PharmacoEconomics - Open (2024) 8:793–808
https://doi.org/10.1007/s41669-024-00517-3

SYSTEMATIC REVIEW

A Systematic Review of the Impact of Spinal Cord Injury on Costs and Health-Related Quality of Life

Modou Diop[1] · David Epstein[2]

Accepted: 28 July 2024 / Published online: 16 August 2024

Abstract

Objective To systematically review the health-related quality of life (HRQoL) burden and costs of spinal cord injury (SCI) on health services, patients and wider society.

Methods A systematic review guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Statement was conducted in March 2021 through Scopus, PubMed and Embase databases. Inclusion criteria were quantitative studies on SCI reporting healthcare costs, social costs and/or HRQoL measured with the Euroqol EQ-5D or Short-Form 36. Risk of bias was assessed using the QualSyst tool. Descriptive analyses, random-effects direct meta-analysis and random-effects meta-regression were conducted.

Results A total of 67 studies were eligible for inclusion. SCI individuals tend to report higher HRQoL in mental than physical dimensions of the Short-Form 36. Neurological level of SCI negatively affects HRQoL. Cross-sectional studies find employment is associated with better HRQoL, but the effect is not observed in longitudinal studies. The estimated lifetime expenditure per individual with SCI ranged from US$0.7 million to US$2.5 million, with greater costs associated with earlier age at injury, neurological level, United States of America healthcare setting and the inclusion of non-healthcare items in the study.

Conclusions SCI is associated with low HRQoL on mobility and physical dimensions. Mental health scores tend to be greater than physical scores, and most dimensions of HRQoL appear to improve over time, at least over the first year. SCI is associated with high costs which vary by country.

Clinical Trials Registration This review was registered in PROSPERO (registration number: CRD42021235801).

Key Points for Decision Makers

Spinal cord injury is associated with low quality of life (QoL) on mobility and physical dimensions. Mental health scores tend to be higher than physical scores.

The severity of spinal cord injury (SCI) impact negatively on quality of life and positively on healthcare costs.

The lifetime costs associated with SCI are substantial and vary by country.

✉ Modou Diop
modou.diop@psemail.eu

[1] Hospinnomics (Paris School of Economics & Assistance Publique - Hôpitaux de Paris), Hôtel Dieu 1 Parvis Notre-Dame, 75004 Paris, France

[2] Department of Applied Economics, University of Granada, Granada, Spain

1 Introduction

Spinal cord injury (SCI), with an annual incidence of between 250,000 and 500,000 people worldwide [1], is a serious medical condition with important functional, psychological and socioeconomic consequences on patients and their families and a substantial burden on the medical and social care system [2]. Medical advances in recent years have improved the life expectancy of people with SCI [3]. However, treating and caring for people with SCI represents a substantial challenge aggravated by the severity of injury, the occurrence in younger people, loss of employment and the need for family members to give up their time to provide informal care [4].

Comparison between studies of costs and quality of life (QoL) of people with SCI needs to be undertaken cautiously. Studies differ in the resource items included. Some studies focus on 'direct' costs related to use of health services, while others may include 'indirect' cost (the broader opportunity costs of SCI on other persons

and sectors, such as families, carers, loss of productivity, the education sector and so on). Measurement of health service unit costs can be influenced by the type of health system, price levels, accounting practices and severity of the condition [5]. Effective treatment of SCI often requires specialist health and social care, but these can, of course, only be accessed by the user if such services are available near to where the person lives. Countries will differ in the quality and quantity of relevant services on offer, and whether paid from insurance or if patients are expected to contribute financially out of pocket [6]. Likewise, QoL, as well as depending on the severity and duration of the injury itself, will also be influenced by the circumstances in which people grow, live, work and age and the resources and infrastructure in place to help them live with their disability [7]. QoL will be influenced by not only the person's neurological impairment but also their perception of wellbeing, which may be conditioned by attitudes and prejudices of society at large towards people with disabilities [8]. Indeed, 'cost' and 'QoL' for SCI will be jointly determined to some extent by wider social and cultural factors beyond the influence of the healthcare service.

The interpretation of the evidence will also depend on the study design. Broadly, two types of primary study (that collect data from individuals) are prevalent in this area: cross-sectional surveys and longitudinal cohort studies. Cross-sectional surveys can explore associations between variables, but comparisons may be confounded by unobserved factors, and these studies cannot make any statements about cause and effect. Prospective longitudinal studies can show trends over time and can control to some extent for observed and unobserved variables at baseline but may be confounded by unobserved factors that change over time. For example, if a longitudinal study finds that people who obtain employment after the injury have better QoL, it is unclear whether gaining employment benefited the person's wellbeing or whether both employment opportunities and gains in QoL arose from an improvement in the underlying health condition. Results of studies will only be representative of the prevalent population with SCI if they have deliberately sampled with this aim, and this also needs to be borne in mind when comparing outcomes.

Furthermore, a wide range of measures for assessing QoL has been used in literature [9]. França et al. [10] measured QoL among SCI population using the WHO-QOL-BREF questionnaire. The authors reported that psychological health and social relationship domains tended to score higher than environmental and physical health. A prospective longitudinal study of patients from Northern India [11] found that Global QoL tended to increase 6 months from the time of injury. Kalyani et al. [12] employed the Ferrans and Powers quality of life questionnaire in Sri Lanka and found higher scores for the family and social/economic dimensions than health/functioning and psychological dimensions. Clayton et al. [13], using the life situation survey (LSS), found that patients with greater disability tended to report better QoL, though this may be a bias of the cross-sectional study design.

Given these uncertainties, there is a need for a comprehensive quantitative synthesis of previous research. Other systematic reviews on SCI have focused on specific interventions, outcomes (costs or QoL), population or regions. Bagnall et al. [14], reviewed spinal fixation surgery and steroids for SCI. Malekzadeh et al. [15] examined direct (that is, health service) costs per hospitalisation unit associated with SCI or traumatic SCI and found that annual cost ranged from US$32,240 to US$1,156,400, with variation between countries arising from differences of the components of cost, time horizon, level and severity of injury and the health system structure. However, this review excluded individuals who were not hospitalised. Furlan et al. [16] found the cost of spinal cord injury during the acute phase and initial rehabilitation among war veterans to range from US$30,770 to US$62,563 per year, generally greater than the costs of other chronic diseases. However, they did not review data beyond the acute phase. Dalvand et al. [17] found that people with SCI in Iran reported half the HRQoL score on the SF-36 physical dimension compared with the general population. Ku [18] conducted a narrative review of SF-36 but did not carry out evidence synthesis of these data. Bokaye et al. [19] noted the biases associated with cross-sectional studies and the lack of longitudinal studies limited any conclusions that could be drawn from their data. Hence, there is a need for a comprehensive systematic review of the burden of SCI on affected individuals, families, healthcare systems and wider society.

A systematic review can identify broad trends in the data from diverse sources, bring together evidence about components and drivers of variation in costs and HRQoL and assess the degree of consensus across studies. The burden of a serious chronic condition such as SCI encompasses multiple dimensions. The quality of life (QoL) of the affected individual is of primary importance. Furthermore, SCI also represents a financial burden on families, health systems and social care [20]. There is also an opportunity cost in terms of the potential lost contribution of the individual (and unpaid carers) to the labour force (often termed indirect costs). This type of quantitative evidence on QoL and impact on families, care systems and wider society is essential information to estimate the long-term benefits and costs of potential interventions and policies to prevent, treat or provide care

for people with SCI. An example which motivated this study is the ongoing PAPAARTIS clinical trial [21], which aims to prevent SCI arising as a complication of surgery.

The objective of this work is to provide a comprehensive systematic review of costs following SCI and health-related quality of life (HRQoL), measured by SF-36 or EQ-5D, accompanied by quantitative evidence synthesis (meta-analysis) where appropriate.

2 Methods

2.1 Registration of Protocol

A systematic review was conducted and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [22]. The protocol was previously registered in the International Prospective Register of Systematic Reviews (CRD42021235801).

2.2 Eligibility Criteria

The inclusion criteria for articles included in the review were as follows: (1) quantitative studies published in English, Spanish, Italian and French; (2) selected condition (SCI population); and (3) original research with primary data. Given the wide variety of instruments to measure QoL in SCI and to facilitate evidence synthesis across studies, outcomes of costs and/or HRQoL measured with the Euroqol EQ5D [23] or Short-form 36 instruments [24, 25]. These are the most common HRQoL tools used in health economic evaluation [26]. The SF-36 measures two distinct physical and mental dimensions of HRQoL, each consisting of four subscales. The physical component summary (PCS) of HRQoL includes the subscales of physical functioning (PF), physical role (PR), bodily pain (BP) and general health (GH). The mental component summary (MCS) includes the subscales of vitality (V), social role (SR), emotional role (ER) and mental health (MH). The EQ-5D assesses five dimensions of HRQoL (mobility, self-care, usual activities, pain/discomfort and anxiety/depression) on a scale with three levels (EQ-5D-3L) or five levels (EQ-5D-5L). Overall health (where 1 is the best possible HRQoL and 0 represents a HRQoL equivalent to death) is scored using a published algorithm specific for each country [27], known as the EQ-5D tariff. No publication date limits were applied. Exclusion criteria were (1) studies that focused on specific health or other needs related to SCI condition such as diagnosed mental illness etc. and (2) studies of specialised interventions to prevent, treat or care for SCI. Hence, randomised controlled trials of SCI interventions were excluded. There were no age limits applied to participant studies.

2.3 Search Terms and Databases

The search was conducted through Scopus, PubMed and Embase databases during March 2021. Search filters were grouped into four broad categories: costs of healthcare, impact on home living and families, employment and income and QoL (Supplementary Table S1).

2.4 Study Selection

Studies were selected in a sequential process (see Fig. 1). Phase I identified articles that had the search terms in their title, abstract or keywords. Phase II eliminated duplicates in the different search sequences, or in more than one database. In phase III, two researchers (M.D. and D.E.) screened studies by title and abstract and classified publications according to whether they address the research questions. Phase IV involved obtaining and independently reading the full text of selected studies by M.D. and D.E. In phase V, the final selection of included articles was made by the two authors by discussion and agreement. Study quality criteria were assessed, and data were extracted.

2.5 Data Collection Process and Data Items

Excel spreadsheets were used to extract data from the included studies. M.D. conducted the data collection process. The mean and standard deviation (SD) of each SF-36 domain and for the EQ-5D tariff was extracted from cross-sectional studies and from longitudinal studies at baseline and each follow-up. We were also interested in the factors associated with HRQoL, such as severity of injury (current neurological level and American Impairment Scale [AIS] score, Supplementary Material), age at date of accident, current age, current marital status, current employment status, time since injury and time spent in hospital. Where studies used regression or similar statistical analysis to estimate the association between HRQoL domains and other factors, the coefficients (or odds ratio) and level of statistical significance (p value) were extracted.

The mean and SD of healthcare (direct) costs was extracted and classified as hospital (surgical procedures, intensive care unit or other), nursing home and rehabilitation. We also extracted the mean and SD of non-healthcare (indirect) costs and classified as adaptions to home, productivity losses arising from loss of employment or sick leave or premature death, payments for carers and informal care (opportunity cost of unpaid carer time). We also classified whether costs were estimated from a societal perspective or not. Local currency was updated to 2023 using the Consumer Price Index (CPI) for each respective country and

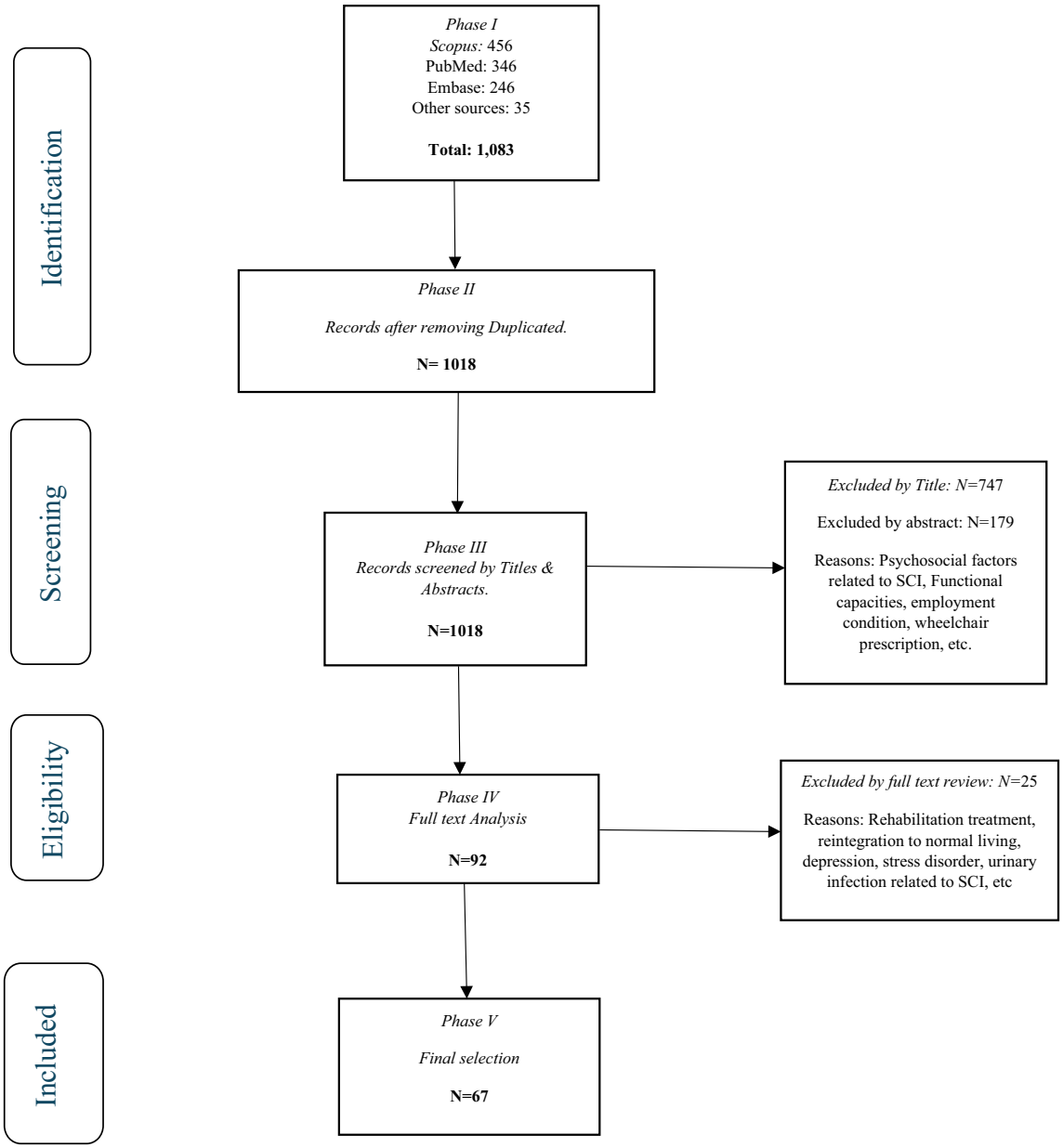

Fig. 1 Prisma

subsequently converted into international dollars ($) at purchasing power parity [28]. The type of study was classified as cross-sectional or longitudinal (for studies that collected primary data) or a mathematical model. Models are used to predict mean cost over the lifetime of a hypothetical cohort, based on aggregate data from the literature on the age distribution of people with SCI, the life expectancy for each age group and the average yearly cost of treating and caring for SCI [29].

2.6 Risk of Bias in Individual Studies

The overall quality of the studies was assessed by one author using the 14 criteria (Supplementary Table S3) of the 'QualSyst' tool (Alberta Heritage Foundation for Medical Research) [30]. The 14 criteria were scored depending on the degree to which the specific criterion was met ('yes' is 2, 'partial' is 1 and 'no' is 0). Criteria not applicable to study design were marked 'n/a' and excluded from the calculation of the summary score. A summary score was calculated for

Table 1 Short-Form 36 health-related quality of life cross-sectional studies

	Mean (†)	95% Confidence interval (†)		Range of means between studies	Heterogeneity (†)		Number of studies (number of subgroups)
		Lower	Upper		I^2	*p*-Value	
High income country							
Physical functioning	23.55	19.9	27.02	(16.1–42.5)	5.6	0.4	12 (14)
Physical role	40.1	27.34	54.41	(19.6–74.4)	71	0	11 (12)
Bodily pain	56,93	50.06	62.03	(39–68)	32.2	0.13	11 (12)
General health	52.8	46.14	59.45	(42.23–69.7)	50.4	0.02	11 (12)
Physical component score	32.97	27.26	38.68	(28.7–34.1)	0	0.87	5 (6)
Emotional role	59.37	42.78	75.97	(31.4–90)	82.3	0	11 (12)
Vitality	46.68	43.3	50.07	(42.9–61.4)	0	0.5	11 (12)
Mental health	61.23	52.69	69.77	(44.3–80.3)	67	0	11 (12)
Social role	55.94	47.92	63.95	(38.7–85.4)	45	0.04	11 (12)
Mental component score	55.11	49.85	69.87	(49.7–58.8)	0	0.98	5 (6)
Middle income country							
Physical functioning	27.62	17.05	38.18	(10–61.2)	58.7	0	11 (15)
Physical role	42.33	32.67	51.99	(20–70.5)	0	0.97	11 (15)
Bodily pain	52.72	45.91	59.54	(37.64–77)	0	0.9	11 (15)
General health	54.2	46.87	61.53	(39–64)	0	1	11 (15)
Physical component score	46.93	31.73	62.13	(31.75–65.2)	0	0.78	3 (5)
Emotional role	50.75	37.45	64.06	(29–74.1)	0	0.99	11 (15)
Vitality	59.1	49.8	68.39	(42–73)	0	0.98	11 (15)
Mental health	54.03	53.44	54.62	(50–85.4)	0	0.93	11 (15)
Social role	58.69	46.92	70.45	(38–83.5)	0	0.9	11 (15)
Mental component score	63.79	48.19	79.4	(50–78.6)	0	0.62	3 (5)

†Estimated by random effects meta-analysis, see Supplementary Material. High-income countries are defined as those with a gross national income per capita of US$12,536 or more, whereas middle-income countries are those falling within the range of US$1036 to US$12,535 based on the World Bank classification

each paper by summing the total score obtained across relevant items and dividing by the total possible score.

2.7 Statistical Analysis

HRQoL data were analysed using descriptive analyses (tabulation), random-effects direct meta-analysis (MA) and random-effects meta-regression [31]. Mean HRQoL was tabulated for cross-sectional studies and for longitudinal studies at each time point. The factors associated with HRQoL were tabulated and graphical analyses were carried using 'graph bar' command in STATA 15 to show the number of studies that reported a positive association or better score when two categories were compared, a negative association or worse score when two categories were compared or no significant association between HRQoL and the factor.

Synthesis of mean HRQoL across cross-sectional studies was conducted using MA, stratified by low-, middle- and high-income countries as defined by the World Health Organisation [32]. Meta-regression analyses explore sources of variation in mean HRQoL and were used when heterogeneity was moderate or high in MA ($I^2 > 25\%$) [33]. Meta-regression analyses were conducted separately for the following variables where data were reasonably complete: mean time since injury, proportion of study sample in employment and proportion of study sample who were paraplegic (rather than tetraplegic). Other variables were not employed because they were not reported in the majority of studies. MA and meta-regression analyses were implemented using the 'metan' and 'metareg' command in STATA 15. MA was not carried out for longitudinal studies as there were few such studies, and outcomes were reported in different formats that precluded quantitative synthesis.

Descriptive graphical analyses of mean costs estimate in primary studies were carried using the 'ggplot' command in R, showing the association of mean costs with the length of follow-up, country, cost items included and neurological level of SCI. Mean lifetime costs per person estimated by modelling studies were tabulated, along with a description of the main sources of input data in each case. Given the differences in study design and reporting, MA was not considered feasible for costs.

Table 2 Mean health-related quality of life and factors associated with health-related quality of life in longitudinal studies

Authors	Population	HRQoL	Baseline	1st year	2nd year	5th year	Δ Year 1 – baseline	Δ Year 2 – baseline
2a. Mean (Standard deviation) health-related quality of life in longitudinal studies								
		SF-36						
Schwartz et al. 2018 [66]	All SCI	Physical functioning		31.7 (30.3)	34.1 (31.1)	30.8 (29)		
		Physical role		40 (31.5)	45.4 (31.1)	46.6 (32.5)		
		Emotional role		69.7 (32.1)	70 (30.4)	71.5 (32)		
		Vitality		51.5 (20)	53 (19.1)	51 (20.2)		
		Mental health		69.1 (19.1)	69.5 (18.6)	69.1 (20)		
		Bodily pain		55.8 (25.7)	57.8 (25.4)	56.1 (27.3)		
		Social role		62.4 (26.7)	65.7 (25.2)	64.7 (26.3)		
		General health		61.5 (21.8)	58.6 (21.7)	59.2 (21.1)		
Lucke et al. 2004 [77]	All SCI	Physical functioning		19.3 (28.9)				
		Physical role		46.4 (41.9)				
		Emotional role		42.9 (41.7)				
		Vitality		55.7 (9.3)				
		Mental health		75.4 (11.4)				
		Bodily pain		59 (29)				
		Social role		73.2 (19.7)				
		General health		65 (18.4)				
		Physical component score		33.3 (12.5)				
		Mental component score		51.8 (8)				
2b. Factors associated with health-related quality of life in longitudinal studies								
		EQ5D, proportion of people reporting problems (a score not equal to 1)						
Paul et al. 2013 [42]	SCI with compensation	Problems of mobility	92.6%	80.2%	70.4%		− 12.4%	− 22.2%
		Problems of self-care	66.1%	53.5%	44.3%		− 12.6	− 21.8%
		Problems of usual activity	90.4%	81.9%	78.4%		− 8.5%	− 12%
		Problems of pain	86.8%	81.8%	77.3%		− 5%	− 9.5%
		Problems of anxiety/depression	50%	37.4%	31.8%		− 12.6%	− 18.2%
	SCI without compensation	Problems of mobility	97%	78%	84%		− 19%	− 13%
		Problems of self-care	65%	52.5%	38%		− 12.5%	− 27%
		Problems of usual activity	90%	96%	76%		6%	− 14%
		Problems of pain	88.6%	98%	78,3%		9.4%	− 10.3
		Problems of anxiety/depression	49%	57%	30.8%		8%	− 18.2%
		SF-36						

Table 2 (continued)

Authors	Population	HRQoL	Baseline	1st year	2nd year	5th year	Δ Year 1 – baseline	Δ Year 2 – baseline
Cotner et al. 2018 [55]	SCI for people with competitively gained employment during the study	Mental component score	56.8 (13.9)	59.9 (9.8)	59.2 (10.6)		3.1	2.4
		Physical component score	30.6 (9.1)	32.6 (9.5)	32.2 (9.8)		2	1.6
	SCI for people without competitive employment	Mental component score	56.7 (11.4)	57.5 (10.7)	56.6 (9.6)		0.8	−0.1
		Physical component score	26.5 (7.7)	29.1 (8)	28.9 (8.2)	]	2.6	2.4[a]
Richard-Denis et al., 2018 [44]	SCI with AIS grade[†] A compared with SCI with AIS grade[†] D	Mental component score		3.2[*] (0.1 to 6.2)				
		Physical component score		−7.1[*] (−9.5 to −4.6				
	SCI with AIS grade[†] B compared with SCI with AIS grade[†] D	Mental component score		1.4[*] (−2.1 to 4.8)				
		Physical component score		−4.5[*] (−7.3 to −1.6)				
	SCI with AIS grade[†] C compared with SCI with AIS grade[†] D	Mental component score		−0.2[*] (−3.2 to 2.8)				
		Physical component score		−3.4[*] (−6.3 to −0.4)				

SF-36, Short-form 36 questionnaire; EQ5D, EuroQol-5D questionnaire; SCI, spinal cord injury; AIS, American Spinal Injury Association impairment scale

[†]AIS grade was measured at baseline; AIS grade A, complete (there is no motor or sensory function left below the level of injury); AIS grade B, incomplete (sensory function but not motor function is preserved below the neurologic level [the first normal level above the level of injury] and some sensation is preserved in the sacral segments S4 and S5); AIS grade C, incomplete (motor function is preserved below the neurologic level but more than half of the key muscles below the neurologic level have a muscle grade less than 3 [i.e. they are not strong enough to move against gravity]); AIS grade D, incomplete (motor function is preserved below the neurologic level, and at least half of the key muscles below the neurologic level have a muscle grade of 3 or more [i.e. the joints can be moved against gravity])

[*]Mean differences; [a]$p < 0.05$

Analysis code and the full data extraction sheets are available on Mendeley Data online [34]. An early version of this work was presented as a conference abstract at the 14th European Public Health Conference [35].

3 Results

Figure 1 shows the PRISMA chart for study selection. Out of 67 publications that met our inclusion criteria, 34 studies evaluated costs, and 33 studies assessed HRQoL [29, 36–101]. Study design characteristics, population and measures of exposure and outcome are recorded in Supplementary Table 2. All studies included either patients with SCI or traumatic SCI.

3.1 Study Characteristics

The overall score from the quality assessment ranged from 64 to 82% (Supplementary Table S3). A total of 46 studies (69%) were conducted in high-income countries and 21 (31%) in low- and middle-income countries (Supplementary Table S4), and 56 (84%) were cross-sectional. The mean age at injury in the included HRQoL studies ranged from 23 to 44 years, while in the cost studies, it ranged from 0 to 80 years, with two studies including patients under 18 years old. The mean age at interview of patients ranged from 33 to 53 years in the HRQoL studies and from 0 to 85 years in the cost studies. Only the cost studies reported the mean time from injury to interview, which varied from 1 to 27 years in the cross-sectional studies and from 0 to 5 years in the longitudinal studies. The proportion of male patients in the HRQoL studies ranged from 61 to 100%, while in the cost studies, it varied from 22

to 100%. Among both cost and HRQoL studies, 57 did not differentiate between the causes of SCI, while others stratified by causes such as falls, motor vehicle accidents, violence and sports.

3.2 Health-Related Quality of Life

Table 1 synthesises using MA the results of cross-section studies that reported HRQoL. SCI individuals tended to report greater HRQoL in mental than physical dimension scores. When comparing the eight domains of SF-36 quality of life, PF showed the lowest score while MH and SR had the highest score. The MA showed moderate and high heterogeneity ($I^2 > 25\%$) in PF for middle-income countries and PR, BP, GH, ER, MH and SR for high-income countries (Supplementary Figs. S1–S10). Reported mean HRQoL tended to be greater in middle income countries than high income countries for nearly all dimensions of the SF-36.

Five studies collected longitudinal data on HRQoL (Table 2). Schwartz et al. [66] used SF-36 questionnaire and reported mean HRQoL scores at 1, 2, and 5 years post-injury. However, no baseline data were reported (Table 2a). Non-significant increases in HRQoL were found in nearly all the subscales from 1 to 2 years. Lucke et al. [77] reported SF-36 at 6 months but no baseline data. SCI individuals reported low PF, PR and ER scores, while reporting high GH, MH and SR scores.

3.3 Within-Study Association Between HRQoL and Modifying Factors

Eight studies [42, 44, 55–57, 59, 68, 72] reported the within-study association between HRQoL and observed potential modifiers such as age, gender, time since injury, level of injury, health problems, time spent at hospital education, marital status, financial support and employment.

Three of those studies reported longitudinal data (Table 2b). Paul et al. [42] examined the effect of receiving financial compensation from an accident insurance scheme on HRQoL by comparing a population of SCI receiving this financial support to another group without support. The study found no significant differences in mean HRQoL after 18 months. The proportion reporting problems tended to diminish over time in both groups, and it was noteworthy that the proportion reporting problems of mental health was considerably lower than those reporting problems of mobility. Cotner et al. [55] compared SCI individuals who had gained competitive employment during the study with those who had not. Employed people tended to report greater HRQoL, but differences were not significant. However, the

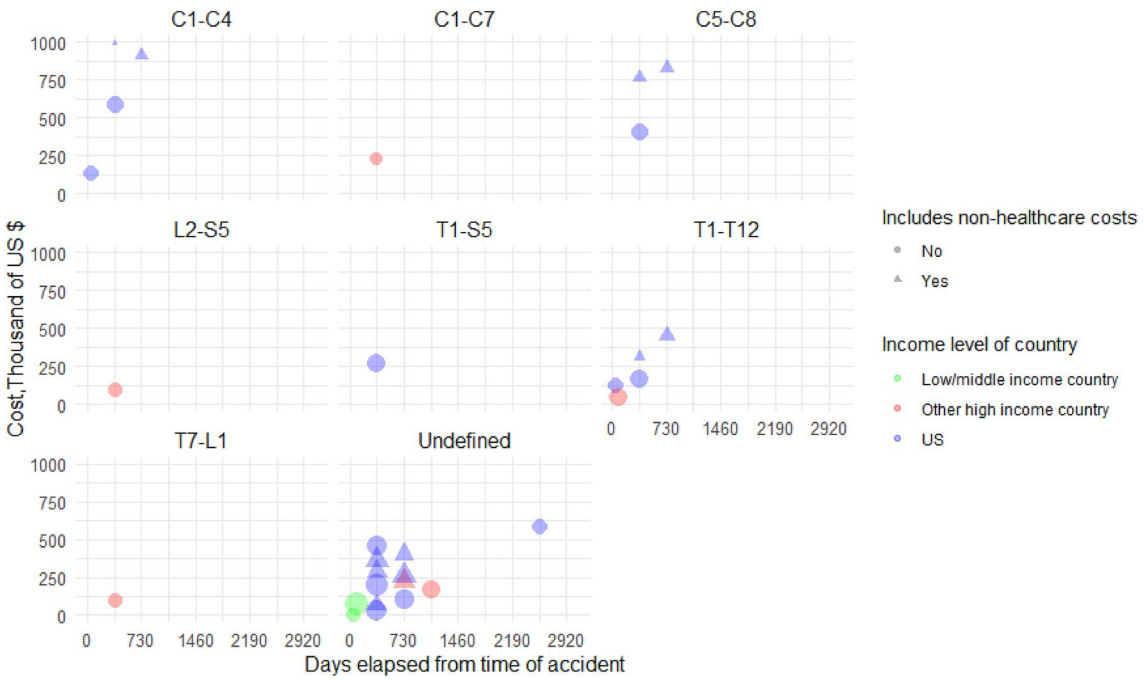

Fig. 2 Costs per injured person (price in US dollars 2023). The size of the point is proportional to the log of the sample size: C1–C7 tetraplegic, C1–C4 high tetraplegic, C5–C8 low tetraplegic, T1–T12 paraplegic (paralysis in the thoracic area), T7–L1 paraplegia (affecting abdominal area), L2–S5 paraplegia (paralysis of lumbar and sacral area) and T1–S5 paraplegia (paralysis in the thoracic, lumbar and sacral area)

authors reported that PCS increased significantly from baseline in the unemployed group. Richard-Denis et al. [44] compared mean HRQoL scores differentiated by the initial severity of the neurological injury. The authors reported that SCI individuals sustaining less severe neurological injury (grade D) reported higher PCS than individuals with grades A, B or C injury. However, individuals with initial grade A injury showed increased MCS, compared with individuals with incomplete grade B, C or D injury.

Results of five cross-section studies reporting factors related to PF, PR, BP, GH, PCS, ER, V, SR, MH and PCS are reported in the Supplementary Figs. S32–S41. All five studies reported that paraplegic individuals showed better PF than tetraplegic individuals. Employment was associated with better PF in three studies. Three studies showed no significant differences between paraplegic and tetraplegic people in GH scores, while there was no consensus among studies that looked at other physical domains. Neurologic level of injury did not seem to contribute to ER, V or SR. One study reported better MH for paraplegic individuals (compared with tetraplegic), whereas three studies did not find significant differences. One study found that single individuals scored significantly lower V, ER and MH scores than those that were married, but others did not find significant differences. Five studies examined gender differences on HRQoL scores, of which two found higher PF, V or MH in men, though other studies did not find significant effects.

3.4 Between-Study Association Between HRQoL and Modifying Factors

Random-effects meta-regression was conducted among the cross-sectional studies where the MA showed moderate or high between-study heterogeneity (Supplementary Figs. S11–S31). No significant associations were found at the 5% level. At the 10% significance level, physical functioning tends to be greater in studies that measured HRQoL at a longer time since the injury, compared with those that measured HRQoL sooner after the injury. Studies with a greater proportion of paraplegic individuals (rather than tetraplegic) tended to report lower bodily pain scores and better emotional role scores.

3.5 Costs

A total of 34 studies reported mean costs of SCI over different time periods, with 18 of these studies conducted in the USA. To facilitate comparison, we categorised the cost data into groups based on the country's income level: the USA; other high-income countries such as Spain, Canada, and Australia; and middle/low-income countries China, Taiwan and Nigeria. Among the studies that estimated costs from primary costs from primary data from the hospital admission period up to 7 years, Fig. 2 shows results grouped by income level of country, neurological level of injury and whether non-healthcare costs were included in the study.

Overall, the costs are substantially higher for injuries to cervical segments compared with thoracic segments. Hospital costs from 30 to 90 days after the initial accident ranged from US$2,227 to US$130,591, while the mean cost at 1-year ranged from US$33,120 to US$992,144. Low- and middle-income countries tended to report lower costs than the USA.

Three modelling studies estimated lifetime mean costs in the United Kingdom or USA of SCI individuals, differentiating by impairment level and cause of injury (Table 3). All studies used a discount rate of 4%. McDaid et al. [29] estimated lifetime costs of tetraplegic injury to be around just under US$2.5 million in the UK for a patient with mean age 46 years at accident and just under US$2 million for paraplegic injuries. Costs items included were surgical procedures, intensive care unit, normal hospital room, nursing home care, adaptions to home, productivity losses of carers/due to sick leave/death and family care. Cao et al. [63] estimated lifetime costs using a similar methodology in the USA for C1 to C4 injuries and C5 to C8 injuries, respectively, with broadly similar results. However, Cao et al. [63] did not include productivity losses arising from carers' time, sick leave or death. Devivo [51] estimated mean lifetime costs (including costs of surgical procedures, intensive care unit, normal hospital room, nursing home care and adaptions to home) between approximately US$700,000 and US$1.1 million (averaged across all neurological levels), depending on the cause of the injury.

4 Discussion

4.1 Summary of Findings

This study attempted to systematically review evidence on the underlying economic and health burden of SCI condition. Despite the heterogeneity in population, outcomes, study methodology or timeframe, there seem to be some general trends that are consistent in the different analyses (meta-regression, the analysis of within-study factors and longitudinal studies). First, as found in early studies [13, 102] SCI and neurological level of injury are associated with low HRQoL on mobility and physical dimensions. Second, the mental health scores of survivors of SCI appear considerably greater than physical scores. Third, most dimensions of HRQoL appear to improve over time, at least over the first year. These results might indicate a decline at first, but this rebounds over time. It has been suggested that this occurs because people tend to adapt to the situation in which

Table 3 Lifetime costs per injured person (price in US dollars 2023)

Authors, year	Country	Population type	Societal perspective	Includes rehabilitation costs	Includes costs of productivity loss and family care (social)	Percent paraplegic	Details of the study to estimate prevalence by age			Source of Resource Use and Cost Data	Modelling method	Discount rates	Costs
							Sample size, *N*	Age at injury, mean	Age at survey Mean (range in sample)				
McDaid et al., 2019 [29]	UK	SCI all causes	Yes	No	Yes	18%	1270		46 (0 to 85+)	§	Markov Model	4%	1,397,644
McDaid et al., 2019 [29]	UK	SCI all causes – tetraplegic ABC	Yes	No	Yes	0%	445		46 (0 to 85+)	§	Markov Model	4%	2,309,976
McDaid et al., 2019 [29]	UK	SCI all causes – paraplegic ABC	Yes	No	Yes	100%	229		46 (0 to 85+)	§	Markov Model	4%	1,717,265
McDaid et al., 2019 [29]	UK	SCI all causes – all D	Yes	No	Yes		596		46 (0 to 85+)	§	Markov Model	4%	593,649
Devivo, J. M., 1997 [51]	USA	SCI caused by motor vehicle accident	No	Yes	No		1010	30			Annual weighted cost †	4%	1,095,551
Devivo, J. M., 1997 [51]	USA	SCI caused by violence	No	Yes	No		830	27			Annual weighted cost †	4%	712,509
Devivo, J. M., 1997 [51]	USA	SCI caused by falls	No	Yes	No		647	24			Annual weighted cost †	4%	751,706
Devivo, J. M., 1997 [51]	USA	SCI caused by sports	No	Yes	No		208	42			Annual weighted cost †	4%	1,081,467
Devivo, J. M., 1997 [51]	USA	other causes of SCI	No	Yes	No		197	38			Annual weighted cost †	4%	749,062
Cao et al. 2011 [63]	USA	SCI all causes – C1 to C4	No	Yes	No			25			Annual weighted cost †	4%	3,780,294
Cao et al. 2011 [63]	USA	SCI all causes – C5 to C8	No	Yes	No			25			Annual weighted cost †	4%	2,575,714

Table 3 (continued)

Authors, year	Country	Population type	Societal perspective	Includes rehabilitation costs	Includes costs of productivity loss and family care (social)	Percent paraplegic	Details of the study to estimate prevalence by age			Source of Resource Use and Cost Data	Modelling method	Discount rates	Costs
							Sample size, *N*	Age at injury, mean	Age at survey Mean (range in sample)				
Cao et al. 2011 [63]	USA	SCI all causes – T1 to S5	No	Yes	No			25			Annual weighted cost †	4%	1,545,920
Cao et al. 2011 [63]	USA	SCI all causes – AIS D	No	Yes	No			25			Annual weighted cost †	4%	1,113,008
Cao et al. 2011 [63]	USA	SCI all causes – C1 to C4	No	Yes	No			50			Annual weighted cost †	4%	2,125,391
Cao et al. 2011 [63]	USA	SCI all causes – C5 to C8	No	Yes	No			50			Annual weighted cost †	4%	1,662,298
Cao et al. 2011 [63]	USA	SCI all causes – T1 to S5	No	Yes	No			50			Annual weighted cost †	4%	1,081,313
Cao et al. 2011 [63]	USA	SCI all causes – AIS D	No	Yes	No			50			Annual weighted cost †	4%	839,949

†The value of lifetime charges for an individual with SCI secondary to each cause was estimated using the mean first year and recurring annual charges for that cause (assuming that the recurring charges are constant after the first year), mean age at time of injury for all persons in the National Spinal Cord Injury Statistical Center database, and the most recent survival data. C1 to C4 High tetraplegic; C5 to C8 Low tetraplegic; T1-S5 paraplegia (paralysis in the thoracic, lumbar and sacral area); AIS Grade A = complete, there is no motor or sensory function left below the level of injury; AIS Grade B = incomplete, sensory function, but not motor function, is preserved below the neurologic level (the first normal level above the level of injury) and some sensation is preserved in the sacral segments S4 and S5.; AIS Grade C = incomplete, motor function is preserved below the neurologic level, but more than half of the key muscles below the neurologic level have a muscle grade less than 3 (i.e., they are not strong enough to move against gravity); AIS Grade D = incomplete, motor function is preserved below the neurologic level, and at least half of the key muscles below the neurologic level have a muscle grade of 3 or more (i.e., the joints can be moved against gravity); All studies included costs of surgical procedures, intensive care unit, normal hospital room, nursing home care and adaptions to home; Productivity losses incurred by carers or due to patient's sick leave or patient's death; § Literature and 2015–2016 English National Schedule of Reference Costs; ¶ hospital record or third parties

they find themselves [103, 104]. Additionally, Bokaye et al. [19] demonstrated that patients with SCI have a decreased quality of life (QOL) compared with the general population, with the most significant deficits in physical functioning and role limitations. Scores among patients with SCI were 10–70 points lower (on a 100-point scale) compared with the general population. The quality of the included studies was assessed as moderate to high with an overall score between 64 and 82%.

Although some cross-sectional studies have linked employment status to higher HRQoL, neither the meta-regression analysis nor the longitudinal study found any significant differences. This could suggest that the effect found in cross-sectional studies is a confounded by unobserved or uncontrolled factors [105]. Given the results of this review, it appears more plausible that adequate physical functioning is usually a condition of gaining competitive employment, rather than the other way around. Furthermore, there is notable variation in gender representation across studies, with certain studies exclusively focusing on SCI populations composed entirely of men. Additionally, our examination of gender differences in HRQoL scores revealed a lack of consensus among studies, highlighting the need for further exploration of gender disparities in both costs and HRQoL assessments.

Healthcare and other costs for people living with SCI are substantial, accumulate over the lifetime based on factors such as the severity of injury, including the level of injury and whether non-healthcare costs were included in the study. Additionally, the extent of injury completeness, influenced by factors such as surgery and ongoing maintenance requirements for equipment, further impacts cost differentials. Most cost studies were in the USA, and it seems that total expenditures in this country are higher than other systems. However, this result should be interpreted cautiously as access to treatment and care services in the USA may depend on the insurance held by the patient. Devivo, et al. [48] highlighted differences when costs are charged to the patient or covered by a third-party insurer. Hospital admission charges for acute care were three times higher when they were charged to a third-party payer and twice as high for 1-year costs and inpatient rehabilitation. Furthermore, the reported costs omit social costs such as accident insurance pension etc. These costs are also important and must be included in the SCI cost assessment.

4.2 Limitations

This review included both cross-sectional and longitudinal study designs. While cross-sectional studies can use regression methods to adjust the measure of association for observed covariates, they, nevertheless, carry a risk of confounding from selection bias, reverse causality or omitted variables. We aimed to be cautious in our conclusions and used different methods of analysis (MA, meta-regression, tabulation and comparison with longitudinal studies). Given the wide variety of existing QoL measures, we limited this review to studies including to EQ5D and SF-36 questionnaires to obtain a degree of homogeneity. These are generic HRQoL instruments that have been validated in many countries and conditions [106]. Nevertheless, they may not capture broader aspects of well-being or some condition-specific dimensions of QoL. Throughout the study, we were conscious that quality of life (and expenditures) on people with SCI depend on wider cultural, institutional and environmental factors, including attitudes to disability.

4.3 Conclusions

SCI is associated with low HRQoL on mobility and physical dimensions. Mental health scores tend to be greater than physical scores, and most dimensions of HRQoL appear to improve over time, at least over the first year. These conditions are associated with high costs which vary by country.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s41669-024-00517-3.

Declarations

Funding This study was supported by the European Union's Horizon 2020 research under grant agreement 733203. The funder had no role in the design and conduct of the study; collection, management, analysis and interpretation of the data; preparation, review or approval of the manuscript; and decision to submit the manuscript for publication.

Conflicts of Interest There are no conflicts of interest to report.

Ethics Approval Not applicable

Consent to Participate Not applicable

Consent for Publication Not applicable

Availability of Data and Material Data of selected studies are available on Mendeley Data online [34].

Code Availability Codes are available on Mendeley Data online [34].

Authors' Contributions Conception and design: M.D., D.E. Analysis and interpretation: M.D., D.E. Data collection: M.D., D.E. Writing the article: M.D., D.E. Critical revision of the article: M.D., D.E. Final approval of the article: M.D., D.E. Statistical analysis: M.D., D.E.

References

1. WHO. International perspectives on spinal cord injury (IPSCI). Top Spinal Cord Inj Rehabil. 2011;16:99–100.
2. Hall OT, McGrath RP, Peterson MD, Chadd EH, DeVivo MJ, Heinemann AW, et al. The burden of traumatic spinal cord injury in the United States: disability-adjusted life years. Arch Phys Med Rehabil. 2019;100:95–100. https://doi.org/10.1016/J.APMR.2018.08.179.
3. Barker R, Amsters D, Pershouse K, Haines T, Kuipers P. The relationship between quality of life and disability across the lifespan for people with spinal cord injury. Spinal Cord. 2009;47:149–55. https://doi.org/10.1038/sc.2008.82.
4. Access Economics. The economic cost of spinal cord injury and traumatic brain injury in Australia. Report by Access Economics for the Victorian Neurotrauma Initiative 2009:31.
5. Espín J, Špacírová Z, Rovira J, Epstein D, Olry de Labry Lima A, García-Mochón L. Development of the European Healthcare and Social Cost Database (EU HCSCD) for use in economic evaluation of healthcare programs. BMC Health Serv Res. 2022;22:1–10. https://doi.org/10.1186/S12913-022-07791-Z/TABLES/2.
6. Papanicolas I, Woskie LR, Jha AK. Health care spending in the United States and other high-income countries. JAMA. 2018;319:1024–39. https://doi.org/10.1001/JAMA.2018.1150.
7. WHO. Closing the gap in a generation: health equity through action on the social determinants of health 2008. https://www.who.int/publications/i/item/9789241563703 (accessed May 7, 2022).
8. Ferdiana A, Post MWM, King N, Bültmann U, van der Klink JJL. Meaning and components of quality of life among individuals with spinal cord injury in Yogyakarta Province, Indonesia. Disabil Rehabil. 2017;40:1183–91. https://doi.org/10.1080/09638288.2017.1294204.
9. Wilson JR, Hashimoto RE, Dettori JR, Fehlings MG. Spinal cord injury and quality of life: a systematic review of outcome measures. Evid Based Spine Care J. 2011;2:37–44. https://doi.org/10.1055/s-0030-1267085.
10. de França IS, Coura AS, de Sousa FS, de Almeida PC, Pagliuca LM. Quality of life in patients with spinal cord injury. Revista gaúcha de enfermagem / EENFUFRGS. 2013;34:155–63.
11. Singh R, Dhankar SS, Rohilla R. Quality of life of people with spinal cord injury in Northern India. Int J Rehabil Res. 2008;31:247–51. https://doi.org/10.1097/MRR.0b013e3282fb7d25.
12. Kalyani HHN, Dassanayake S, Senarath U. Effects of paraplegia on quality of life and family economy among patients with spinal cord injuries in selected hospitals of Sri Lanka. Spinal Cord. 2015;53:446–50. https://doi.org/10.1038/sc.2014.183.
13. Clayton KS, Chubon RA. Factors associated with the quality of life of long-term spinal cord injured persons. Arch Phys Med Rehabil. 1994;75:633–8. https://doi.org/10.1016/0003-9993(94)90184-8.
14. Bagnall A-M, Jones L, Richardson G, Duffy S, Riemsma R. Effectiveness and cost-effectiveness of acute hospital-based spinal cord injuries services: systematic review. Health Technol Assess (Rockv). 2003. https://doi.org/10.3310/hta7190.
15. Malekzadeh H, Golpayegani M, Ghodsi Z, Sadeghi-Naini M, Asgardoon M, Baigi V, et al. Direct cost of illness for spinal cord injury: a systematic review. Global Spine J. 2021. https://doi.org/10.1177/21925682211031190.
16. Furlan JC, Gulasingam S, Craven BC. The health economics of the spinal cord injury or disease among veterans of war: a systematic review. J Spinal Cord Med. 2017;40:649–64. https://doi.org/10.1080/10790268.2017.1368267.
17. Dalvand S, Hammam N, Mirzaei N, Ghanei Gheshlagh R. Health-related quality of life of patients with spinal cord injury in Iran: a systematic review and meta-analysis. Shiraz E Med J. 2019. https://doi.org/10.5812/semj.91402.
18. Ku JH. Health-related quality of life in patients with spinal cord injury: review of the Short Form 36-Health Questionnaire Survey. Yonsei Med J. 2007;48:360. https://doi.org/10.3349/ymj.2007.48.3.360.
19. Boakye M, Leigh BC, Skelly AC. Quality of life in persons with spinal cord injury: comparisons with other populations. J Neurosurg Spine. 2012;17:29–37. https://doi.org/10.3171/2012.6.AOSPINE1252.
20. Singh A, Tetreault L, Kalsi-Ryan S, Nouri A, Fehlings MG. Global prevalence and incidence of traumatic spinal cord injury. Clin Epidemiol. 2014;6:309–31. https://doi.org/10.2147/CLEP.S68889.
21. Petroff D, Czerny M, Kölbel T, Melissano G, Lonn L, Haunschild J, et al. Paraplegia prevention in aortic aneurysm repair by thoracoabdominal staging with 'minimally invasive staged segmental artery coil embolisation' (MIS^{2}ACE): trial protocol for a randomised controlled multicentre trial. BMJ Open. 2019;9:e025488. https://doi.org/10.1136/BMJOPEN-2018-025488.
22. Moher D, Liberati A, Tetzlaff J, Altman DG, Group TP. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2009. https://doi.org/10.1371/journal.pmed.1000097.
23. Devlin NJ, Shah KK, Feng Y, Mulhern B, van Hout B. Valuing health-related quality of life: an EQ-5D-5L value set for England-specific PROs focus on specific health. Health Econ. 2017. https://doi.org/10.1002/hec.3564.
24. Ware JE, Sherbourne CD. The MOS 36-item short-form health survey (SF-36): I. conceptual framework and item selection on JSTOR 1992. https://www.jstor.org/stable/3765916?casa_token=MCohMK5SuyYAAAAA%3AHcICRt3tuFuume6tOXi0fn3Eaaiqf1Q2wnlzuT8gj8XBPuZxVXhL7QuDPk_HfKSpUqG3_7tB_2HpztulC7RHS-tc3FTYI-TblrXE4eZXHMp98dBcNSZc0w&seq=1 (accessed May 8, 2022).
25. Ware JE, Kosinski M, Keller SD. A 12-item short-form health survey: construction of scales and preliminary tests of reliability and validity on JSTOR 1996. https://www.jstor.org/stable/3766749?casa_token=bCJZpiLNFSMAAAAA%3AmjUMf435uG4OY12h2KOf2fpxRegh3ZK0nGXO_x8oixUZM4J9l7eyjeHQbx2DKtWilSoYnAOwtoMTGlXHIZCZVER3DWowdKYtN6lD5qsfQYb0lQu1zibo1w&seq=1 (accessed May 8, 2022).
26. Shearer D, Morshed S. Common generic measures of health related quality of life in injured patients. Injury. 2011;42:241–7. https://doi.org/10.1016/J.INJURY.2010.11.044.
27. Euroqol. EQ-5D 2022. https://euroqol.org/ (accessed June 21, 2022).
28. OECD, Eurostat. Eurostat-OECD methodological manual on purchasing power parities. 2012th ed. Paris: OECD Publishing; 2012. https://doi.org/10.1787/9789264189232-enen.
29. McDaid D, la Park A, Gall A, Purcell M, Bacon M. Understanding and modelling the economic impact of spinal cord injuries in the United Kingdom. Spinal Cord. 2019;57:778–88. https://doi.org/10.1038/s41393-019-0285-1.
30. Kmet LM, Lee RC, Cook LS. Standard quality assessment criteria for evaluating primary research papers from a variety of fields. 2004.
31. Cheung MW-L, Ho RCM, Lim Y, Mak A. Conducting a meta-analysis: basics and good practices. Int J Rheum Dis. 2012. https://doi.org/10.1111/j.1756-185X.2012.01712.x.

32. WBG. World Bank Country and Lending Groups – World Bank Data Help Desk 2022. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups (accessed March 3, 2022).
33. Higgins JPT, Thompson SG. Quantifying heterogeneity in a meta-analysis. Statist Med. 2002;21:1539–58. https://doi.org/10.1002/sim.1186.
34. Diop M. A systematic review of impact of spinal cord injury on costs and health related quality of life—Mendeley Data 2022. https://doi.org/10.17632/rd4v52p6ks.3.
35. Diop M, Diop M, Epstein D, Gaggero A, Cherif I, Cherif I, et al. Quality of life, health and social costs of patients with spinal cord injury: a systematic review. Eur J Public Health. 2021. https://doi.org/10.1093/EURPUB/CKAB165.177.
36. Moghimian M, Kashani F, Cheraghi MA, Mohammadnejad E. Quality of life and related factors among people with spinal cord injuries in Tehran, Iran. Arch Trauma Res. 2015. https://doi.org/10.5812/atr.19280.
37. Hossain MS, Islam MS, Rahman MA, Glinsky JV, Herbert RD, Ducharme S, et al. Health status, quality of life and socioeconomic situation of people with spinal cord injuries six years after discharge from a hospital in Bangladesh. Spinal Cord. 2019;57:652–61. https://doi.org/10.1038/s41393-019-0261-9.
38. Arango-Lasprilla JC, Nicholls E, Olivera SL, Perdomo JL, Arango JA. Health-related quality of life in individuals with spinal cord injury in Colombia, South America. NeuroRehabilitation. 2010;27:313–9. https://doi.org/10.3233/NRE-2010-0614.
39. Ataoğlu E, Tiftik T, Kara M, Tunç H, Ersöz M, Akkuş S. Effects of chronic pain on quality of life and depression in patients with spinal cord injury. Spinal Cord. 2013;51:23–6. https://doi.org/10.1038/sc.2012.51.
40. Johnson RL, Gerhart KA, McCray J, Menconi JC, Whiteneck GG. Secondary conditions following spinal cord injury in a population-based sample. Spinal Cord. 1998;36:45–50. https://doi.org/10.1038/sj.sc.3100494.
41. Haran MJ, Lee BB, King MT, Marial O, Stockler MR. Health status rated with the medical outcomes study 36-item short-form health survey after spinal cord injury. Arch Phys Med Rehabil. 2005;86:2290–5. https://doi.org/10.1016/j.apmr.2005.07.293.
42. Paul C, Derrett S, Mcallister S, Herbison P, Beaver C, Sullivan M. Socioeconomic outcomes following spinal cord injury and the role of no-fault compensation: longitudinal study. Spinal Cord. 2013;51:919–25. https://doi.org/10.1038/sc.2013.110.
43. García-Altés A, Pérez K, Novoa A, Suelves JM, Bernabeu M, Vidal J, et al. Spinal cord injury and traumatic brain injury: a cost-of-illness study. Neuroepidemiology. 2012;39:103–8. https://doi.org/10.1159/000338297.
44. Richard-Denis A, Thompson C, Mac-Thiong J-M. Quality of life in the subacute period following a cervical traumatic spinal cord injury based on the initial severity of the injury: a prospective cohort study. Spinal Cord. 2018;56:1042–50. https://doi.org/10.1038/s41393-018-0178-8.
45. Richard-Denis A, Feldman DE, Thompson C, Bourassa-Moreau É, Mac-Thiong JM. Costs and length of stay for the acute care of patients with motor-complete spinal cord injury following cervical trauma. Am J Phys Med Rehabil. 2017;96:449–56. https://doi.org/10.1097/PHM.0000000000000659.
46. Sundance P, Cope DN, Kirshblum S, Parsons KC, Apple DF. Systematic care management: clinical and economic analysis of a national sample of patients with spinal cord injury. Top Spinal Cord Inj Rehabil. 2004;10:17–34. https://doi.org/10.1310/2E3M-X01K-786H-V8FC.
47. Carrillo EH, Gonzalez JK, Carrillo LE, Chacon PM, Namias N, Kirton OC, et al. Spinal cord injuries in adolescents after gunshot wounds: an increasing phenomenon in urban North America. Injury. 1998;29:503–7. https://doi.org/10.1016/S0020-1383(98)00110-7.
48. DeVivo MJ, Chen Y, Mennemeyer ST, Deutsch A. Costs of care following spinal cord injury. Top Spinal Cord Inj Rehabil. 2011;16:1–9. https://doi.org/10.1310/sci1604-1.
49. Charles ED, Fine PR, Stover SL, Wood T, Lott AF, Kronenfeld J. The costs of spinal cord injury. Paraplegia. 1978;15:302–10. https://doi.org/10.1038/sc.1977.46.
50. Margolis JM, Juneau P, Sadosky A, Cappelleri JC, Bryce TN, Nieshoff EC. Health care resource utilization and medical costs of spinal cord injury with neuropathic pain in a commercially insured population in the United States. Arch Phys Med Rehabil. 2014;95:2279–87. https://doi.org/10.1016/j.apmr.2014.07.416.
51. DeVivo MJ. Causes and costs of spinal cord injury in the United States. Spinal Cord. 1997;35:809–13. https://doi.org/10.1038/sj.sc.3100501.
52. Munce SEP, Wodchis WP, Guilcher SJT, Couris CM, Verrier M, Fung K, et al. Direct costs of adult traumatic spinal cord injury in ontario. Spinal Cord. 2013;51:64–9. https://doi.org/10.1038/sc.2012.81.
53. Glennie RA, Batke J, Fallah N, Cheng CL, Rivers CS, Noonan VK, et al. Rural and urban living in persons with spinal cord injury and comparing environmental barriers, their health, and quality-of-life outcomes. J Neurotrauma. 2017;34:2877–82. https://doi.org/10.1089/neu.2016.4931.
54. Unalan H, Celik B, Sahin A, Caglar N, Esen S, Karamehmetoglu SS. Quality of life after spinal cord injury: the comparison of the SF-36 health survey and its spinal cord injury-modified version in assessing the health status of people with spinal cord injury. Neurosurg Q. 2007;17:175–9. https://doi.org/10.1097/WNQ.0b013e318063eb72.
55. Cotner BA, Ottomanelli L, O'Connor DR, Njoh EN, Barnett SD, Miech EJ. Quality of life outcomes for veterans with spinal cord injury receiving individual placement and support (IPS). Top Spinal Cord Inj Rehabil. 2018;24:325–35. https://doi.org/10.1310/sci17-00046.
56. Leduc BE, Lepage Y. Health-related quality of life after spinal cord injury. Disabil Rehabil. 2002;24:196–202. https://doi.org/10.1080/09638280110067603.
57. Lidal IB, Veenstra M, Hjeltnes N, Biering-Sørensen F. Health-related quality of life in persons with long-standing spinal cord injury. Spinal Cord. 2008;46:710–5. https://doi.org/10.1038/sc.2008.17.
58. Gurcay E, Bal A, Eksioglu E, Cakci A. Quality of life in patients with spinal cord injury. Int J Rehabil Res. 2010;33:356–8. https://doi.org/10.1097/MRR.0b013e328338b034.
59. Westgren N, Levi R. Quality of life and traumatic spinal cord injury. Arch Phys Med Rehabil. 1998;79:1433–9. https://doi.org/10.1016/S0003-9993(98)90240-4.
60. Rivers CS, Fallah N, Noonan VK, Whitehurst DG, Schwartz CE, Finkelstein JA, et al. Health conditions: effect on function, health-related quality of life, and life satisfaction after traumatic spinal cord injury. A prospective observational registry cohort study. Arch Phys Med Rehabil. 2018;99:443–51. https://doi.org/10.1016/j.apmr.2017.06.012.
61. Tate DG, Forchheimer M. Health-related quality of life and life satisfaction for women with spinal cord injury. Top Spinal Cord Inj Rehabil. 2001;7:1–15. https://doi.org/10.1310/9JHX-AVUL-89VL-RCQN.
62. Harvey C, Wilson SE, Greene CG, Berkowitz M, Stripling TE. New estimates of the direct costs of traumatic spinal cord injuries: results of a nationwide survey. Paraplegia. 1992;30:834–50. https://doi.org/10.1038/sc.1992.160.

63. Cao Y, Chen Y, DeVivo MJ. Lifetime direct costs after spinal cord injury. Top Spinal Cord Inj Rehabil. 2011;16:10–6. https://doi.org/10.1310/sci1604-10.
64. Tator CH, Duncan EG, Edmonds VE, Lapczak LI, Andrews DF. Complications and costs of management of acute spinal cord injury. Paraplegia. 1993;31:700–14. https://doi.org/10.1038/sc.1993.112.
65. Mahabaleshwarkar R, Khanna R. National hospitalization burden associated with spinal cord injuries in the United States. Spinal Cord. 2014;52:139–44. https://doi.org/10.1038/sc.2013.144.
66. Schwartz CE, Stucky B, Rivers CS, Noonan VK, Finkelstein JA. Quality of life and adaptation in people with spinal cord injury: response shift effects from 1 to 5 years postinjury. Arch Phys Med Rehabil. 2018;99:1599-1608.e1. https://doi.org/10.1016/j.apmr.2018.01.028.
67. Andresen EM, Fouts BS, Romeis JC, Brownson CA. Performance of health-related quality-of-life instruments in a spinal cord injured population. Arch Phys Med Rehabil. 1999;80:877–84. https://doi.org/10.1016/S0003-9993(99)90077-1.
68. Forchheimer M, McAweeney M, Tate DG. Use of the SF-36 among persons with spinal cord injury. Am J Phys Med Rehabil. 2004;83:390–5. https://doi.org/10.1097/01.PHM.0000124441.78275.C9.
69. Oh SJ, Ku JH, Jeon HG, Shin HI, Paik NJ, Yoo T. Health-related quality of life of patients using clean intermittent catheterization for neurogenic bladder secondary to spinal cord injury. Urology. 2005;65:306–10. https://doi.org/10.1016/J.UROLOGY.2004.09.032.
70. Tavakoli SAH, Kavian M, Bakhsh SC, Ghajarzadeh M, Hamedan MS, Ghazwin MY, et al. is level of injury a determinant of quality of life among individuals with spinal cord injury? A tertiary rehabilitation center report. Oman Med J. 2016;31:112–6. https://doi.org/10.5001/omj.2016.22.
71. Edwards L, Krassioukov A, Fehlings MG. Importance of access to research information among individuals with spinal cord injury: results of an evidenced-based questionnaire. Spinal Cord. 2002;40:529–35. https://doi.org/10.1038/sj.sc.3101364.
72. Kreuter M, Siösteen A, Erkholm B, Byström U, Brown DJ. Health and quality of life of persons with spinal cord lesion in Australia and Sweden. Spinal Cord. 2004;43:123–9. https://doi.org/10.1038/sj.sc.3101692.
73. Yazdanshenas Ghazwin M, Chaibakhsh S, Latifi S, Tavakoli AH, Koushki D. Quality of life in iranian men with spinal cord injury in comparison with general population. Arch Neurosci. 2014. https://doi.org/10.5812/archneurosci.21529.
74. Ebrahimzadeh MH, Soltani-Moghaddas SH, Birjandinejad A, Omidi-Kashani F, Bozorgnia S. Quality of life among veterans with chronic spinal cord injury and related variables. Arch Trauma Res. 2014;3: e17917. https://doi.org/10.5812/atr.17917.
75. Ebrahimzadeh MH, Golhasani-Keshtan F, Shojaee BS. Correlation between health-related quality of life in veterans with chronic spinal cord injury and their caregiving spouses. Arch Trauma Res. 2014;3: e16720. https://doi.org/10.5812/atr.16720.
76. Horner-Johnson W, Krahn GL, Suzuki R, Peterson JJ, Roid G, Hall T. Differential performance of SF-36 items in healthy adults with and without functional limitations. Arch Phys Med Rehabil. 2010;91:570–5. https://doi.org/10.1016/J.APMR.2009.12.015.
77. Lucke KT, Coccia H, Goode JS, Lucke JF. Quality of life in spinal cord injured individuals and their caregivers during the initial 6 months following rehabilitation. Qual Life Res. 2004;13:97–110. https://doi.org/10.1023/B:QURE.0000015284.95515.17.
78. Middleton J, Tran Y, Craig A. Relationship between quality of life and self-efficacy in persons with spinal cord injuries. Arch Phys Med Rehabil. 2007;88:1643–8. https://doi.org/10.1016/J.APMR.2007.09.001.
79. Salamati P, Rostami R, Saadat S, Taheri T, Tajabadi M, Ranjbari G, et al. Comparison of health related quality of life between two groups of veteran and non-veteran spinal cord injured patients. Med J Islam Repub Iran 2015;29:198.
80. Elfström ML, Rydén A, Kreuter M, Taft C, Sullivan M. Relations between coping strategies and health-related quality of life in patients with spinal cord lesion. J Rehabil Med. 2005;37:9–16. https://doi.org/10.1080/16501970410034414.
81. Yasami S, Khadem M, Safaei G, Latifi S, Koushki D, Yazdanshenas GM. The association between bladder-emptying methods and health-related quality of life among Iranian individuals with spinal cord injury. J Spinal Cord Med. 2017;40:530–7. https://doi.org/10.1080/10790268.2016.1173320.
82. Sabour H, Soltani Z, Latifi S, Norouzi-Javidan A, Arman F, Emami-Razavi SH, et al. Injury-related characteristics and quality-of-life among Iranian individuals with spinal cord injury. Iran J Neurol. 2015;14:136–41.
83. Deutsch A, Almagor O, Rowles DM, Pucci D, Chen D. Characteristics and outcomes of aged medicare beneficiaries with a traumatic spinal cord injury: 2002–2005. Top Spinal Cord Inj Rehabil. 2011;16:17–26. https://doi.org/10.1310/sci1604-17.
84. Kawu AA, Olawepo A, Salami AOO, Kuranga SA, Abdulhameed S, Esenwah VC. A cost analysis of conservative management of spinal cord-injured patients in Nigeria. Spinal Cord. 2011;49:1134–7. https://doi.org/10.1038/sc.2011.69.
85. Krause JS, Murday D, Corley EH, DiPiro ND. Concentration of costs among high utilizers of health care services over the first 10 years after spinal cord injury rehabilitation: a population-based study. Arch Phys Med Rehabil. 2019;100:938–44. https://doi.org/10.1016/j.apmr.2018.10.020.
86. Lessing NL, Zuckerman SL, Lazaro A, Leech AA, Leidinger A, Rutabasibwa N, et al. Cost-effectiveness of operating on traumatic spinal injuries in low-middle income countries: a preliminary report from a major east african referral center. Global Spine J. 2022;12:15–23. https://doi.org/10.1177/2192568220944888.
87. Li J, Liu G, Zheng Y, Hao C, Zhang Y, Wei B, et al. The epidemiological survey of acute traumatic spinal cord injury (ATSCI) of 2002 in Beijing municipality. Spinal Cord. 2011;49:777–82. https://doi.org/10.1038/sc.2011.8.
88. Porgo TV, Moore L, Truchon C, Berthelot S, Stelfox HT, Cameron PA, et al. Patient-level resource use for injury admissions in Canada: a multicentre retrospective cohort study. Injury. 2019;50:1192–201. https://doi.org/10.1016/j.injury.2019.03.038.
89. Price C, Makintubee S, Hemdon W, Istre GR. Epidemiology of traumatic spinal cord injury and acute hospitalization and rehabilitation charges for spinal cord injuries in Oklahoma, 1988–1990. Am J Epidemiol. 1994;139:37–47. https://doi.org/10.1093/oxfordjournals.aje.a116933.
90. Radhakrishna M, Makriyianni I, Marcoux J, Zhang X. Effects of injury level and severity on direct costs of care for acute spinal cord injury. Int J Rehabil Res. 2014;37:349–53. https://doi.org/10.1097/MRR.0000000000000081.
91. Vaikuntam BP, Middleton JW, McElduff P, Connelly L, Pearse J, Stanford R, et al. Identifying predictors of higher acute care costs for patients with traumatic spinal cord injury and modeling acute care pathway redesign: a record linkage study. Spine (Phila Pa 1976). 2019;44:E974–83. https://doi.org/10.1097/BRS.0000000000003021.
92. Webster B, Giunti G, Young A, Pransky G, Nesathurai S. Work-related tetraplegia: cause of injury and annual medical costs. Spinal Cord. 2004;42:240–7. https://doi.org/10.1038/sj.sc.3101526.
93. Yang NP, Deng CY, Lee YH, Lin CH, Kao CH, Chou P. The incidence and characterisation of hospitalised acute spinal trauma

in Taiwan—a population-based study. Injury. 2008;39:443–50. https://doi.org/10.1016/j.injury.2007.12.007.
94. Yu W, Smith B, Kim S, Chow A, Weaver FM. Major medical conditions and VA healthcare costs near end of life for veterans with spinal cord injuries and disorders. J Rehabil Res Dev. 2008;45:831–40. https://doi.org/10.1682/JRRD.2006.08.0102.
95. Tsai JC, Chang WY, Hsueh IH, Yang MC, Chiu WT, Huang WS, et al. In-patient medical resource utilization for high-level cervical spinal cord injury without bone fracture in Taiwan. Spinal Cord. 2005;43:426–33. https://doi.org/10.1038/sj.sc.3101733.
96. Smith W, Simmonds JO, Alam ZS, Grant RE. Spinal cord injury caused by gunshot wounds: the cost of rehabilitation. Clin Orthop Relat Res. 2003;408:145–51. https://doi.org/10.1097/00003086-200303000-00017.
97. Sikka S, Callender L, Driver S, Bennett M, Reynolds M, Hamilton R, et al. Healthcare utilization following spinal cord injury: objective findings from a regional hospital registry. J Spinal Cord Med. 2019;42:194–200. https://doi.org/10.1080/10790268.2018.1505330.
98. Seel RT, Huang ME, Cifu DX, Kolakowsky-Hayner SA, McKinley WO. Age-related differences in length of stays, hospitalization costs, and outcomes for an injury-matched sample of adults with paraplegia. J Spinal Cord Med. 2001;24:241–50. https://doi.org/10.1080/10790268.2001.11753581.
99. Seel RT, Tewksbury MA. Nontraumatic vs. traumatic spinal cord injury: a rehabilitation outcome comparison. Am J Phys Med Rehabil. 2001;80(9):693–9.
100. Mac-Thiong JM, Feldman DE, Thompson C, Bourassa-Moreau E, Parent S. Does timing of surgery affect hospitalization costs and length of stay for acute care following a traumatic spinal cord injury? J Neurotrauma. 2012;29:2816–22. https://doi.org/10.1089/neu.2012.2503.
101. Chan L, Koepsell TD, Deyo RA, Esselman PC, Haselkorn JK, Lowery JK, et al. The effect of medicare's payment system for rehabilitation hospitals on length of stay, charges, and total payments. N Engl J Med. 1997;337:978–85. https://doi.org/10.1056/NEJM199710023371406.
102. Cuthbertson BH, Roughton S, Jenkinson D, Maclennan G, Vale L. Quality of life in the five years after intensive care: a cohort study. Crit Care. 2010. https://doi.org/10.1186/cc8848.
103. Singh V, Mitra S. Autonomic variability, depression and the disability paradox in spinal cord injury. Spinal Cord Ser Cases. 2022. https://doi.org/10.1038/s41394-022-00542-6.
104. Albrecht GL, Devlieger PJ. The disability paradox: High quality of life against all odds. Soc Sci Med. 1999;48:977–88. https://doi.org/10.1016/S0277-9536(98)00411-0.
105. Lidal IB, Huynh TK, Biering-Sørensen F. Return to work following spinal cord injury: a review. Disabil Rehabil. 2007;29:1341–75. https://doi.org/10.1080/09638280701320839.
106. Guyatt GH, Feeny DH, Patrick DL. Measuring health-related quality of life. Ann Intern Med. 1993;118:622–9. https://doi.org/10.7326/0003-4819-118-8-199304150-00009.