	Y	Y	Y	Y	NA	Y	Y	8
	Sabre et al	Y	U	Y	Y	Y	Y	Y	NA	Y	Y	8
	Sabre et al	Y	U	Y	Y	Y	N	Y	NA	Y	Y	7
Finland	Niemi-nikkola et al	Y	U	Y	Y	Y	N	Y	NA	Y	Y	6
	Koskinen et al	Y	U	U	Y	Y	Y	Y	NA	Y	Y	7
Former Yugoslav Republic of Macedonia	Jakimovska et al	U	Y	Y	Y	Y	Y	Y	NA	Y	Y	8
Iceland	Kristinsdóttir et al.	Y	U	Y	Y	Y	Y	Y	NA	Y	Y	8
Iran	Sharif-alhoseini and Rahimi-Movaghar	Y	U	U	N	N	Y	Y	NA	Y	Y	5
Ireland	Smith et al	Y	U	Y	Y	Y	N	U	NA	Y	U	5
	Smith et al	Y	U	U	Y	Y	Y	Y	NA	Y	Y	7
Italy	Ferro et al	Y	Y	U	Y	Y	N	Y	NA	Y	Y	7
Japan	Katoh et al	N	U	U	Y	Y	Y	Y	NA	Y	Y	6
	Kudo et al	Y	Y	Y	Y	Y	Y	Y	NA	Y	Y	9
Latvia	Nulle et al	U	U	U	U	Y	Y	Y	NA	Y	Y	5
Netherland	Nijendijk et al	Y	U	Y	Y	N	N	Y	NA	Y	Y	6
New Zealand	Mitchell et al	Y	U	U	Y	Y	Y	Y	NA	Y	Y	7
Norway	Halvorsen et al	Y	U	U	Y	Y	Y	Y	NA	Y	Y	7
Pakistan	Bilal and Mujeeb-Ur-Rahman	Y	U	U	N	U	Y	Y	NA	Y	U	4
Russia	Mirzaeva et al	Y	Y	Y	Y	Y	Y	Y	NA	Y	Y	9
	Lobzin et al	Y	Y	Y	Y	Y	Y	Y	NA	Y	Y	9
Scotland	McCaughey et al	Y	U	U	Y	Y	Y	Y	NA	Y	Y	7
South Africa	Joseph et al	Y	U	U	Y	Y	Y	Y	NA	Y	Y	7
	Pefile et al	Y	U	U	Y	N	Y	Y	NA	Y	Y	6
	Philips et al	Y	Y	Y	Y	Y	Y	Y	NA	Y	Y	9
South Korea	Choi et al	Y	U	Y	Y	Y	N	Y	NA	Y	Y	7
Spain	Montoto-marqués et al	Y	Y	Y	Y	Y	Y	Y	NA	Y	Y	9
	Alcacer et al	Y	Y	Y	Y	Y	Y	Y	NA	Y	Y	9
	Bárbara-bataller et al	Y	U	Y	Y	Y	Y	Y	NA	Y	Y	8
	Bárbara-bataller et al	Y	U	U	Y	Y	Y	Y	NA	Y	Y	7
Sweden	Joseph et al	Y	Y	Y	Y	Y	Y	Y	NA	Y	Y	9
Switzerland	Chamberlain et al	Y	U	Y	Y	Y	N	Y	NA	Y	Y	7
	Chamberlain et al	Y	U	U	Y	Y	N	Y	NA	Y	Y	6
Taiwan	Wu et al	Y	Y	Y	Y	Y	N	Y	NA	Y	Y	8
Tanzania	Moshi et al	U	U	U	Y	N	N	Y	NA	Y	Y	4
United States	Selvarajah et al	Y	U	Y	Y	Y	Y	Y	NA	Y	Y	8
	Jain et al	Y	U	Y	Y	Y	N	Y	NA	Y	Y	7
	Selassie et al	Y	U	Y	Y	Y	N	Y	NA	Y	Y	7

Q: Question; N, *no; U, unclear; Y, yes; NA, not applicable; ASCIR: Australian Spinal Cord Injury Registry*.
Q1: Were there clear criteria for inclusion in the case series?.
Q2: Was the condition measured in a standard, reliable way for all participants?.
Q3: Were valid methods used for identification of the condition for all participants included?.
Q4: Did the case series have consecutive inclusion of Participants?.
Q5: Did the case series have complete inclusion of participants?.
Q6: Was there clear reporting of the demographics of the participants in the study?.
Q7: Was the condition measured in a standard, reliable way for all participants?.
Q8: Were the outcomes or follow up results of cases clearly reported?.
Q9: Was there clear reporting of the presenting site(s)/clinic(s) demographic information?.
Q10: Was statistical analysis appropriate?.

In a study by Selvarajah et al[33] using the NEDS database, the incidence of TSCI for adults aged 18 and more was 56.4 cases per million (cpm) in 2007–2009. Patients were managed in a designated trauma center in 70% of the time during the study period. The study published by Jain et al[72] reported SCI incidence based on NIS data for 20 years from 1993 to 2012 with a range of 45–64 cpm in the US. They described a substantial decline in TSCI incidence among males between 16 and 24 years (from 144 to 88 cpm) and 25–44 years (from 91 to 71 cpm) between 1993 and 2012 (Table 2).

Selassie et al[37] designed a population-based study using statewide TSCI surveillance and follow-up registry in South Carolina between 1998 and 2012. The age-standardized incidence rate of TSCI increased significantly from 66.9 in 1998 to 111.7 cpm in 2012. The overall incidence rate was 84.9 cpm.

TSCI individuals treated in a single center in Quebec, Canada, during an 11-year period from 2000 to 2010 were included in a study by Thompson's et al[31] The incidence of TSCI was 10.6 in 2000, 22.6 in 2005, and 17.8 cpm in 2010. The incidence of TSCI between 1995 and 2004 in British Colombia province of Canada is reported in a prospective population-based study, by utilizing data from the main SCI referral center of British Colombia and British Colombia trauma registry.[32] The incidence of TSCI in this study ranged between 43.4 cpm in 1996 to 28.7 cpm in 2003 (Table 2).

Table 2
Summary of the included studies.

WHO region	Country	Study source	Years of study	Type	Extend	Study design	No. of patients	Incidence rate per million	Prehospital mortality Included?	ISCoS* Format Utilized?	Age range
AFR E	Botswana	Löfvenmark et al.	2011–2012	Survey	Subnational Gaborone	Prospective hospital-based	52	13	No	Yes	0–99
	South Africa	Joseph et al.	2013–2014	Survey	Subnational Cape Town	Prospective population-based	147	75.6	No	Yes	18–99
		Phillips et al.	2013–2014	Survey	Subnational Cape Town	Prospective population-based	160	61.1	No	Yes	18–99
		Pefile et al.	2009–2015	Survey	Subnational KwaZulu-Natal and the Eastern Cape provinces	Retrospective Hospital-based	84	55.19	No	Yes	16–99
	Tanzania	Moshi et al.	2010–2014	Survey	Subnational Kilimanjaro rural region, north-east Tanzania	Retrospective Hospital-based	218	26	No	Yes	0–99
AMR A	Canada	Thompson et al.	2000	Registry	Subnational Québec	Retrospective Hospital-based	46	10.6	No	No	0–99
			2001	Registry	Subnational Québec	Retrospective Hospital-based	54	12.4	No	No	0–99
			2002	Registry	Subnational Québec	Retrospective Hospital-based	61	13.9	No	No	0–99
			2003	Registry	Subnational Québec	Retrospective Hospital-based	53	12	No	No	0–99
			2004	Registry	Subnational Québec	Retrospective Hospital-based	100	22.5	No	No	0–99
			2005	Registry	Subnational Québec	Retrospective Hospital-based	101	22.6	No	No	0–99
			2006	Registry	Subnational Québec	Retrospective Hospital-based	79	17.6	No	No	0–99
			2007	Registry	Subnational Québec	Retrospective Hospital-based	93	20.5	No	No	0–99
			2008	Registry	Subnational Québec	Retrospective Hospital-based	81	17.7	No	No	0–99
			2009	Registry	Subnational Québec	Retrospective Hospital-based	80	17.3	No	No	0–99
			2010	Registry	Subnational Québec	Retrospective Hospital-based	83	17.8	No	No	0–99
			2000–2010	Registry	Subnational Québec	Retrospective Hospital-based	831	16.8	No	No	0–99
		Lenehan et al	1995	Registry and Survey	Subnational British Columbia	Prospective Population-based	102	45.6	No	No	15–99
			1996	Registry and Survey	Subnational British Columbia	Prospective Population-based	106	46	No	No	15–99
			1997	Registry and Survey	Subnational British Columbia	Prospective Population-based	97	43.1	No	No	15–99
			1998	Registry and Survey	Subnational British Columbia	Prospective Population-based	102	42.3	No	No	15–99
			1999	Registry and Survey	Subnational British Columbia	Prospective Population-based	77	32.7	No	No	15–99
			2000	Registry and Survey	Subnational British Columbia	Prospective Population-based	103	43.8	No	No	15–99
			2001	Registry and Survey	Subnational British Columbia	Prospective Population-based	83	37.4	No	No	15–99
			2002	Registry and Survey	Subnational British Columbia	Prospective Population-based	85	36.3	No	No	15–99
			2003	Registry and Survey	Subnational British Columbia	Prospective Population-based	87	35.4	No	No	15–99
			2004	Registry and Survey	Subnational British Columbia	Prospective Population-based	88	37	No	No	15–99

(*continued on next page*)

Table 2 (*continued*)

WHO region	Country	Study source	Years of study	Type	Extend	Study design	No. of patients	Incidence rate per million	Prehospital mortality Included?	ISCoS* Format Utilized?	Age range
	US	Selvarajah et al.	2007	Registry	National USA	Prospective Other	13,169	57	No	No	18–109
			2008	Registry	National USA	Prospective Other	14,207	58.4	No	No	18–109
			2009	Registry	National USA	Prospective Other	12,526	56.4	No	No	18–109
			2007–2009	Registry	National USA	Prospective Other	43137	56.4	No	No	18–109
		Jain et al.	1993	Registry	National USA	Retrospective Population-based	2659	53.1	No	No	0–99
			1994	Registry	National USA	Retrospective Population-based	2680	53.58	No	No	0–99
			1995	Registry	National USA	Retrospective Population-based	3112	54.94	No	No	0–99
			1996	Registry	National USA	Retrospective Population-based	2983	52.87	No	No	0–99
			1997	Registry	National USA	Retrospective Population-based	3048	48.07	No	No	0–99
			1998	Registry	National USA	Retrospective Population-based	2848	53.63	No	No	0–99
			1999	Registry	National USA	Retrospective Population-based	2946	51.65	No	No	0–99
			2000	Registry	National USA	Retrospective Population-based	2849	47.77	No	No	0–99
			2001	Registry	National USA	Retrospective Population-based	2611	45.06	No	No	0–99
			2002	Registry	National USA	Retrospective Population-based	3025	48.97	No	No	0–99
			2003	Registry	National USA	Retrospective Population-based	3180	51.02	No	No	0–99
			2004	Registry	National USA	Retrospective Population-based	3993	63.86	No	No	0–99
			2005	Registry	National USA	Retrospective Population-based	3021	47.78	No	No	0–99
			2006	Registry	National USA	Retrospective Population-based	3453	54.57	No	No	0–99
			2007	Registry	National USA	Retrospective Population-based	3357	53.66	No	No	0–99
			2008	Registry	National USA	Retrospective Population-based	3274	50.4	No	No	0–99
			2009	Registry	National USA	Retrospective Population-based	3217	50.18	No	No	0–99
			2010	Registry	National USA	Retrospective Population-based	4106	64.3	No	No	0–99
			2011	Registry	National USA	Retrospective Population-based	3354	50.15	No	No	0–99
			2012	Registry	National USA	Retrospective Population-based	3393	54.04	No	No	0–99
		Selassie et al.	1998	Registry	Subnational South Carolina	Cross-sectional Population-based	N/A	66.9	No	No	22–99
			2012	Registry	Subnational South Carolina	Cross-sectional Population-based	N/A	111.7	No	No	22–99

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Table 2 (*continued*)

WHO region	Country	Study source	Years of study	Type	Extend	Study design	No. of patients	Incidence rate per million	Prehospital mortality Included?	ISCoS* Format Utilized?	Age range
			1998–2012	Registry	Subnational South Carolina	Cross-sectional Population-based	3365	70.8	No	No	22–99
EMR B	Iran	Sharif-Alhoseini and Rahimi-Movaghar	2010–2011	Survey	Subnational Tehran	Retrospective Hospital-based	138	10.5	No	No	0–99
EMR D	Pakistan	Bilal and Mujeeb-Ur-Rahman	2008	Survey	Subnational Khyber Pukhtunkhwa	Retrospective Rehabilitation-based	242	11	No	No	0–99
			2009	Survey	Subnational Khyber Pukhtunkhwa	Retrospective Rehabilitation-based	208	9.45	No	No	0–99
			2010	Survey	Subnational Khyber Pukhtunkhwa	Retrospective Rehabilitation-based	234	10.63	No	No	0–99
			2011	Survey	Subnational Khyber Pukhtunkhwa	Retrospective Rehabilitation-based	228	10.36	No	No	0–99
			2012	Survey	Subnational Khyber Pukhtunkhwa	Retrospective Rehabilitation-based	224	10.18	No	No	0–99
			2008–2012	Survey	Subnational Khyber Pukhtunkhwa	Retrospective Rehabilitation-based	1136	10.23	No	No	0–99
EUR A	Austria	Majdan et al.	2002	Registry	National Austria	Retrospective Population-based	N/A	15.96	Yes	No	0–99
			2003	Registry	National Austria	Retrospective Population-based	N/A	16.26	Yes	No	0–99
			2004	Registry	National Austria	Retrospective Population-based	N/A	14.07	Yes	No	0–99
			2005	Registry	National Austria	Retrospective Population-based	N/A	16.05	Yes	No	0–99
			2006	Registry	National Austria	Retrospective Population-based	N/A	12.57	Yes	No	0–99
			2007	Registry	National Austria	Retrospective Population-based	N/A	15.07	Yes	No	0–99
			2008	Registry	National Austria	Retrospective Population-based	N/A	20.79	Yes	No	0–99
			2009	Registry	National Austria	Retrospective Population-based	N/A	19.66	Yes	No	0–99
			2010	Registry	National Austria	Retrospective Population-based	N/A	19.02	Yes	No	0–99
			2011	Registry	National Austria	Retrospective Population-based	N/A	18.12	Yes	No	0–99
			2012	Registry	National Austria	Retrospective Population-based	N/A	18.75	Yes	No	0–99
			2002–2012	Registry	National Austria	Retrospective Population-based	1543	16.96	Yes	No	0–99
	Czech republic	Kriz et al.	2006–2015	Survey	National Czech republic	Prospective Population-based	1736	16.5	No	No	0–99
	Denmark	NOE et al.	1990–1994	Survey	Subnational Western Denmark	Retrospective Rehabilitation-based	153	10.7	No	Yes	0–99
			1995–1999	Survey	Subnational Western Denmark	Retrospective Rehabilitation-based	129	8.7	No	Yes	0–99
			2000–2004	Survey	Subnational Western Denmark	Retrospective Rehabilitation-based	174	11.8	No	Yes	0–99

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Table 2 (*continued*)

WHO region	Country	Study source	Years of study	Type	Extend	Study design	No. of patients	Incidence rate per million	Prehospital mortality Included?	ISCoS* Format Utilized?	Age range
			2005–2009	Survey	Subnational Western Denmark	Retrospective Rehabilitation-based	159	10.6	No	Yes	0–99
			2010–2012	Survey	Subnational Western Denmark	Retrospective Rehabilitation-based	76	8.3	No	Yes	0–99
			1990–2012	Survey	Subnational Western Denmark	Retrospective Rehabilitation-based	691	10.2	No	Yes	0–99
	Finland	Koskinen et al.	2012–2013	Survey	Subnational Oulu and Tampere	Prospective Population-based	77	25.1	No	Yes	0–99
		Niemi-Nikkola et al.	2007–2012	Survey	Subnational Oulu	Retrospective Hospital-based	101	36.4	No	Yes	0–99
	Ireland	Smith et al.	2010	Survey	National Ireland	Retrospective Population-based	57	12.5	No	Yes	0–99
			2011	Survey	National Ireland	Retrospective Population-based	56	12.2	No	Yes	0–99
			2012	Survey	National Ireland	Retrospective Population-based	60	13.1	No	Yes	0–99
			2013	Survey	National Ireland	Retrospective Population-based	61	13.3	No	Yes	0–99
			2014	Survey	National Ireland	Retrospective Population-based	53	11.5	No	Yes	0–99
			2015	Survey	National Ireland	Retrospective Population-based	60	12.9	No	Yes	0–99
			2010–2015	Survey	National Ireland	Retrospective Population-based	347	12.6	No	Yes	0–99
		Smith et al.	2016	Survey	National Ireland	Prospective Population-based	61	12.8	No	Yes	0–99
	Italy	Ferro et al.	2013–2014	Survey	National Italy	Prospective Population-based	445	14.7	No	Yes	0–99
		Speziali et al.	2013	Survey	Subnational Umbria	Prospective Hospital-based	19	21.4	Not available	Not available	0–99
	Netherlands	Nijendijk et al.	2010	Registry	National Netherlands	Retrospective Other	185	14	No	No	0–99
	Norway	Sabre et al.	1997–2001	Survey	Subnational Western Norway	Retrospective Population-based	71	24.9	No	Yes	0–99
		Halvorsen et al.	2012	Registry	National Norway	Cross-sectional Population-based	57	11.4	No	Yes	0–99
			2013	Registry	National Norway	Cross-sectional Population-based	60	11.9	No	Yes	0–99
			2014	Registry	National Norway	Cross-sectional Population-based	81	15.9	No	Yes	0–99
			2015	Registry	National Norway	Cross-sectional Population-based	76	14.7	No	Yes	0–99
			2016	Registry	National Norway	Cross-sectional Population-based	75	14.4	No	Yes	0–99
			2012–2016	Registry	National Norway	Cross-sectional Population-based	349	13.6	No	Yes	0–99
	United Kingdome	McCaughey et al.	1994–1998	Survey	Subnational Scotland	Retrospective Other	N/A	13.3	No	Yes	12–99
			1999–2003	Survey	Subnational Scotland	Retrospective Other	N/A	15.9	No	Yes	12–99
			2004–2008	Survey	Subnational Scotland	Retrospective Other	N/A	17.5	No	Yes	12–99
			2009–2013	Survey	Subnational Scotland	Retropective Other	N/A	17	No	Yes	12–99

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Table 2 (*continued*)

WHO region	Country	Study source	Years of study	Type	Extend	Study design	No. of patients	Incidence rate per million	Prehospital mortality Included?	ISCoS* Format Utilized?	Age range
			1994–2013	Survey	Subnational Scotland	Retrospective Other	1638	15.9	No	Yes	12–99
	Spain	Montoto-Marqués et al.	1995–2014	Survey	Subnational Galicia	Ambispective Hospital-based	1195	21.7	No	No	0–99
			1995–1999	Survey	Subnational Galicia	Ambispective Hospital-based	335	23.4	No	No	0–99
			2000–2004	Survey	Subnational Galicia	Ambispective Hospital-based	292	19.7	No	No	0–99
			2005–2009	Survey	Subnational Galicia	Ambispective Hospital-based	289	20.9	No	No	0–99
			2010–2014	Survey	Subnational Galicia	Ambispective Hospital-based	279	16.7	No	No	0–99
		Bárbara-Bataller et al.	2000–2005	Survey	Subnational Gran Canaria Islands	Retrospective Hospital-based	66	17.8	No	No	15–99
			2006–2010	Survey	Subnational Gran Canaria Islands	Retrospective Hospital-based	41	9.7	No	No	15–99
			2011–2014	Survey	Subnational Gran Canaria Islands	Retrospective Hospital-based	34	9.9	No	No	15–99
			2000–2014	Survey	Subnational Gran Canaria Islands	Retrospective Hospital-based	141	12	No	No	15–99
		Bárbara-Bataller et al.	2001–2005	Survey	Subnational Canarias region	Prospective Hospital-based	116	13	No	No	15–99
			2006–2010	Survey	Subnational Canarias region	Prospective Hospital-based	76	7.5	No	No	15–99
			2011–2015	Survey	Subnational Canarias region	Prospective Hospital-based	90	8.5	No	No	15–99
			2001–2015	Survey	Subnational Canarias region	Prospective Hospital-based	282	9.3	No	No	15–99
		Sebastia-Alcacer et al.	2001	Survey	Subnational Valenciana	Retrospective Hospital-based	31	6	No	No	0–99
			2002	Survey	Subnational Valenciana	Retrospective Hospital-based	29	5.7	No	No	0–99
			2003	Survey	Subnational Valenciana	Retrospective Hospital-based	30	5.8	No	No	0–99
			2004	Survey	Subnational Valenciana	Retrospective Hospital-based	19	3.7	No	No	0–99
			2005	Survey	Subnational Valenciana	Retrospective Hospital-based	38	7.4	No	No	0–99
			2006	Survey	Subnational Valenciana	Retrospective Hospital-based	17	3.3	No	No	0–99
			2007	Survey	Subnational Valenciana	Retrospective Hospital-based	31	6	No	No	0–99
			2008	Survey	Subnational Valenciana	Retrospective Hospital-based	23	4.5	No	No	0–99
			2009	Survey	Subnational Valenciana	Retrospective Hospital-based	19	3.7	No	No	0–99
			2010	Survey	Subnational Valenciana	Retrospective Hospital-based	24	4.7	No	No	0–99
			2001–2010	Survey	Subnational Valenciana	Retrospective Hospital-based	261	5.1	No	No	0–99
	Sweden	Joseph et al.	2014–2015	Registry	Subnational greater Stockholm	Prospective Population-based	45	19	No	Yes	18–99
	Switzerland	Chamberlain et al.	2005–2012	Registry	National Switzerland	Retrospective Population-based	932	18	No	Yes	16–99
		Chamberlain et al.	2012–2013	different data sources Registry	National Switzerland	Retrospective Other	Ranges from 231 to 621 based on case identification strategy	Ranges from 19.9 to 54.3	No	Yes	16–99
EUR B	Poland	Tederko et al.	2005–2008	Survey	Subnational Lubuskie	Retrospective Hospital-based	343	14.5	Not available	Not available	0–99
EUR C	Estonia	Sabre et al.	1997–2001	Survey	National Estonia	Retrospective Population-based	244	37.4	No	Yes	0–99
		Sabre et al.	1997–2007	Survey	National Estonia	Retrospective Population-based	595	39.4	No	Yes	0–99

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Table 2 (*continued*)

WHO region	Country	Study source	Years of study	Type	Extend	Study design	No. of patients	Incidence rate per million	Prehospital mortality Included?	ISCoS* Format Utilized?	Age range
		Sabre et al.	2005–2007	Survey	National Estonia	Retrospective Population-based	183 without PHM 391 with PHM	43.8 without PHM 93.9 With PHM	Yes	No	0–99
	Former Yugoslav Republic of Macedonia	Jakimovska et al.	2015–2016	Survey	National Former Yugoslav Republic of Macedonia	Prospective Hospital-based	38	13	No	Yes	16–99
	Iceland	Kristinsdóttir et al.	2010–2014	Survey	National Iceland	Retrospective Population-based	26	16	No	Yes	4–99
	Lithuania	Juocevicius et al.	2015	Survey	National Lithuania	Retrospective Rehabilitation-based	NA	24	No	No	18–99
	Latvia	Nulle et al.	2011	Survey	National Latvia	Retrospective Rehabilitation-based	42	21	No	Yes	16–99
			2012	Survey	National Latvia	Retrospective Rehabilitation-based	31	15.5	No	Yes	16–99
			2013	Survey	National Latvia	Retrospective Rehabilitation-based	21	10.5	No	Yes	16–99
			2014	Survey	National Latvia	Retrospective Rehabilitation-based	40	20	No	Yes	16–99
			2011–2014	Survey	National Latvia	Retrospective Rehabilitation-based	134	16.75	No	Yes	16–99
	Russia	Mirzaeva et al.	2012	Survey	Subnational Saint Petersburg	Retrospective Population-based	53	12.4	No	Yes	18–99
			2013	Survey	Subnational Saint Petersburg	Retrospective Population-based	91	21.2	No	Yes	18–99
			2014	Survey	Subnational Saint Petersburg	Retrospective Population-based	79	18	No	Yes	18–99
			2015	Survey	Subnational Saint Petersburg	Retrospective Population-based	78	17.7	No	Yes	18–99
			2016	Survey	Subnational Saint Petersburg	Retrospective Population-based	60	13.6	No	Yes	18–99
		Lobzin et al.	2012–2016	Survey	Subnational Saint Petersburg	Retrospective Population-based	361	16.6	No	Yes	18–99
WPR A	Australia	New et al.	2011	Survey and registry data	National Australia	Retrospective Other	470 or 721 based on case identification criteria	21 or 32.3	No	No	0–99
		Moorin et al.	2003–2008	Registry	Subnational Western Australia	Retrospective Population-based	335	33	No	No	0–99
		Beck et al.	2007–2016	Registry	Subnational Victoria	Retrospective Population-based	706	12.5	No	No	0–99
		Tovell & Harrison et al.	2008	Registry	National Australia	Prospective Population-based	263	14	No	No	15–99
		Tovell & Harrison et al.	2009	Registry	National Australia	Prospective Population-based	227	12.3	No	No	15–99
		Tovell & Harrison et al.	2010	Registry	National Australia	Prospective Population-based	269	14.3	No	No	15–99
		Tovell et al.	2011	Registry	National Australia	Prospective Population-based	220	10.9	No	No	15–99
		Tovell et al.	2012	Registry	National Australia	Prospective Population-based	241	12.2	No	No	15–99

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Table 2 (*continued*)

WHO region	Country	Study source	Years of study	Type	Extend	Study design	No. of patients	Incidence rate per million	Prehospital mortality Included?	ISCoS* Format Utilized?	Age range
		Tovell et al.	2013	Registry	National Australia	Prospective Population-based	236	11.8	No	No	15–99
		Tovell et al.	2014	Registry	National Australia	Prospective Population-based	264	12.8	No	No	15–99
		Tovell et al.	2015	Registry	National Australia	Prospective Population-based	253	12.1	No	No	15–99
		Tovell et al.	2016	Registry	National Australia	Prospective Population-based	227	11.1	No	No	15–99
	Japan	Katoh et al.	2011	Survey	Subnational Tokushima	Retrospective Population-based	95	121.4	No	No	16–99
			2012	Survey	Subnational Tokushima	Retrospective Population-based	91	117.1	No	No	16–99
		Kudo et al.	2012	Survey	Subnational Akita	Retrospective Hospital-based	111	104	No	No	0–99
			2013	Survey	Subnational Akita	Retrospective Hospital-based	90	86	No	No	0–99
			2014	Survey	Subnational Akita	Retrospective Hospital-based	89	86	No	No	0–99
			2015	Survey	Subnational Akita	Retrospective Hospital-based	72	70	No	No	0–99
			2016	Survey	Subnational Akita	Retrospective Hospital-based	87	86	No	No	0–99
			2012–2016	Survey	Subnational Akita	Retrospective Hospital-based	449	86	No	No	0–99
	New Zealand	Mitchell et al.	2007	Registry	National New Zealand	Ambispective Population-based	72	17.88	No	Yes	16–99
			2008	Registry	National New Zealand	Ambispective Population-based	81	20.11	No	Yes	16–99
			2009	Registry	National New Zealand	Ambispective Population-based	91	22.59	No	Yes	16–99
			2010	Registry	National New Zealand	Ambispective Population-based	89	20.98	No	Yes	16–99
			2011	Registry	National New Zealand	Ambispective Population-based	92	21.69	No	Yes	16–99
			2012	Registry	National New Zealand	Ambispective Population-based	73	17.21	No	Yes	16–99
			2013	Registry	National New Zealand	Ambispective Population-based	99	23.34	No	Yes	16–99
			2014	Registry	National New Zealand	Ambispective Population-based	91	21.45	No	Yes	16–99
			2015	Registry	National New Zealand	Ambispective Population-based	126	29.70	No	Yes	16–99
			2016	Registry	National New Zealand	Ambispective Population-based	115	27.11	No	Yes	16–99
			2007–2016	Registry	National New Zealand	Ambispective Population-based	929	22	No	Yes	16–99
WPR B	South Korea	Choi et al.	2007	Registry	National South Korea	Retrospective Population-based	1156	25.07	No	No	0–99
			2008	Registry	National South Korea	Retrospective Population-based	905	25.33	No	No	0–99
			2009	Registry	National South Korea	Retrospective Population-based	967	25.6	No	No	0–99

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Table 2 (*continued*)

WHO region	Country	Study source	Years of study	Type	Extend	Study design	No. of patients	Incidence rate per million	Prehospital mortality Included?	ISCoS* Format Utilized?	Age range
			2010	Registry	National South Korea	Retrospective Population-based	1101	25.86	No	No	0–99
			2011	Registry	National South Korea	Retrospective Population-based	1061	26.13	No	No	0–99
			2012	Registry	National South Korea	Retrospective Population-based	1004	26.4	No	No	0–99
			2013	Registry	National South Korea	Retrospective Population-based	1104	26.68	No	No	0–99
			2014	Registry	National South Korea	Retrospective Population-based	1231	26.95	No	No	0–99
			2015	Registry	National South Korea	Retrospective Population-based	1164	27.23	No	No	0–99
			2016	Registry	National South Korea	Retrospective Population-based	1285	27.52	No	No	0–99
			2017	Registry	National South Korea	Retrospective Population-based	1159	27.8	No	No	0–99
			2007–2017	Registry	National South Korea	Retrospective Population-based	12,137	26.4	No	No	0–99
N/A	Taiwan	Wu et al.	1998–2008	Registry	National Taiwan	Prospective Population-based	25,439	150.48	No	No	20–99

* ISCoS: International Spinal Cord Society.

11. African region (AFR)

In our previous systematic review[4] we could find only three papers with TSCI incidence data from Sierra Leone, South Africa and Zimbabwe. In the current review, we identified five reports from Botswana,[35] South Africa[28,29,36] and Tanzania.[30] All these reports were subnational studies.

Statistics from a single referral center in Gaborone, the capital city of Botswana showed that TSCI occurs with an estimated annual incidence of 13 cpm.[35] Results of the first prospective multicenter study in Cape Town, South Africa showed an incidence of 75.6 cpm TSCI for one year from 2013 to 2014. This study included survivors of acute TSCI who were 18 years or older in all government-funded hospitals within Cape Town.[36] Another study in same area with the same inclusion criteria but in the private sector showed a significantly lower rate in TSCI incidence compared to the government sector (20 vs 75.6 cpm).[28] Considering both sectors, the incidence of TSCI in Cape Town from 2013 to 2014 would be 61.1 cpm (95% CI 52.4–71.4). The only available study in Tanzania was a retrospective hospital-based study in northeast Tanzania region.[30] The authors reviewed case record of patients and estimated the annual incidence rate of 26 cpm (Table 2).

12. Eastern Mediterranean region (EMR)

In our previous systematic review (4) we found six papers in this region form Iran, Jordan, Kuwait, Qatar, Saudi Arabia, and Pakistan. The current study could identify two studies in this region as of 2013.[38,39] The first study[38] collected information from most (61/68) hospitals treating TSCI in Tehran, capital of Iran and the second source[39] collected information from three SCI rehabilitation centers in Khyber Pukhtunkhwa, Pakistan. The incidence rates were similar in two countries (10.5 cpm in Iran and 10.23 cpm in Pakistan) (Table 2).

13. European region (EUR)

European region includes 51 countries within three sub-region EUR A, EUR B and EUR C. In our previous systematic review[4] we could find data for 22 countries in this region. The current review identified 29 reports[2,9,40–59,67–70,73–75] from 19 countries. Five countries were found for the first time in this review including: Former Yugoslav Republic of Macedonia,[67] Czech Republic,[41] Latvia,[74] Lithuania[68] and Poland.[75] This means that data regarding TSCI incidence is now available for more than half of European countries. We could not find up-to-date reports for Turkey, Romania, Bulgaria, Portugal, Israel and Greece in this review. Most European report are population studies from trauma registries and are being updated periodically. This has brought a wealth of knowledge in this region regarding TSCI epidemiology and has helped planning preventive measures. Such knowledge has led to a decreasing/stable pattern of SCI in most countries of the region (Table 2).

14. Western pacific region (WPR)

In our previous systematic review[4] we found 23 reports from seven countries in the region including Australia, New Zealand, Japan, Fiji islands, Malaysia and Vietnam. In this review, we found 17 reports from Australia,[18–26,60–62] Japan,[64] New Zealand[17] and South Korea.[65] All of the reports from Australia and New Zealand were national registry-based studies. Annual reports of Australian Spinal Cord Registry (ASCIR) are available from 1986 to 2017. These reports compose most of available data in this region. The New Zealand SCI registry (NZSCIR) is a new SCI registry in this region established in 2016 in partnership with Praxis Spinal Cord Institute (formerly known as Rick Hansen Institute).[76] The registry contains data for both traumatic and non-traumatic SCI and has published two annual reports so far.[77,78] The South Korean study was a

retrospective population-based cohort study that sourced data from Korea's national health insurance system, which covers 98% of Korean population.[65] The registry could identify 12,137 cases in an 11-year period from 2007 to 2017. The average age-standardized incidence rate was 26.4 cpm (Table 2).

15. South East Asia Region (SEAR) and Taiwan

In our previous systematic review[4] we found only one report for SEAR region (Thailand) and three reports for Taiwan. In the current review, we found only one report for Taiwan sourced from National Health Insurance Research Database of Taiwan, covering over 99% of the Taiwanese population.[66] The incidence rate was 150.48 cpm for the period between 1998 and 2008. This is the highest reported rate from a national study to date (Table 2).

16. Discussion

TSCI is a life-changing condition that imposes a heavy economic burden on individuals, their families, and the society. Existing literature has shown that TSCI epidemiology and etiology varies between countries based on socio-economic development index; given that, transport-related injuries are generally the leading cause of SCI in developing countries whereas in developed countries falls are the main etiology.[14,79,80] Therefore, understanding epidemiology of TSCI at country-level is imperative for planning cost-effective practical preventive plans.

In our previous systematic review[4] we found 101 reports regarding TSCI incidence from 41 countries in the world by utilizing an extensive search strategy including both published and unpublished literature. In this systematic review, we repeated our search strategy up to May 5th 2020 and found 58 reports for 31 countries. This number of articles in an 8-year period (2013–2020) is more than 57% (58/101) of all papers we found previously for 78 years from 1935 to 2013. This high number of published papers implies on a trend in increasing number of papers published globally. While single center, individual series are being published from developing and low/middle-income countries around the world, European countries continue to update their knowledge periodically. This pattern of publication in part reflects the importance of infrastructure in such countries. Developed countries have established registry systems, which enables them to accurately monitor and report epidemiological data on SCI. With the advances in information technology in recent years and transformation of paper medical documents into electronic health records, now it is easier to detect and follow-up patients.

The result of our recent search lead to finding TSCI incidence data for eight new countries including Botswana, Czech Republic, Former Yugoslav Republic of Macedonia, Latvia, Lithuania, Poland, South Korea and Tanzania, which overall shapes our knowledge of TSCI for 49 countries of the world. This means that there is still a huge gap to fill if we want to draw a global map for TSCI incidence. Recently InSCI initiative[3] has been announced to provide comprehensive and comparable information about the lived experience of disability throughout an international community survey in 28 countries from all six WHO regions. Reports of 19 countries have been published to date and are available to public. We obtained information for Poland and Lithuania from these valuable reports.[68,75]

The introduction of International Spinal Cord Society (ISCoS) dataset[5,6] has provided a well-instructed data platform especially for developing countries to base their knowledge of TSCI in an evidence-based manner. Seventeen countries including all African countries in our review used ISCoS format to report TSCI. This finding is promising as it provides an international dataset for deeper analysis of TSCI in future.

Despite recent efforts to provide information regarding epidemiology of TSCI, there are some challenges to comparability of TSCI incidence rates. For example, the definition and method of case identification in TSCI was not clear in most of our retrieved reports. In addition, the International Codes of Disease (ICD-codes) used for identification of TSCI among studies were not similar. The method of case definition of studies is depicted in Table 3. On one hand, some studies exclude cauda equina cases, and on the other hand, some studies include The ASIA (American Spinal Injury Association) Impairment Scale (AIS) grade E patients as spinal cord injured patients. Use of various definitions for TSCI may lead to heterogeneity in reports. Use of sensitivity analyses based on

Table 3
TSCI case identification/ascertainment method of studies.

Reference	TSCI definition/ascertainment method
Moorin et al.	ICD-10 codes S14.0; S14.1–S14.13; S14.70–S14.78 S24.0; S24.10–S24.12; S24.70–S24.77 S34.0; S34.70–S34.76
Reports of ASCIR, Beck et al and New et al.	ICD-10 Australian modification (ICD-10-AM) S14.0, S14.10–S14.13, S14.70–S14.78 S24.0, S24.10–S24.12, S24.70–S24.77 S34.0, S34.1, S34.70–S34.76 T06.0, T06.1 and T09.03.
Majden et al.	ICD-10 codes For fatal cases: S14.0–14.2, S24.0–24.2, S34.0–34.2, S12.0–12.2, S12.7, S22.0, S22.1, S32.0, S32.1, S32.7 and T91.3. For hospital admissions: S14.0, S14.1, S24.0, S24.1, S34.0 and S34.1
Sabre et al.	ICD-10 codes: G82 S12.0, S12.1, S12.2 S12.7 S13.0, S13.2, S13.4, S14.0, S14.1 S22.0, S23.0, S23.1, S24.0, S24.1 S32.0, S33.0, S33.1 S34.0, S34.1, S34.3 T06.0, T06.1,T09.3, T91.1, T91.3
Niemi-Nikkola et al.	ICD-10 codes: S14.0, S14.1 S24.0,S24.1 S34.0,S34.1 T09.3, T91.3 Nordic Classification of Surgical Procedures codes: NAJ00, NAJ10, NAJ12, NAJ20, NAJ22, NAJ30, NAJ32, NAJ99
Mirzaeva et al and Lobzin et al.	ICD-10 codes S14.0, S14.1

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Table 3 (*continued*)

Reference	TSCI definition/ascertainment method
	S24.0, S24.1 S34.0, S34.1, S34.3
Choi et al.	ICD-10 code S14.0, S14.1 S24.0, S24.1 S34.0, S34.1
Chamberlain et al.	ICD-10 codes S14.0, S14.1 S24.0, S24.1 S34.0, S34.1, S34.3 T.060, T.061, T.093, and T91.3.
Kristinsdóttir et al and Thompson et al.	ICD-10 codes S14.X, S24.X, and S34.X ICD-9 codes 806.X and 952.X
Wu et al, Selvarajah et al, Jain et al, Lenehan et al, Selassie et al, Nijendijk et al.	ICD-9 codes 806.X and 952.X
Chamberlain et al	Did not mention ICD codes. Traumatic SCI was defined as the event of an acute traumatic lesion of neural elements in the spinal canal (spinal cord and cauda equina) that resulted in temporary or permanent sensory and/or motor deficit.
Halvorsen et al.	Did not mention ICD codes. Traumatic SCI was defined as impairment of the spinal cord or cauda equina function resulting from the application of an external force of any magnitude.
Ferro et al.	Did not mention ICD codes. A traumatic case was defined as a new hospital admission caused by an acquired traumatic lesion of the spinal cord or cauda equina, resulting in a complete or partial, transient or permanent loss of motor, sensory, bladder or bowel function below the level of the lesion, occurring in the study period
NOE et al.	Did not mention ICD codes. A traumatic case was defined as an acute, traumatic lesion of the spinal cord with varying degrees of motor and/or sensory deficit or paralysis. Injury of the cauda equina was included in the definition, but isolated injury of other nerve roots was excluded.
Mitchell et al.	Did not mention ICD codes. The NZSCIR defines SCI as impairment of the spinal cord or cauda equina function resulting in either a motor or sensory deficit or both.
Kriz et al.	Did not mention ICD codes. A traumatic case was defined as a SCI caused by external force at different levels with a persistent neurological deficit. Cauda equina injury was also included in the data set but not isolated injury of nerve roots.
Joseph et al.	Did not mention ICD codes. TSCI case was defined as: 1. abnormal imaging, such as with magnetic resonance imaging scan or multi-slice computerized tomography scan, confirming an acute TSCI or cauda equina lesion; 2. the injury must result in persisting impairment (i.e. not just a concussion) after emergence from neurogenic shock, which generally occurs within the first 24–72 h after injury
Philips et al.	Did not mention ICD codes. The presence or absence of a TSCI or quada equina syndrome was assessed by magnetic resonance imaging (MRI).
Montoto-Marqués et al.	Did not mention ICD codes. The presence or absence of a traumatic spinal injury was assessed by means of the conduct of a computerized tomography (CT) scan and magnetic resonance imaging (MRI) and was classified as follows: absence of an injury, fracture, dislocation, fracture-dislocation and others.
Sebastia-Alcacer et al.	Did not mention ICD codes. The presence or absence of a TSCI was assessed by magnetic resonance imaging (MRI). Patients with cauda equina were excluded.
Kudo et al.	Did not mention ICD codes. TSCI was defined as "an acute traumatic lesion of the neural elements in the spinal canal, resulting in temporary or permanent sensory deficit, motor deficit, or bowel/bladder dysfunction" The presence or absence of a TSCI was assessed by magnetic resonance imaging (MRI).
Bárbara-Bataller et al, Bilal et al, Jakimovska et al, Joseph et al, Katoh et al Koskinen et al, Löfvenmark et al, McCaughey et al, Moshi et al, Nulle et al, Sharif-Alhoseini et al, Smith et al, Pefile et al	Did not mention ICD codes or definition of TSCI.

reasonable classification criteria can aid in offering a uniform set of case identification and ascertainment criteria for TSCI.

There are also challenges to depict the true incidence of TSCI. Rehabilitation-based studies are prone to coverage bias based on the non-participation rate of patients in rehabilitation programs. This is shown in Swiss Spinal Cord Injury (SwiSCI) cohort study by comparing electronically collected administrative hospital-discharge data to SwiSCI data, which is sourced from rehabilitation centers.[58] The difference in incidence of SCI was remarkable (19.9 cpm from SwiSCI study vs 54.3 cpm from hospital-discharge data). Moreover, New et al in Australia also showed the same issue.[60] They estimated TSCI incidence using two different population-based hospital discharge data in Australia. They reported a lower 21 cpm and an upper 32.3 cpm incidence rate of TSCI in 2011. The lower estimate came from adult patients admitted to rehabilitation units in Australia during 2006 and pediatric patients admitted to the only pediatric trauma hospital in Victoria between 2000 and 2010, while the upper limit was based on a population-based dataset of all patients discharged from Australian hospitals between July 1st, 1999 and June 30th, 2011. The authors believe that the numbers reported in ASCIR are underestimated. Even the lower estimate was near 30% higher than the Australian Spinal Cord Injury Registry report for 2011.[23,60]

Another issue in underestimation of the true incidence of SCI is inclusion of patients who die at the scene of injury or during acute hospitalization. Sabre et al have demonstrated the impact of including

prehospital mortality on the true incidence rate of TSCI.[9] They recruited medical and autopsy reports of all hospitals in Estonia during 2005–2007 along with the data from Estonian Forensic Science Institute. The impact was striking; TSCI incidence including prehospital mortality was more than two times when they exclude the prehospital fatalities (97.0 cpm compared to 43.8 cpm). Similar studies with notable but less significant differences have been conducted in the US (Mississippi, Minnesota, and Utah),[81–83] Canada (Alberta),[34] Portugal,[84] and Austria.[40] Overall, only sixstudies have included prehospital deaths in their reports of TSCI.[9,34,40,81,82,83]

The incidence of TSCI in our previous review ranged from 3.6 to 195.4 cpm from two subnational studies from Canada and Ireland, respectively.[4] If we consider only national studies after 2000, the incidence of TSCI would range between 8.3 cpm in Denmark[42] to 150.5 cpm in Taiwan.[66]

17. Conclusion

This study showed that there is major heterogeneity in the identification and report of spinal cord injury among studies. We suggest that future studies clearly report the inclusion or exclusion of patients with cauda equina, AIS E, and prehospital deaths when reporting TSCI incidence. Furthermore, the exact set of ICD codes should be reported accordingly. We found that the mostly shared ICD codes among studies are S14.0, S14.1, S24.0, S24.1, S34.0, and S34.1 for ICD-10 and 806.X and 952.X for ICD-9 codes. Future studies can use this series of ICD codes in order to minimize the heterogeneity in the definition of TSCI. We also suggest using the ISCoS data platform when recording data for patients with TSCI.

Developing countries lack a central organization in registry or report of TSCI and may consider working along with internationally known institutions in designing registries, data reporting templates, and form regional collaborations to overcome the difficulties in data standardization and reporting in TSCI literature. The absence of a standard form of reporting TSCI hinders the comparability of data across different data sources. It is necessary to understand that the incidence rates reported as numbers are not easily comparable due to differences in TSCI definition, identification methods, and different study scales.

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Credit Author Statement

Seyed Behnam Jazayeri: Conceptualization, Methodology, Writing - original draft. **Seyed Farzad Maroufi:** Formal analysis, Investigation, Validation. **Esmaeil Mohammadi:** Methodology, Writing - original draft. **Mohammad Amin Dabbagh Ohadi:** Investigation, Visualisation. **Ellen-Merete Hagen:** Writing - Review & Editing. **Maryam Chalangari:** Investigation, Visualisation. **Seyed Behzad Jazayeri:** Conceptualization, Writing - Review & Editing. **Mahdi Safdarian:** Investigation, Validation. **Shayan Abdollah Zadegan:** Investigation, Validation. **Zahra Ghodsi:** Project administration. **Vafa Rahimi-Movaghar:** Conceptualization, Supervision

Declaration of competing interest

None.

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Appendix A. Supplementary data

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