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REVIEW ARTICLE

Epidemiology of spinal cord injury in China: A systematic review of the chinese and english literature

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STUDY DESIGN: Systematic review.
OBJECTIVES: We aimed to provide a comprehensive overview of the English and Chinese literature reporting epidemiological data on spinal cord injury (SCI) in China.
METHODS: 3 English and 3 Chinese language electronic databases were searched from the earliest record to 15 March 2020. Sociodemographic characteristics, incidence rates, etiology and lesion characteristics, in-hospital mortality, and secondary health conditions and complications were extracted from included reports.
RESULTS: A total of 51 studies were included, 32 in the Chinese language. Forty-seven studies were based on hospital records. Mean age of incident cases ranged from 34 to 55 years and male-to-female ratios ranged from 0.35:1 to 15.3:1. SCI incidence varied from 14.6 to 60.6 per million. Thirty-five studies reported only on traumatic SCI with traffic accidents, high falls, low falls and being hit by objects being the most common causes. Specific causes for non-traumatic SCI were poorly reported. Proportions with tetraplegia and complete injury ranged from 37.4% to 82.0% and 14.1% to 73.9%, respectively. Reported in-hospital mortality attributed to SCI varied from 1.1% to 18.4%. Leading cause of in-hospital mortality for acute SCI was respiratory problems; respiratory problems, urinary tract infections and pressure sores were the most common complications.
CONCLUSION: Epidemiological data on SCI in China are only available for a limited number of provinces and mostly outdated. Updated data on incidence with accurate geographical information and etiology across all Chinese provinces are needed for targeted implementation of preventive strategies. Research on community outcomes needs to be developed in China.

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INTRODUCTION

Regularly updated epidemiological data on spinal cord injury (SCI) are important for tracing case numbers and causes, identifying prevention targets and risk factors for poor health outcomes or premature mortality after onset, as well as for public health and clinical resource allocation [1–4]. More specifically, having sound data on the epidemiology of SCI enables the optimization of targeted preventive interventions as well as the development of rehabilitation services and ultimately health policy planning. China is an interesting case for studying the epidemiology of SCI because of its rapid economic growth, urbanization, and an aging population. Growth in private car ownership and in traffic volume since early 2000 has led to a significant increase in traffic accidents [5]. This likely impacts on traumatic SCI incidence. Moreover, population ageing has led to an increase in non-communicable diseases and disability, with an increase in non-traumatic SCI being a possible consequence [6].

Two systematic reviews of the epidemiology of SCI in China have been conducted. Yuan and colleagues [7] reviewed 17 studies published until January 2018 and Chen and colleagues [8] reviewed 32 studies from January 1978 to August 2017. Both reviews used narrow inclusion criteria. Yuan and colleagues restricted their review to four cities and four provinces, including only publications in English, while Chen and colleagues solely reviewed studies that focused on the treatment costs of traumatic SCI and ignored other data. A non-systematic, narrative review by Reinhardt and colleagues [9] on epidemiological data solely covered the English literature as indexed in PubMed up to 2016.

The present study aims to address these gaps by systematically reviewing the English and Chinese literature reporting epidemiological data on SCI in China, extracting data on study methodology, demographic and injury characteristics, incidence and prevalence rates; and outcomes including in-hospital mortality, and secondary health conditions and complications.

METHODS

Design

This is a systematic review of the literature.

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Eligibility criteria

We included original articles written in Chinese or English that reported epidemiological data on: (1) demographic characteristics of the studied SCI populations; (2) incidence and/or prevalence estimates; (3) injury characteristics; and/or (4) outcomes including in-hospital mortality for incident SCI as well as readmissions and secondary health conditions and complications for traumatic or non-traumatic SCI in China. As a minimum requirement, included studies needed to report on patient source and sample size, age and gender, and basic etiology of SCI (traumatic vs. non-traumatic). Included were only studies that reported data for defined populations/cohorts based on hospital records or population-based registries and surveys. No restrictions regarding year of publication were imposed.

Studies on populations with spinal fractures that did not report separate data for those with SCI, those focusing on a specific etiology such as traffic accidents or neoplasms, or on a specific lesion type (complete or incomplete only) or lesion level (paraplegia or tetraplegia only) were also ineligible. If studies reported the same data in Chinese and English, the English language version was selected for data extraction. Comments, reviews, proceedings, conference abstracts, case reports, letters and editorials were excluded

Retrieval of records and search strategy

We searched the following databases for original peer-reviewed studies from the earliest record to 15 March 2020: Web of Science, PubMed, Embase, Wan Fang Data, China Science and Technology Journal Database (VIP) and China National Knowledge Infrastructure Database (CNKI). The search strategy combined relevant epidemiological terms and terms related to SCI in a free text search of all fields of database records, with the exception of PubMed where the search was restricted to title and abstract as otherwise too many irrelevant records were retrieved. An example for Embase was: ((“spinal cord” or “spinal cord injury” or “paraplegia” or “tetraplegia”) and (“epidemiology” or “incidence” or “etiology” or “prevalence”) and “China”). The full search strategy can be found in the Supplementary Appendix (Table S1). In order to capture all relevant reports, the reference lists of all included studies and relevant systematic reviews were also screened.

Study selection

All references from the six electronic databases were uploaded into EndNote (X9), and duplicates removed. Two authors (CC and WL) independently screened titles and abstracts based on the eligibility criteria. Full texts of relevant articles were then obtained, and both of the reviewers assessed these independently for eligibility. Conflicts were resolved by discussion among the reviewers, or where necessary by involvement of a third researcher (JR).

Data extraction and synthesis

Two authors (CC, and WL or XQ) independently completed data extraction. For each study, we extracted the following data into an Excel spreadsheet: (1) basic study characteristics, including first author, region of study, study period, data source (e.g. hospital records, database of community organization), case type (incident vs. prevalent), and sample size; (2) sample demographics: age range, mean age, modal age group, male-female ratio, employment status and type of occupation if employed; (3) incidence and prevalence estimates; (4) lesion characteristics: etiology, lesion level and severity; (5) duration of inpatient hospitalization (for hospital-based studies, separated by acute vs. rehabilitation and first admissions vs. readmissions if this information was available), secondary health conditions and complications (occurrence and leading cause), and in-hospital mortality (rate and leading cause).

Data were synthesized narratively using a synthesis without meta-analysis (SWiM) [10] approach.

Quality assessment

Quality assessment was performed by two authors (CC and WL) using the Appraisal tool for Cross-Sectional Studies (AXIS tool) [11]. The AXIS tool has 20 items (see Supplementary Appendix Table S2) that relate to the overall quality of reporting (7 items), study design (7 items), and sources of bias (6 items). Items were summed, with higher scores (range 0–20) indicating better quality.

RESULTS

The study selection process is presented in Fig. 1. The initial database search yielded 1,108 records, with 386 from Web of Science, 55 from PubMed, 300 from Embase, 237 from Wan Fang Data, 55 from VIP and 77 from CNKI. Five additional records were identified from reference lists of papers included in full text review as well as the three previous reviews [7–9].

Study characteristics

Fifty-one relevant studies (*1–*51, see Supplementary Appendix for the reference list) were identified; their general characteristics are detailed in Table 1. Quality scores ranged from 5 to 17 (Median: 14, IQR: 13–15); details are given in Supplementary Appendix (Table S3). Regarding sources of bias, only 3 studies reported measures used to address non-responders/missing data and less than half of the studies (20) discussed the limitations of the study.

Forty-eight (94%) studies were based on reviews of hospital records, two were based on information from community surveys, and one extracted information from a database of a community organization providing services to people with SCI. Thirty-five studies reported on incident cases (all based on admissions to hospital with new SCI in a given period), three studies reported on prevalent cases, and for 13 studies this was unclear. Of the three studies reporting on prevalent cases, two were community surveys: one (Chan *1) was based on samples of people with SCI registered as outpatients at various rehabilitation centers or as users of a community resource center in Hong Kong (average time since injury 13.3 years, (standard deviation [SD] 10) and the other one (Wang *30) reports results from a mailed survey of members of a Taiwanese SCI patient organization and users of community-based outpatient rehabilitation centers with a range of time since SCI from 6 months to over 10 years (no average given). The third study (Chang *2) analyzed data on people with SCI who had received services from community-based outpatient rehabilitation centers. These data were extracted from the management system of the Disabled Persons Federation of Shanghai (time from injury to service 12.8, SD 10.6). Epidemiological data reported covered the period from 1978 to 2017; only one study from Hong Kong (Chan *1) did not report the study period. Maximum sample size was 3,832, and minimum was 35. The data were from 21 provinces, representing a total of 956 million population (census 2010): Tianjin, Guangxi, Guangdong, Shanxi, Fujian, Beijing, Jilin, Shaanxi, Liaoning, Hunan, Hubei, Jiangsu, Shanghai, Chongqing, Heilongjiang, Taiwan, Sichuan, Guizhou, Shandong, Hong Kong and Anhui. Over 50% of the studies investigated SCI populations from only five provinces/cities, namely: Tianjin (10 studies), Beijing (6 studies), Shanghai, Guangdong, and Shanxi (4 studies from each). Three studies did not report the geographical area of data collection. No studies were found for 13 provinces: Xinjiang, Tibet, Gansu, Qinghai, Neimenggu (inner Mongolia), Henan, Hebei, Yunnan, Jiangxi, Hainan, Macao, Zhejiang and Ningxia (Fig. 2), representing a population of 407 million (census 2010).

Demographic characteristics

Of the studies included in this review, one reported on children only (Wang *32) and one on elderly persons only (Yu *48). When we exclude these two studies, the mean age of incident cases investigated ranged from 34–54 years, and the mean age of

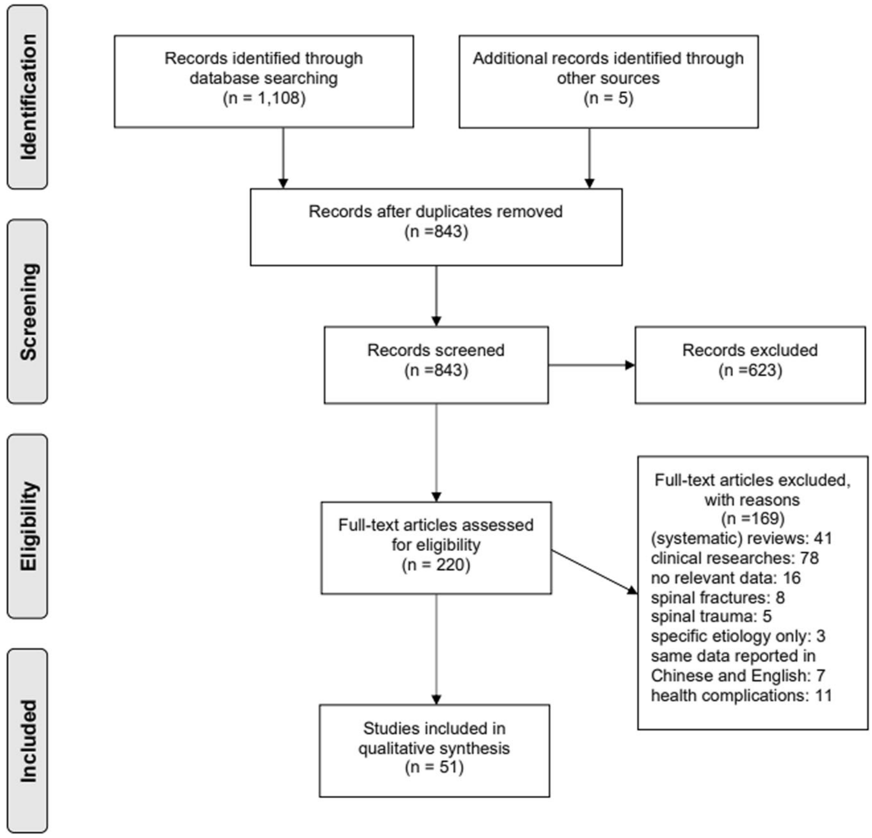

Fig. 1 Flow diagram of study selection in the review. Adapted from Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).

prevalent cases was 45.2 years. Ten studies did not report details on the age range. The largest age group in most studies comprised people aged 30–60 years; only three studies (Jiao *34, Feng *12, Chen *3) reported that the largest age group was under 30 years. A study from Beijing (Wang *32) reported the lowest male-to-female ratio (0.35:1) and a study from Shanxi (Jiang *18) the highest (15.3:1). There were only two studies in which the male-to-female ratio was below 1, the one from Beijing (0.35:1) (Wang *32) and one from Sichuan (0.94:1) (Liu *23). Twelve articles reported on the rate of people with SCI who were not employed at injury which ranged from under one (Yang *43) to 87% (Wang *30). Studies showed a high proportion of persons not in employment before 2010, which declined in 2010-2014 and was lowest in the last five years (2015-2019) (Table 2). Less than half of the studies reported on the type of occupation of people with SCI who were employed at the time of the injury. The most common occupational groups were unskilled worker and small farmers/ farmhands.

Incidence and prevalence

Incidence rates, that is the number of cases with new SCI in a defined area during a specific time period divided by the total population at risk during the same time period, were reported in nine studies (see Table 2, Fig. 2). Incidence rates for traumatic SCI varied from 14.6 per million per year in Taiwan in 1985 (Chen *3) to 60.6 per million per year in Beijing in 2002 (Li *21). Only one study drew on data collected after 2010 (Ru *28), and only one study conducted in 2005 (Wei *34) included non-traumatic SCI. The latter study estimated the combined incidence rate for both traumatic and non-traumatic SCI but did not provide numbers for the etiology subgroups. An increasing trend in incidence rates over time was found in two studies from Taiwan (Chen *3, Chen *4) and two from Tianjin (Ning *24, Yu *46). Two studies from Beijing conducted at different time points (Li *21, Wei *34) showed similar incidence rates. However, the latter study (Wei *34) also included an unspecified proportion with non-traumatic SCI (Fig. 2).

Prevalence rates were not reported in any study.

Injury characteristics: Etiology, lesion level and lesion severity

Thirty-five (69%) studies reported on traumatic SCI only and 16 studies on both traumatic and non-traumatic SCI; none of the studies focused on non-traumatic SCI only. In the studies reporting on both traumatic and non-traumatic SCI, only three (18%) reported proportions for different etiologies; traumatic SCI accounted for 58% (Chang *2), 72% (Yuan *50), and 90% (Wei *34), respectively. Modal age groups (average age was only reported by Wei *34) differed between those studies; the younger the modal age group was, the higher was the reported proportion of traumatic SCI. Trauma was the leading cause of SCI among those aged 16–60 years, while non-traumatic causes were more common in people who were older. The following specific causes were reported for traumatic SCI in at least one of the reviewed studies (Table 2): traffic accidents, falls at ground level (low falls), falls from a height (high falls), crush injury (mostly resulting from falling objects), work-related injury, sport-related injury, and surgical complications. Among these causes, traffic accidents, high falls, low falls and being hit by falling objects were the leading causes in all reports apart from one 2012 study from Shanxi (Jiang *19) which listed coal mine work-related injuries as the most frequent cause of SCI, and one 2000 report from Hong Kong (Chan *1) which noted that work-related injuries and surgical complications were the most common causes. Specific causes for non-traumatic SCI were not reported in any study.

Twelve studies (Chan *1, Chen *3, Chen *8, Feng *13, Li *22, Ning *24, Ning *25, Ru *28, Wang *30, Yang *41, Yi *44, Zhou *51) reported on lesion level and lesion severity, while 16 studies (Chang *2, Chen *5, Chen *6, Hao *14, Hua *16, Huang *17, Jiang

Table 1. Description of the studies included in the systematic review.

Study	Overall study quality	Language	Province/ city	Study period	Source	Case type	Sample size	SCI type	Incidence rate estimate	Mortality	Etiology	Lesion characteristics	SHC and complications	Occupation
Chan *1	14	EN	Hong Kong	NR	Hospital (multiple) and community	Prevalent (community survey of registered outpatients and members of community organization)	66	Both			√	√		√
Chang *2	16	EN	Shanghai	2009–2015	Community	Prevalent (extracted from records of Disabled Persons Federation)	808	Both			√	√	√	
Chen *3	13	EN	Taiwan	1978–1981	Hospital (multiple)	Incident (new admissions)	560	TSCI	√	√	√	√		
Chen *4	14	EN	Taiwan	1992–1996	Hospital (multiple)	Incident (new admissions)	1586	TSCI	√				√	
Chen *5	7	CN	Shandong	2002–2007	Hospital (single)	NR	251	TSCI			√	√		
Chen *6	13	CN	Guangdong	1996–2010	Hospital (single)	Incident (follow-up of just discharged cases)	286	Both		√	√	√	√	√
Chen *7	12	CN	Guizhou	2012–2015	Hospital (single)	Incident (follow-up of just discharged cases)	50	Both						
Chen *8	15	EN	Heilongjiang	2009–2013	Hospital (multiple)	NR	232	TSCI			√	√		√
Chen *9	14	CN	Shanghai	2010–2016	Hospital (single)	Incident (new admissions)	109	TSCI		√	√		√	√
Cheng *10	15	CN	Shanghai	1997–2007	Hospital (single)	Incident (new admissions)	676	Both			√			
Deng *11	14	CN	Hubei	2012–2014	Hospital (single)	Incident (new admissions)	424	Both			√			
Feng *12	6	CN	Jiangsu	1991	Hospital (multiple)	Incident (new admissions)	35	TSCI	√		√			√
Feng *13	15	EN	Tianjin	1998–2009	Hospital (single)	Incident (new admissions)	239	TSCI		√	√	√		√
Hao *14	14	CN	Beijing	1992–2006	Hospital (single)	NR	1264	Both			√	√	√	
Hao *15	14	CN	Shaanxi	2011–2013	Hospital (single)	Incident (new admissions)	2565	TSCI			√		√	√
Hua *16	15	EN	Not reported	2001–2010	Hospital (multiple)	Incident (new admissions)	561	TSCI			√	√		
Huang *17	14	CN	Guangdong	2012–2016	Hospital (single)	NR	397	Both			√	√	√	
Jiang *18	14	CN	Shanxi	2002–2011	Hospital (single)	Incident (new admissions)	423	TSCI		√	√	√	√	√
Jiang *19	12	CN	Shanxi	2000–2010	Hospital (single)	Incident (new admissions)	327	TSCI		√	√		√	
Jiao *20	15	CN	Tianjin	2004–2008	Hospital (multiple)	Incident (new admissions)	553	TSCI		√	√		√	√
Li *21	15	EN	Beijing	2002	Hospital (multiple)	Incident (new admissions)	264	TSCI	√		√			√
Li *22	16	EN	Tianjin	1999–2016	Hospital (single)	NR	735	TSCI		√	√	√		√
Liu *23	9	CN	Sichuan	2008	Hospital (single)	Incident (new admissions)	35	Both			√	√		
Ning *24	13	EN	Tianjin	2004–2008	Hospital (multiple)	Incident (new admissions)	869	TSCI	√	√	√	√		
Ning *25	14	EN	Chongqing	2009–2013	Hospital (single)	Incident (new admissions)	554	TSCI			√	√	√	√
Niu *26	14	CN	Jiangsu	2009–2014	Hospital (multiple)	NR	859	Both			√	√	√	√

Table 1. continued

Study	Overall study quality	Language	Province/city	Study period	Source	Case type	Sample size	SCI type	Incidence rate estimate	Mortality	Etiology	Lesion characteristics	SHC and complications	Occupation
Pan *27	13	CN	Shanghai	2005–2007	Hospital (multiple)	Incident (new admissions)	200	TSCI	√		√			√
Ru *28	15	CN	Liaoning	2010–2012	Hospital (multiple)	Incident (new admissions)	1155	TSCI	√	√	√	√	√	
Tang *29	14	CN	Guangxi	2006–2010	Hospital (single)	Incident (new admissions)	221	TSCI			√		√	√
Wang *30	14	EN	Taiwan	1999	Community	Prevalent (community survey of members of SCI association and clients of community-based rehabilitation centers)	91	Both			√	√	√	√
Wang *31	13	EN	Anhui	2007–2010	Hospital (multiple)	NR	761	TSCI			√			
Wang *32	14	CN	Beijing	2005–2014	Hospital (single)	Incident (new admissions)	120	TSCI			√	√	√	
Wang *33	15	CN	Beijing	2012–2015	Hospital (single)	Incident (new admissions)	625	TSCI			√		√	√
Wei *34	15	CN	Beijing	2005	Hospital (multiple)	Incident (new admissions)	254	Both	√		√	√	√	√
Wu *35	14	EN	Tianjin	2008–2011	Hospital (single)	NR	143	TSCI		√	√		√	√
Wu *36	16	EN	Tianjin	2004–2007	Hospital (multiple)	Incident (new admissions)	631	TSCI			√		√	
Xu *37	13	CN	Jilin	2010–2011	Hospital (single)	Incident (new admissions)	1274	TSCI			√			
Xu *38	14	CN	Guangxi	2012–2017	Hospital (single)	Incident (new admissions)	385	TSCI		√	√		√	√
Yang *39	14	CN	Shanxi	2008–2011	Hospital (multiple)	Incident (new admissions)	76	TSCI			√	√		
Yang *40	15	EN	Guangdong	2003–2011	Hospital (multiple)	Incident (new admissions)	3832	Both			√	√	√	√
Yang *41	14	CN	Fujian	2004–2014	Hospital (single)	Incident (new admissions)	1089	Both		√	√	√	√	√
Yang *42	14	CN	Beijing	2009–2014	Hospital (single)	NR	1027	Both		√	√		√	
Yang *43	17	EN	Guangdong	2003–2011	Hospital (multiple)	Incident (new admissions)	1340	TSCI		√	√	√	√	√
Yi *44	17	CN	Hunan	2012–2014	Hospital (multiple)	NR	261	TSCI			√	√	√	√
Yu *45	14	CN	Tianjin	1998–2008	Hospital (single)	Incident (new admissions)	216	TSCI		√	√		√	
Yu *46	14	CN	Tianjin	2007	Hospital (multiple)	Incident (new admissions)	73	TSCI	√	√	√	√	√	
Yu *47	14	CN	Tianjin	2004–2008	Hospital (multiple)	Incident (new admissions)	102	TSCI			√	√		√
Yu *48	14	CN	Not reported	2004–2008	Hospital (single)	NR	138	TSCI			√			
Yu *49	9	CN	Not reported	2004–2010	Hospital (single)	NR	518	TSCI			√			
Yuan *50	5	CN	Shanxi	2011–2014	Hospital (single)	NR	58	Both			√	√	√	
Zhou *51	15	EN	Tianjin	2009–2014	Hospital (single)	Incident (new admissions)	354	TSCI		√	√	√	√	√

CN Chinese, *EN* English, single or multiple, the studies based on hospital records indicated if these were single or multiple hospitals, *TSCI* Traumatic spinal cord injury, Both, traumatic and non-traumatic spinal cord injury; √, reported in the study, *NR* Not reported, *SHC* Secondary health conditions.

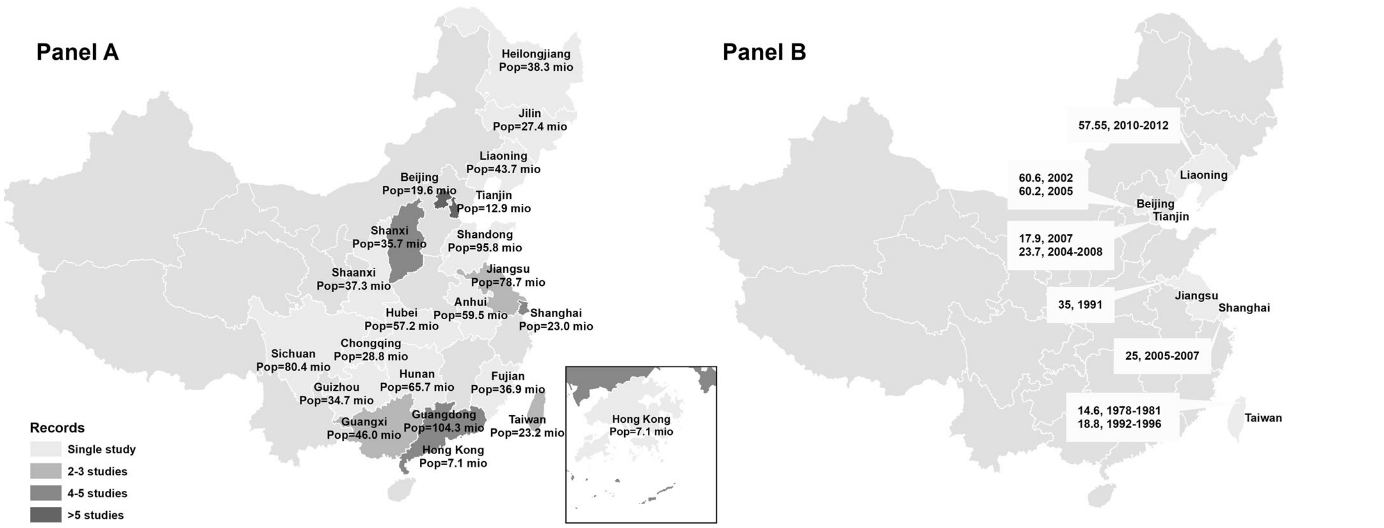

Fig. 2 Map of SCI research across China. The figure shows the distribution of studies (**A**) and reported SCI incidence (**B**) across various provinces and territories of China. The numbers of studies from each province and SCI incidence in each province of China where data was available are presented in these two maps of China highlighting the relevant provinces and cities and using shading to indicate the number of studies reporting relevant data. Pop Population size, mio Million.

*18, Niu *26, Wang *32, Wei *34, Yang *39, Yang *40, Yang *43, Yu *46, Yu *47, Yuan *50) reported only on lesion severity. The proportion with tetraplegia was higher than that with paraplegia in nine studies (Chen *8, Feng *13, Li *22, Ning *24, Ning *25, Ru *28, Yang *41, Yi *44, Zhou *51), while three studies (Chan *1, Chen *3, Wang *30) reported the opposite.

In-hospital mortality and complications

Eleven studies (21.6%) reported the average length of stay in the hospital, all for a first admissions for acute SCI; the duration ranged from 13.7 to 100 days. Two studies (Chen *3, Chen *4) reported length of stay by lesion level and lesion severity. In both, length of stay was longest for people with complete tetraplegia. Reported in-hospital mortality attributed to SCI in studies of incident cases varied from 1.1% (Yang *41) to 18.4% (Chen *9); 31 studies did not provide mortality figures. A comparison of eight studies conducted in Tianjin from 2010 to 2019 and two performed in Guangdong in 2011 and 2017 shows decreasing in-hospital mortality. Eighteen studies (35%) reported the leading cause of death, which were respiratory problems in all studies except one from Tianjin conducted in 2016 (Zhou *51). (Table 3).

Most studies reported a high occurrence of secondary health conditions and complications, ranging from 25 to 88% in studies of prevalent cases and from 6 to 97% in studies of incident cases. Only two studies reported a rate of secondary health conditions and complications below 10%, one from Liaoning performed in 2014 (Ru *28) (8%) and one from Tianjin performed in 2016 (6%) (Zhou *51). In the 25 studies that reported on the occurrence of complications in hospital, on average 26% of the patients treated experienced any complications (weighted by sample size; 95% confidence interval: 19% to 34%). The three most common complications were respiratory problems, urinary tract infections and pressure sores. In the only study (Wang *30) that reported on secondary health conditions and complications in community-dwelling persons with SCI, prevalence was 88% with urinary tract infections, pain, and pressure ulcers being the most frequent conditions (Table 3).

DISCUSSION

This systematic review provides an update on the epidemiology of SCI in China, and is the first that includes epidemiological data from all provinces of China, where available. We reviewed 51 studies from 21 provinces; none reported national epidemiological data. Notably, the absence of any research related to SCI epidemiology in 13 provinces and cities with provincial status, and the existence of a single study only from another 13 provinces severely limits the derivation of epidemiological data for the entire country. This issue is even more severe when it comes to estimates of incidence rates, with relevant data being available only for six out of 34 provinces/territories and cities (Fig. 2). In addition, data are outdated: only one study reported on incidence rates after 2010. While the number of studies conducted in different provinces roughly reflects economic development, with more studies conducted in the better developed east and south of China, it is unclear why epidemiological research on SCI, and in particular attempts to estimate SCI incidence, have significantly declined in the last decade. One possible explanation is the increased competitiveness of research grants in China over the last decade, with studies solely reviewing hospital records generally not funded any longer.

The range of incidence rates for SCI reported in the studies was similar to estimates from a previous systematic review focusing on the Asian region [12] that found incidence rates for traumatic SCI ranging between 12.06 and 61.6 per million persons; the range was slightly lower than figures from North America (27.1 to 83.0 per million) [13]. However, incidence rates were only estimated for traumatic SCI, and only one study from Liaoning (Ru *28) was available from the last decade. At time of writing, data on the prevalence and incidence of non-traumatic SCI had not been collected in China.

A trend towards an increasing age at SCI was seen when comparing studies from the same province conducted at different time points, most likely owing to population ageing. In our review, there were significant gender and occupational differences between reports, with a higher proportion of men than of women incurring SCI, and a higher proportion of small farmers/farmhands and unskilled workers than of other occupational groups. High male-to-female ratios in traumatic SCI are well known from previous reviews [7, 14]. One possible reason for this finding in China is that men are more likely to work in high-risk occupations such as taxi or truck driver, construction worker or miner. For example, one report from Shanxi (Jiang *19) studied patients with SCI who had been working in coal mines and reported the highest

Table 2. Demographic characteristics, incidence rates, and injury characteristics of included study populations.

Study	Age (years)			Male to female ratio	Unemployed (%)	Main occupational groups[a]	Incidence (per million)	Etiology (main causes)[b]	Lesion level		Lesion severity	
	Age range	Mean age	Modal age group						Paraplegia (%)	Tetraplegia (%)	Complete (%)	Incomplete (%)
Chan *1	NR	45.2	NR	4	77.3	NR	NR	Work-related (29.0%), disease (29.0%), surgical complications (21.0%)	57.6	42.4	56.1	43.9
Chang *2	NR	NR	46–60	2.08	NR	NR	NR	Traumatic injury (58.0%), non-traumatic causes (42.0%)	NR	NR	46.7	53.3
Chen *3	NR	NR	20–29	4.89	NR	NR	14.6	Traffic accidents (44.5%), low and high falls (28.5%), hit by objects (14.6%)	53.2	46.8	58	42
Chen *4	NR	46.1	25–34	3.01	NR	NR	18.8	NR	NR	NR	NR	NR
Chen *5	18–89	40.4	30–50	3.48	NR	NR	NR	High falls (38.6%), traffic accidents (29.1%), low falls (19.1%)	NR	NR	27.1	72.9
Chen *6	6–72	36.3	30–39	7.41	NR	Worker, peasant, technician	NR	High falls (35.7%), traffic accidents (31.1%), hit by objects (19.2%)	NR	NR	61.2	38.8
Chen *7	22–58	38	NR	1.5	NR	NR	NR	NR	NR	NR	NR	NR
Chen *8	18–82	45.4	46–60	4.04	NR	Peasant, retired, civil servant	NR	Traffic accidents (42.7%), low falls (22.4%), high falls (13.8%)	23.7	76.3	18.1	81.9
Chen *9	NR	53.7	60–69	8.08	NR	Retired, peasant, worker	NR	Traffic accident (41.3%), low falls (20.2%), work-related (15.6%)	NR	NR	NR	NR
Cheng *10	2–92	42.2	30–39	1.74	NR	NR	NR	Low falls (53.6%), traffic accidents (28.4%), hit by objects (10.8%)	NR	NR	NR	NR
Deng *11	3–80	46.5	40–49	2.03	NR	NR	NR	High falls (42.0%), traffic accidents (27.6%), low falls (20.1%)	NR	NR	NR	NR
Feng *12	20–68	33.9	20–30	7.75	NR	Peasant, worker	35	High falls (62.9%), traffic accidents (11.4%), hit by objects (14.3%)	NR	NR	NR	NR
Feng *13	NR	45.4	45–54	4.21	48.5	Peasant, worker, retired	NR	Traffic accidents (36.4%), low falls (35.2%), high falls (16.7%)	18	82	28.5	71.5
Hao *14	1–83	34.9	30–39	3.98	NR	NR	NR	Traffic accidents (44.3%), high falls (21.8%), hit by objects (14.2%)	NR	NR	56.7	43.3
Hao *15	20–87	41.5	30–49	4.7	NR	Peasant, worker	NR	Low falls (37.8%), high falls (29.4%), traffic accidents (22.5%)	NR	NR	NR	NR
Hua *16	0–67	34.7	NR	4.1	NR	NR	NR	Traffic accident (51.2%), high falls (23.9%), tamping (8.6%)	NR	NR	49.9	50.1
Huang *17	3–82	40.1	40–49	3.96	NR	NR	NR	High falls (31.7%), traffic accidents (22.9%), hit by objects (14.6%)	NR	NR	14.1	85.9
Jiang *18	15–80	40	30–39	15.3	NR	Coal miner, peasant	NR	Work-related (61.7%), high falls (13.2%), traffic accidents (9.5%)	NR	NR	45.4	54.6
Jiang *19	15–60	40	30–39	All male	NR	NR	NR	Coal mine work-related (100%)	NR	NR	NR	NR
Jiao *20	11–90	48	≥50	6.57	7.2	Worker, peasant, office clerks	NR	Traffic accidents (37.6%), low falls (36.0%), high falls (15.7%)	NR	NR	NR	NR
Li *21	6–80	41.7	30–39	3.13	NR	Peasant, worker	60.6	High falls (41.3%), traffic accidents (22.3%), stroke by objects (18.6%)	NR	NR	NR	NR
Li *22	≥15	49.7	45–59	2.91	27.1	Peasant, worker, retired	NR	Traffic accidents (36.9%%), low falls (55.2%), stroke by objects (3.9%)	32.1	67.9	23.7	76.3
Liu *23	14–73	38	NR	0.94	NR	NR	NR	Hit by objects (74.3%), high falls (22.9%)	NR	NR	42.9	57.1
Ning *24	16–90	46	46–60	5.63	NR	NR	23.7	Low falls (37.6%), traffic accidents (34.1%), high falls (19.3%)	28.4	71.6	25.2	74.8
Ning *25	4–81	45.6	31–45	4.33	24.2	Peasant, worker, office clerks	NR	High falls (50.9%), traffic accidents (21.8%), hit by objects (13.4%)	45.1	54.9	39.3	60.7
Niu *26	10–85	47.5	40–49	2.41	NR	Worker, peasant	NR	High falls (27.0%), traffic accidents (19.4%), myelitis (12.3%)	NR	NR	19.4	80.6
Pan *27[a]	14–87	44.5	NR	2.85	NR	Worker, office clerks, peasant	25	High falls (NR), traffic accidents (NR), accidental injury (NR)	NR	NR	NR	NR
Ru *28	3–89	50.1	41–50	2.42	NR	NR	57.55	Traffic accidents (32.5%), low falls (28.1%), high falls (22.6%)	41	59	14.6	85.4
Tang *29	12–73	38.3	30–39	6.37	NR	Peasant, worker, self-employed	NR	Traffic accidents (38.0%), high falls (21.7%), crush injury (12.7%)	NR	NR	NR	NR

Table 2. continued

Study	Age (years)			Male to female ratio	Unemployed (%)	Main occupational groups[a]	Incidence (per million)	Etiology (main causes)[b]	Lesion level		Lesion severity	
	Age range	Mean age	Modal age group						Paraplegia (%)	Tetraplegia (%)	Complete (%)	Incomplete (%)
Wang *30	NR	NR	30–39	5.07	86.8	NR	NR	Traffic accidents (48.4%), low falls (19.8%), hit by objects (7.7%)	62.6	37.4	29.7	70.3
Wang *31	5–87	45	31–45	3.4	NR	Peasant, worker, civil servant	NR	High falls (52.6%), traffic accidents (21.2%), low falls (12.7%)	NR	NR	NR	NR
Wang *32	0–13	NR	NR	0.35	NR	NR	NR	Sports-related (50.0%), traffic accidents (29.2%), high falls (5.8%)	NR	NR	73.9	26.1
Wang *33	3–83	38.2	40–49	4.53	NR	Worker, peasant, student	NR	High falls (40.8%), traffic accidents (28.6%), hit by objects (15.2%)	NR	NR	NR	NR
Wei *34[c]	NR	41	21–30	2.34	43.7	Civil servant, peasant, office clerks	60.2	Traumatic causes (90.2%), non-traumatic causes (9.8%)	NR	NR	35.8	46.9
Wu *35	18–87	54.6	55–64	4.96	NR	Peasant, retired, worker	NR	Low falls (49.7%), traffic accidents (36.4%), stroke by objects (4.9%)	NR	NR	NR	NR
Wu *36	NR	NR	46–60	5.71	NR	NR	NR	Low falls (38.7%), traffic accidents (34.4%), high falls (17.9%)	NR	NR	NR	NR
Xu *37	5–87	43.6	40–49	2.32	NR	NR	NR	Accident injury (79.0%), traffic accidents (8.8%), high falls (6.6%)	NR	NR	NR	NR
Xu *38	2–82	47.9	45–54	4.42	4.9	Peasant, worker, retired	NR	High falls (34.3%), traffic accidents (30.9%), low falls (29.4%),	NR	NR	NR	NR
Yang *39	24–78	46.7	NR	4.43	NR	NR	NR	Traffic accidents (40.8%), high falls (26.3%), low falls (19.7%)	NR	NR	32.9	67.1
Yang *40	1–94	42.4	41–60	3.08	13.9	Worker, peasant, retired	NR	Traffic accidents (21.7%), hit by objects (19.5%), crush injury (15.1%)	NR	NR	17.7	82.3
Yang *41	16–87	44.7	40–49	3.54	NR	Peasant, worker, driver	NR	High falls (39.4%), traffic accident (32.2%), low falls (12.3%)	28.5	71.5	32.6	67.4
Yang *42	4–83	42.5	NR	3.58	NR	NR	NR	Traffic accident (31.3%), high falls (28.0%), hit by objects (14.0%)	NR	NR	NR	NR
Yang *43	1–84	41.6	41–60	3.5	0.75	Student, peasant, teacher	NR	High falls (41.0%), traffic accidents (37.8%), hit by objects (8.8%)	NR	NR	26.4	73.6
Yi *44	16–79	53.8	50–59	1.12	NR	Worker, peasant, student	NR	Low falls (33.7%), traffic accidents (29.5%), high falls (21.1%)	45.2	54.8	21.5	78.5
Yu *45	7–84	44.8	41–50	4.68	NR	NR	NR	Traffic accidents (37.5%), low falls (22.2%), tumble (16.2%)	NR	NR	NR	NR
Yu *46	21–87	51.3	40–59	3.56	NR	NR	17.9	Low falls (50.7%), traffic accidents (35.6%), high falls (5.5%)	NR	NR	26.4	72.6
Yu *47	15–75	37.6	31–45	4.67	49	Peasant, worker	NR	High falls (39.2%), traffic accidents (33.3%), hit by objects (13.7%)	NR	NR	57.8	42.2
Yu *48	60–90	67.8	NR	3.76	NR	NR	NR	Low falls (56.5%), traffic accidents (32.6%), high falls (5.1%)	NR	NR	NR	NR
Yu *49	18–90	50.8	NR	6.73	NR	NR	NR	Low falls (50.4%), traffic accidents (27.4%), high falls (5.6%)	NR	NR	NR	NR
Yuan *50	NR	NR	15–45	3.83	NR	NR	NR	Traumatic causes (72.42%), non-traumatic causes (27.58%)	NR	NR	65.5	34.5
Zhou *51	15–85	50.1	46–60	2.34	16.9	Peasant, worker, retired	NR	Traffic accident (35.9%), low falls (33.6%), high falls (21.5%)	32.8	67.2	20.9	79.1

[a]The three most frequently reported occupations are displayed. [b]The three most frequent causes are displayed. [c]Did not report specific data on etiology. *NR* Not reported.

Table 3. Length of hospital stay, in-hospital mortality and secondary health conditions and complications in included study populations.

Study	Average length of stay (days)	In-hospital mortality		Secondary health conditions and complications	
		Rate (%)	Leading cause	Occurrence (%)	Main complications
Chan *1	NR	NR	NR	NR	NR
Chang *2	NR	NR	NR	24.5	NR
Chen *3	Incomplete paraplegia 44 Complete paraplegia 81 Incomplete tetraplegia 90 Complete tetraplegia 100	6.0	Respiratory problems	NR	NR
Chen *4	Incomplete paraplegia 37 Complete paraplegia 47 Incomplete tetraplegia 58 Complete tetraplegia 67	6.6	NR	NR	Bladder dysfunction, urinary tract infections, pressure sores
Chen *5	NR	2.4	NR	NR	NR
Chen *6	NR	16.8	Respiratory problems	96.5	Urinary tract infections, respiratory problems, pain
Chen *7	NR	NR	NR	NR	NR
Chen *8	NR	NR	NR	NR	NR
Chen *9	NR	18.4	Respiratory problems	NR	Electrolyte disturbances, respiratory problems, pressure sores
Cheng *10	NR	NR	NR	NR	NR
Deng *11	NR	NR	NR	NR	NR
Feng *12	NR	NR	NR	NR	NR
Feng *13	NR	3.4	Respiratory problems	NR	NR
Hao *14	NR	NR	NR	28.9	Urinary tract infections, pressure sores, bladder dysfunction
Hao *15	NR	NR	NR	36.5	Respiratory problems, hyponatremia, pressure sores
Hua *16	NR	NR	NR	NR	NR
Huang *17	NR	NR	NR	46.1	Urinary tract infections, pressure sores, bladder dysfunction
Jiang *18	NR	2.1	Respiratory problems	18.4	Urinary tract infections, pressure sores, respiratory problems
Jiang *19	39	2.8	Respiratory problems	23.9	Urinary tract infections, pressure sores, respiratory problems
Jiao *20	23.2	4.0	Respiratory problems	28.2	Respiratory problems, cardiovascular diseases, electrolyte disturbances
Li *21	18.9	NR	NR	NR	NR
Li *22	NR	1.8	Respiratory problems	NR	NR
Liu *23	NR	NR	NR	NR	NR
Ning *24	NR	1.9	Respiratory problems	NR	NR
Ning *25	28.3	NR	NR	12.6	Respiratory problems, pressure sores, electrolyte disturbances
Niu *26	NR	NR	NR	33.2	Urinary tract infections, respiratory problems, pressure sores
Pan *27	NR	NR	NR	NR	NR
Ru *28	NR	1.8	Respiratory problems	8.4	Respiratory problems, electrolyte disturbances, pressure sores
Tang *29	NR	NR	NR	55.7	Urinary tract infections, pressure sores, respiratory problems
Wang *30	NR	NR	NR	87.9	Urinary tract infections, pain, pressure sores
Wang *31	17	NR	NR	NR	NR
Wang *32	NR	NR	NR	59.2	Urinary tract infections, bladder dysfunction, pressure sores

Table 3. continued

Study	Average length of stay (days)	In-hospital mortality		Secondary health conditions and complications	
		Rate (%)	Leading cause	Occurrence (%)	Main complications
Wang *33	NR	NR	NR	28.5	Pressure sores, respiratory problems
Wei *34	NR	NR	NR	NR	Bowel dysfunction, muscle spasms, urinary tract infections
Wu *35	NR	4.2	Respiratory problems	50.3	Hyponatremia, urinary tract infections, respiratory problems
Wu *36	32.4	NR	NR	22.0	Respiratory problems, urinary tract infections, hyponatremia
Xu *37	NR	NR	NR	NR	NR
Xu *38	26.5	2.6	Respiratory problems	73.8	Respiratory problems, urinary tract infections, pressure sores
Yang *39	NR	NR	NR	NR	NR
Yang *40	NR	NR	NR	12.8	Respiratory problems, urinary tract infections, pressure sores
Yang *41	NR	1.1	Respiratory problems	16.6	Respiratory problems, urinary tract infections, pressure sores
Yang *42	NR	6.5	Respiratory problems	21.4	Pressure sores, respiratory problems, urinary tract infections
Yang *43	46.8	1.4	Respiratory problems	25.1	Respiratory problems, urinary tract infections, pressure sores
Yi *44	13.7	NR	NR	72.4	Respiratory problems, urinary tract infections, electrolyte disturbances
Yu *45	NR	2.3	Respiratory problems	NR	Respiratory problems, electrolyte disturbances, urinary tract infections
Yu *46	NR	8.2	Respiratory problems	30.1	Respiratory problems, urinary tract infections, electrolyte disturbances
Yu *47	NR	NR	NR	NR	Respiratory problems, urinary tract infections, pressure sores
Yu *48	NR	NR	NR	NR	NR
Yu *49	NR	NR	NR	NR	NR
Yuan *50	NR	NR	NR	NR	Sexual dysfunction, bladder dysfunction, pain
Zhou *51	NR	1.7	Multiple organ failure	6.2	Respiratory problems, urinary tract infections, pressure sores

Only the leading mortality cause and the three most frequent secondary health conditions and complications are displayed. *NR* Not reported.

male to female ratio. Insufficient safety provisions at work, unsafe transportation such as motorcycles and motorized tricycles and limited affordability of health care for treatment of non-traumatic conditions that may cause spinal cord lesions may be responsible for higher rates of SCI in peasants and unskilled workers. Efforts of the government of the People's Republic of China to improve safety at work and on the road need to be intensified.

In the current study, traffic accidents and falls (including high falls and low falls) were the main causes of SCI, a finding already reported by earlier reviews [7, 9]. Increasing numbers of private cars and an increase in traffic volume due to urbanization may be important contributors to traffic-related injuries. Lack of safety on construction sites (Jiang *19) and an increasing numbers of suicide attempts [15] may play important roles in high falls. In contrast, low falls are more common in the elderly. Low falls may have become more pronounced due to a growing number of elderly people in China who live alone and not within the household of their children as it traditionally was the case. Being hit by falling objects is a cause we do not frequently see in other countries with data on SCI etiology. This type of mechanism may result from natural disasters (e.g., earthquakes and storms) but also from construction and mining accidents. It is further of note that studies including cases with non-traumatic SCI did not report any specific etiology. As a result, non-traumatic SCI in China remains a largely unknown issue.

Only a few studies reported on hospital mortality and an unknown number of patients with SCI may have died on site or while being transported toa hospital.

One consequence of increased survival after SCI is the high number of reported complications. We found that respiratory problems, urinary tract infections and pressure sores were the main complications, which is consistent with results from other countries and underlines the global importance of research into the prevention and treatment of these conditions after the onset of SCI [16, 17]. However, we observed striking differences in the prevalence of secondary health conditions and complications across studies (ranging from 97% [Chen *6] to below 10% [Ru *28, Zhou *51]). It remains therefore unclear whether the data are comparable as it is highly likely that secondary conditions and complications were defined and assessed differently in these studies.

Several limitations of this review should be noted. First, our search strategy did not specify medical subject headings (MeSH) and the PubMed search was limited to the title and abstract only. This strategy was chosen to avoid the retrieval of too many irrelevant records. In contrast to studies with a primary epidemiological purpose which were likely to be captured by our search, we may have missed studies that had another main focus but nevertheless reported relevant epidemiological data. Second, most studies were reviews of hospital records and community-based research was very limited, making it impossible to draw any conclusions about community outcomes. However, hospital records might allow for more reliable conclusions, as non-response bias is less of concern than in community-based studies. Third, time series data are lacking and any time trends reported here are based on a comparison of cross-sectional studies from the same province conducted at different time points, often employing different methodology. This makes it impossible to disentangle longitudinal developments from variations in the selection of samples and the methodology used. Fourth, epidemiological data on SCI were variably defined in the included studies, for example with regard to level and completeness or lesion, precluding meta-analysis. It is desirable that future studies adhere to common data collection standards such as the international SCI Core Data Set [18], ICF (International Classification of Functioning, Disability and Health) Core Sets for SCI [19], and those suggested by the IPSCI (International Perspectives on Spinal Cord Injury) [20] to enable better comparability between studies.

CONCLUSIONS

Epidemiological data on SCI in China are sparse, especially for incidence, and are non-existent for prevalence. The available data were mostly extracted from hospital records and community studies were limited. Research has mainly concentrated on a few better-resourced provinces in the East and South of China, and for unknown reasons interest in the epidemiology of SCI seems to have declined in the past decades. As SCI is oftentimes preventable, epidemiological data on incidence with accurate geographical information and etiology across all Chinese provinces is a necessary requirement for a targeted implementation of preventive strategies. To this end, better collaboration between units for SCI rehabilitation and university-level public health institutes and governmental public health departments such as the Chinese Center for Disease Control and Prevention is suggested. Furthermore, SCI is not a death sentence and living a full life with SCI in the community is possible; to promote the latter, research on community outcomes and related factors needs to be developed in China. We hope that this review can serve as a wake-up call for all stakeholders involved in SCI prevention, treatment, rehabilitation, and support in China.

DATA AVAILABILITY

All data generated or analyzed during this study are included in this published article and its supplementary information files.

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AUTHOR CONTRIBUTIONS

CC wrote the first draft of this manuscript and JR, WL, and CF revised the manuscript for important intellectual content. CC and WL contributed in literature search, screening and data extraction; CC, XQ, WL, CF and JR designed the study and analyzed and interpreted the data and wrote the manuscript; CC, XQ, CF, WL, and JR have approved the submitted version of the manuscript. Each author had participated sufficiently in the work to take public responsibility for appropriate portions of the content.

COMPETING INTERESTS

The authors declare no competing interests.

ADDITIONAL INFORMATION

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