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Assessment of Impairment in Patients with Acute Traumatic Spinal Cord Injury: A Systematic Review of the Literature

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Abstract

The most common primary end-point of the trial on treatment of traumatic spinal cord injury (SCI) is the degree of impairment. The American Spinal Injury Association (ASIA) Standards have been widely used to assess motor function and pin-prick and light-touch sensory function. In addition, pain assessment is another clinically relevant aspect of the impairment in individuals with SCI. Given this, we sought to systematically review the studies that focused on the psychometric properties of ASIA Standards and all previously used outcome measures of pain in the SCI population in the acute care setting. For the primary literature search strategy, the MEDLINE, CINAHL, EMBASE, and Cochrane databases were sought out. Subsequently, a secondary search strategy was carried out using the articles listed in the references of meta-analysis, systematic, and non-systematic review articles. Two reviewers (JCF and VN) independently selected the articles that fulfill the inclusion and exclusion, assessed the level of evidence of each article, and appraised the psychometric properties of each instrument. Divergences during those steps were solved by consensus between both reviewers. Of 400 abstracts captured in our primary search strategy on the ASIA Standards, 16 full articles fulfilled the inclusion and exclusion criteria. An additional 40 references were obtained from two prior systematic reviews on ASIA Standards. While 45 of 56 of the studies on ASIA Standards provided level 4 evidence, there were 11 level 2b evidence studies. Convergent construct validity ($n = 34$), reliability ($n = 12$), and responsiveness ($n = 10$) were the most commonly studied psychometric properties of the ASIA Standards, but two prior studies examined their content validity. Of the 267 abstracts yielded in our primary search on pain assessment, 24 articles with level 4 evidence fulfilled the inclusion and exclusion criteria. There was no study that examined pain assessment in the acute care setting. While 18 of 24 articles studied an instrument for assessment of pain intensity, the remaining six studies were focused on classifications of pain in the SCI population. In conclusion, the ASIA Standards represent an appropriate instrument to categorize and evaluate spinal cord injured adults over time with respect to their motor and sensory function. Nevertheless, further investigation of the psychometric properties of the ASIA Standards is recommended due to a lack of studies focused on some key elements of responsiveness, including minimal clinically important difference. The visual analog scale (VAS) is the most commonly studied instrument of assessment of pain intensity in the SCI population. However, further investigation is required with regard to its reliability and responsiveness in the SCI population. Our results also suggest that there is no instrument with appropriate psychometric properties for this particular population.

Key words: ASIA Standards; impairment; pain; spinal cord injury; systematic review

Introduction

Traumatic spinal cord injury (SCI) can cause significant motor, sensory, and autonomic dysfunction caudally to the level of injury. The current constraints of the pharmacological treatment to restore spinal cord function after SCI in the clinical setting have led to numerous preclinical studies that have indicated novel rising neuroprotective and neuroregenerative strategies with the potential to reduce neuronal death after central nervous system (CNS) injury, enhance the intrinsic growth capacity of postmitotic neurons, or modify the CNS extracellular milieu that is hostile

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to neuronal growth (Jacobs and Fehlings, 2003). The potential translation of those strategies to the clinical practice will eventually require well-designed trials that assess their efficacy on reduction of impairment and disability.

The most commonly accepted primary end-point of the trial on treatment of SCI is an assessment of the degree of impairment. As defined by the International Classification of Functioning, Disability, and Health from the World Health Organization (WHO), impairment is related to the level of "motor and sensory function" (WHO, 2001). The instruments of choice for assessment of impairment of SCI in the clinical arena and research areas should preferably be proper for descriptive and evaluative purposes, as delineated by the framework of Kirschner and Guyatt (1985). The American Spinal Injury Association (ASIA) Standards have been widely used to assess motor function and pin-prick and light-touch sensory function in the SCI population in both clinical and research arenas. However, the ASIA Standards do not include assessment of pain, which is a common clinically relevant complication after traumatic SCI. Of note, there remained a paucity of outcome measures that comprehensively assesses autonomic function of individuals with SCI (Krassioukov et al., 2007). Recently, an international SCI research committee has developed an instrument for descriptive assessment of the impact of SCI on various organs and viscera that would allow the clinicians and researchers to appraise the degree of autonomic dysfunctions after SCI (Alexander et al., 2009). Nonetheless, psychometric properties of these novel autonomic standards have not been tested yet.

Given this background, we carried out a systematic review of the studies that were focused on the psychometric properties of ASIA score and all previously used outcome measures of pain in the SCI population in the acute care setting.

Methods

This systematic review included the ASIA Standards and several outcome measures of pain after traumatic SCI that were published in the literature. Based on the examination of their psychometric properties (i.e., item generation, item reduction, reliability, validity, and responsiveness), this review was focused on the following key questions:

1. Do the ASIA Standards have appropriate psychometric properties as outcome measure of motor and sensory function for acutely spinal cord injured patients?
2. What is the most reliable, validated, and responsive outcome measure of pain for patients with acute traumatic SCI?

Inclusion and exclusion criteria

This review included only original articles that assessed at least one psychometric property of either the ASIA Standards or an outcome measure of pain in patients with traumatic SCI. Case reports, editorial articles, and meeting abstracts were excluded.

Literature search strategy

In the primary literature search strategy, the MEDLINE, CINAHL, EMBASE, and Cochrane databases were sought out. Subsequently, a secondary search strategy was carried out using the articles listed in the references of meta-analysis, systematic, and non-systematic review articles that were captured in the primary search strategy.

Given that the first version of the ASIA Standards was published in 1982, the literature searches for this instrument addressed publications from 1982 to April 2009. The search strategy included the following specific terms: "ASIA Standards," "American Spinal Injury Association Standards," "ASIA score," and "American Spinal Injury Association score."

In a broad literature investigation, the searches for the instruments of pain assessments referred to publications since the beginning of the database records (1966) to April 2009. This search strategy included "pain" as the specific key word.

In both searches, the above specific key words were paired with the following medical subject headings: "spinal cord injury," "SCI," "tetraplegia," "quadriplegia," and "paraplegia." The literature search was limited to articles written in English.

Data abstraction and synthesis

In the culling process, two reviewers (JCF and VN) independently selected the articles that fulfilled the inclusion and exclusion for each topic. Disagreements were resolved by a consensus between both reviewers.

The relevant data from each selected article were extracted by a research assistant. Subsequently, both reviewers assessed all clinical studies with respect to the extracted data and, hereafter, determined the level of evidence according to the criteria of Sackett and colleagues (2000). Then, every instrument of assessment of impairment was examined with regard to its psychometric properties using the quality criteria from Terwee and colleagues (2007). Divergences during those steps were resolved by consensus between both reviewers.

Definitions of psychometric properties

In this systematic review, the psychometric properties were classified according to Terwee and co-workers (2007), as delineated in Table 1. *Content validity* refers to the extent to which items in the instrument comprehensively represent the concepts of interest (Guyatt et al., 1993). *Internal consistency* refers to the extent to which items in a instrument (sub)scale are homogenously correlated and, hence, measure the same concept (Terwee et al., 2007). *Criterion validity* refers to the degree to which the instrument measures in comparison with the criterion or "gold standard" (Furlan et al., 2008). Of note, criterion validity was not assessed in this review, due to the lack of gold standard for assessing impairment in patients with SCI. *Construct validity* is frequently divided into convergent or divergent. While *convergent construct validity* indicates the degree of similarity between two constructs that theoretically should be related to each other, *divergent construct validity* reveals how dissimilar two constructs are that in theory should not be related to each other (Furlan et al., 2008). *Reproducibility* refers to the degree to which repeated measurements in steady patients provide similar results (Terwee et al., 2007). Reproducibility is generally divided into agreement and reliability. While *agreement* reflects the absolute measurement error, *reliability* refers to the degree to which patients can be distinguished from each other regardless of measurement error (Terwee et al., 2007). *Responsiveness* concerns the ability of a measurement

Table 1. Quality Criteria for Psychometric Properties of Instruments[a]

Psychometric property	*Quality criteria*
1. Content validity	+ A clear description is provided of the measurement aim, the target population, the concepts that are being measured, and the item selection and target population and (investigators or experts) were involved in item selection. ? A clear description of above-mentioned aspects is lacking or only target population involved or doubtful design or method.[b] − No target population involvement. 0 No information found on target population involvement.
2. Internal consistency	+ Factor analyses performed on adequate sample size (7 * # items and ≥100) and Cronbach's alpha(s) calculated per dimension and Cronbach's alpha(s) between 0.70 and 0.95. ? No factor analysis or doubtful design or method.[b] − Cronbach's alpha(s) <0.70 or >0.95, despite adequate design and method. 0 No information found on internal consistency.
3. Criterion validity	+ Convincing arguments that gold standard is ''gold'' and correlation with gold standard ≥0.70. ? No convincing arguments that gold standard is ''gold'' or doubtful design or method.[b] − Correlation with gold standard <0.70, despite adequate design and method. 0 No information found on criterion validity.
4. Construct validity	+ Specific hypotheses were formulated and at least 75% of the results are in accordance with these hypotheses. ? Doubtful design or method[b] (e.g., no hypotheses). − Less than 75% of hypotheses were confirmed, despite adequate design and methods. 0 No information found on construct validity.
5. Reproducibility	+ MIC $<$ SDC or MIC outside the LOA or convincing arguments that agreement is cceptable.
5.1. Agreement	? Doubtful design or method[b] (or MIC not defined and no convincing arguments that agreement is acceptable). − MIC ≥ SDC or MIC equals or inside LOA, despite adequate design and method. 0 No information found on agreement.
5.2. Reliability	+ ICC or weighted kappa ≥0.70. ? Doubtful design or method[b] (e.g., time interval not mentioned). − ICC or weighted kappa <0.70, despite adequate design and method. 0 No information found on reliability.
6. Responsiveness	+ SDC or SDC $<$ MIC or MIC outside the LOA or RR ≤1.96 or AUC ≥0.70. ? Doubtful design or method.[b] − SDC or SDC ≥ MIC or MIC equals or inside LOA or RR ≤1.96 or AUC <0.70, despite adequate design and methods. 0 No information found on responsiveness.
7. Floor and ceiling effects	+ ≤15% of the respondents achieved the highest or lowest possible scores. ? Doubtful design or method.[b] − >15% of the respondents achieved the highest or lowest possible scores, despite adequate design and methods. 0 No information found on interpretation.
8. Interpretability	+ Mean and SD scores presented of at least four relevant subgroups of patients and MIC defined. ? Doubtful design or method[b] or less than four subgroups or no MIC defined. 0 No information found on interpretation.

[a]According to the criteria of Terwee and associates (2007).
[b]Doubtful design or method: lacking a clear description of the design or methods of the study, sample size smaller than 50 subjects (should be at least 50 in every (subgroup) analysis), or important methodological weakness in the design or execution of the study.
MIC, minimal important change; SDC, smallest detectable change; LOA, limits of agreement; ICC, intraclass correlation; SD, standard deviation; +, positive rating; ?, indeterminate rating; −, negative rating; 0, no information available.

instrument to accurately detect change when it has occurred (de Bruin et al., 1992). *Floor or ceiling effects* occur when more than 15% of examined patients reached the lowest or highest possible score, respectively (McHorney and Tarlov, 1995). Finally, *interpretability* concerns the degree to which one can assign qualitative meaning to quantitative scores (Lohr et al., 1996).

Establishment of recommendations

The authors answered the focused questions formerly compiled using the information summarized in the tables included here. Then, a panel of scientific experts in the field of acute SCI (including basic scientists, clinician-scientists, surgeons, rehabilitation specialists, nurses, and clinical epidemiologists) examined the summary tables and answers to the focused question, and eventually provided its evidence-based recommendations using a modified Delphi method (Reid, 1993).

Results

ASIA Standards

Of the 400 abstracts captured in our primary search strategy, 16 full articles fulfilled the inclusion and exclusion criteria and were reviewed by the two reviewers. An additional 40 references were obtained from a prior systematic review (Furlan et al., 2008).

While the majority of the studies on ASIA Standards provided level 4 evidence (45 of 56), there were 11 level 2b evidence studies (Table 2). Convergent construct validity ($n = 34$), reliability ($n = 12$), and responsiveness ($n = 10$) were the most commonly studied psychometric properties of the ASIA Standards, but two prior studies examined their content validity. Their item generation and reduction, as well as differences among the five versions of the ASIA Standards, are examined in detail elsewhere (Furlan et al., 2008).

Using the criteria of Terwee and colleagues (2007), the ASIA Standards were assessed with regard to their quality based on the literature (Table 3). Generally speaking, convergent and divergent construct validity was shown in several prior studies that examined the ASIA Standards in the SCI population, but criterion validity was not previously studied due to the lack of a gold standard for assessment of impairment. In general, the ASIA Standards were found to be reliable instruments for descriptive and evaluative purposes in the SCI population. However, two previous studies suggested that the ASIA Standards are not reliable for assessment of SCI children who are less than 4 years old (Mulcahey and Gaughan, 2005; Mulcahey et al., 2007a). Although the ASIA Standards appear to be responsive to changes in the patients' motor and sensory function, there are four major issues with regard to their responsiveness as follows: (1) a neurological examination using the ASIA Standards earlier than 72 h may not be appropriate; (2) the use of ASIA upper and lower extremity motor subscores appears to be more appropriate than the use of a single ASIA motor score; (3) the minimal clinically important difference of the ASIA Standards is unknown; and (4) the functionally meaningful ASIA score threshold to document the benefit of a novel therapeutic intervention varies according to the level and severity of SCI. Finally, the psychometric properties of the ASIA Standards were relatively well tested in the acute care, rehabilitation, and community settings.

Instruments of pain assessment

Of the 267 abstracts yielded in our primary search, 24 articles that fulfilled the inclusion and exclusion criteria were reviewed by the two reviewers. All 24 studies were level 4 evidence (Table 4). All those studies were carried out in the community or rehabilitation setting, but there was no study that examined pain assessment in the acute care setting. While 18 of 24 articles studied an instrument for assessment of pain intensity (Table 5), the remaining six studies focused on classifications of pain in the SCI population (Table 6). The visual analog scale (VAS) is the most commonly studied instrument of assessment of pain intensity in the SCI population. Although the construct validity of the VAS has been shown in several prior studies, further investigation is required with regard to its reliability and responsiveness in the SCI population. In addition to the paucity of studies on the classification instruments for pain in the SCI population, our results suggest that there is no instrument with appropriate psychometric properties for this particular population.

Discussion

Our systematic review indicates that the ASIA Standards represent an appropriate instrument to categorize and evaluate spinal cord injured adults over time with respect to their motor and sensory function. Nevertheless, further investigation of the psychometric properties of the ASIA Standards is recommended due to a lack of studies focused on some key elements of responsiveness. In addition, the visual analog scale (VAS) appears to be the most commonly studied instrument of assessment of pain intensity in the SCI population. Again, further investigation is required with regard to its reliability and responsiveness in the SCI population. Our results also suggest that there is no instrument with appropriate psychometric properties for this particular population.

ASIA Standards

The ASIA Standards are commonly used to classify and evaluate neurological deficit after SCI in both clinical and research arenas. In this systematic review, we identified 56 clinical studies that examine the psychometric properties of the ASIA standards in the assessment of motor and sensory function of patients with SCI. While convergent construct validity, reliability, and responsiveness were the most commonly studied psychometric properties of the ASIA Standards, criterion validity of the ASIA Standards was not assessed because there is no gold standard.

Generally speaking, the results of our systematic review suggest that the ASIA Standards is a reliable, valid, and responsive instrument for descriptive and evaluative purposes in the adult SCI population in the acute care, rehabilitation, and community settings. However, there are important issues with regard to reliability and responsiveness of the ASIA Standards that limit their use in particular circumstances. First, two previous prospective studies suggest the unsuitability of ASIA Standards for assessment of SCI in children who are under the age of 4 years (Mulcahey and Gaughan, 2005; Mulcahey et al., 2007a). Second, there are concerns with regard to the reliability of the ASIA Standards for assessments earlier than 72 h after acute SCI, due to previously reported variability when patients are examined within the first 24 h. Given this finding, it has been recommended that a 72 h assessment using ASI Standards should follow any earlier neurological evaluation of patients with acute SCI. Third, the use of ASIA upper and lower extremity motor sub-scores is recommended rather than a single ASIA motor score to reduce the floor to ceiling effects (Marino and Graves, 2004). An important precept of a multipart scale is an overall unidimensionality. When no hierarchy of components is considered in an outcome measure, the concept of unidimensionality may become weak because some components can deteriorate while others improve and there is no consideration of which are more important. This is particularly important when looking at changes in severity of impairment. Finally, to our knowledge, the minimal clinically important difference of the ASIA Standards remains unknown.

Table 2. Summary of Articles on ASIA Standards with Level of Evidence Included in Systematic Review

Reference	*Psychometric property*	*Sample size (no.)*	*Inclusion and exclusion criteria*	*Study population*	*Injury features*	*Version of ASIA Standards*	*LOE*
Lazar et al., 1989	Convergent construct validity (MBI)	78	Included all patients with SCI admitted within 72 h. Pts were excluded if they had TBI, history of neurologic disease or disability, other trauma that precluded examination, or rehabilitation interrupted by acute medical complication.	NR	Level of SCI • Cervical = 52 • Thoracic/lumbar = 26	1982 ASIA Standards	4
Schaefer et al., 1989	Convergent construct validity (MRI parameters)	78	Patients with cervical spine trauma admitted from Aug 1987 to Jan 1989 were included.	Mean age, 34 yr; age range, 11–91 yr; males/females, 64/14	Severity of SCI • Frankel A = 23 • Frankel B = 7 • Frankel C = 5 • Frankel D = 19 • Frankel E = 21 Cause of SCI • MVA = 28 • Fall = 17 • Diving = 15 • Fight = 6 • Sport = 6 • Stab = 3 • Other = 3	1982/1984 ASIA Standards (Frankel grading)	4
Donovan et al., 1990	Inter-rater reliability	5	NR	Mean age, 34 yr; median age, 27; males/females, 4/1	Level of SCI • Cervical = 3 • Thoracic/lumbar = 2 Mean time since SCI = 5 mo Median time since SCI = 5 mo Time since SCI = 5 wk–1 yr	1984 ASIA Standards	4

(*continued*)

Table 2. (Continued)

Reference	*Psychometric property*	*Sample size (no.)*	*Inclusion and exclusion criteria*	*Study population*	*Injury features*	*Version of ASIA Standards*	*LOE*
Flanders et al., 1990	Convergent construct validity (MRI parameters)	78	Consecutive patients with acute cervical spine trauma admitted during a 17-mo period were included. All cases must have had a demonstrable cervical fracture or subluxation or neurological deficit and had undergone MRI during initial admission. Pts were excluded if the MRI study had nondiagnostic results or if pt sustained additional SCI below C7.	Mean age, 34.3 yr; median age, 30 yr; males/females, 64/14	Severity of SCI • Frankel A = 23 • Frankel B = 8 • Frankel C = 5 • Frankel D = 18 • Frankel E = 24 Cause of SCI • MVA = 36% • Fall = 22% • Diving = 19% • Sports = 9% • Assaults = 14% Type of SCI • Central cord syndrome = 36% • Anterior cord syndrome = 9% • Brown-Sequard syndrome = 4% • Unknown = 31%	1982/1984 ASIA Standards (Frankel grading)	4
Brown et al., 1991	Responsiveness	29	Subjects with motor complete SCI who were admitted within 24 h after SCI from Jan 1985 to Dec 1988. Individuals who evolved to incomplete SCI were excluded.	Age range, 15 – 70 yr	Severity of SCI: motor complete (n = 29) Level: C4 to C7	1982 ASIA Standards	4
Priebe and Waring, 1991	Inter-rater reliability	5	Five subjects with varying degrees of SCI.	NR	Level of SCI: • Quadriplegia = 2 • Paraplegia = 3	1982 & 1989 ASIA Standards	4

Herbison et al., 1992	Responsiveness	40	Only patients with motor complete (Frankel A/B) cervical SCI who were admitted within 24 h after injury were included. Pts with fractures in tested extremities or pre-existing physical or psychological deficits that could affect examination were excluded.	Age range, 16–65 yr; males/females, 36/4	Severity of SCI • Frankel A = 30 • Frankel B = 10 Level of SCI • C4 = 14 • C5 = 9 • C6 = 14 • C7 = 3 Cause of SCI • MVA = 21 • Gunshot = 7 • Fall = 7 • Sport = 2 • Others = 3	1989 ASIA Standards	4
Silberstein et al., 1992	Convergent construct validity (MRI and CT scan parameters)	21	Patients with acute SCI who had MRI from 1987 to 1990. Pts were excluded if they had spinal surgery in the 1 yr after injury, MRI was unsatisfactory, clinical level was caudal to the conus medullaris, or more than one clinical level present.	Mean age, 34 yr; age range, 12–70 yr; males/females, 20/12	Severity of SCI • Frankel A = 23 • Frankel B = 3 • Frankel C = 3 • Frankel D = 3	1982/1984 ASIA Standards (Frankel grading)	4
Waters et al., 1992	Responsiveness	148	Patients with traumatic paraplegia (T2-L2 SCI) who were admitted from 1985 to 1990.	Mean age, 26.6 yr; age range, 18–48 yr; males/females, 136/12	Cause of SCI • Gunshot = 73 • MVA = 35 • Motorcycle = 13 • Fall = 19 • Other = 8 Mean time since SCI = 21.9 d Time since SCI = 3–60 d	1990 ASIA Standards	4

(*continued*)

Table 2. (Continued)

Reference	Psychometric property	Sample size (no.)	Inclusion and exclusion criteria	Study population	Injury features	Version of ASIA Standards	LOE
Bednarczyk and Sanderson, 1993	Convergent construct validity (Wheelchair Basketball Sports Test)	30	Only subjects with traumatic SCI were included. All individuals must be able to propel their wheelchair.	Mean age, 39 yr; • age range, 20–50 yr; males/females, 26/4	Severity of SCI • Complete = 20 • Incomplete = 10 Level of SCI: • Cervical = 9 • Thoracic = 15 • Lumbar = 6 Mean time since SCI = 74 mo Time since SCI = 4–203 mo	1989 ASIA Standards	2b
Blaustein et al., 1993	Responsiveness	26	Quadriplegic patients admitted from March 1988 to March 1990 were included. Pts with incomplete SCI (Frankel C or D), fractures in any extremity to be tested, previous psychiatric disease, TBI, or prior neurologic deficit were excluded.	Age range, 15–70 yr; males/females, 24/2	Level of SCI • C4 = 12 • C5 = 5 • C6 = 5 • C7 = 1 • C8 = 1 Severity of SCI • Frankel A = 19 • Frankel B = 7	1982 ASIA Standards	4
Marciello et al., 1993	Convergent construct validity (MRI parameters)	24	Subjects with cervical (C4-T1) SCI (Frankel A-D) who were admitted within 72 h and had a MRI within the first 10 d after SCI were included. Cases were excluded if the MRI was not diagnostic quality, or if neurological examination at 1 yr was incomplete.	Mean age, 30.4 yr; median age, 27 yr; age range, 17–62 yr	Severity of SCI • Frankel A = 14 • Frankel B = 2 • Frankel C = 4 • Frankel D = 4 Cause of SCI • Diving = 29% • MVA = 25% • Fall = 17% • Sports = 12.5% • Assaults = 12.5% • Farm = 4%	1982 ASIA Standards (Frankel grading)	2b

Marino et al., 1993	Convergent construct validity (QIF and FIM)	22	Included patients with traumatic cervical SCI admitted within the first 72 h of injury during the period from 1989 to 1991.	Mean age, 33 yr; age range, 18–63 yr	Severity of SCI • Frankel A = 4 • Frankel B = 11 • Frankel C = 2 • Frankel D = 5	1992 ASIA Standards	4
Waters et al., 1993	Inter-rater reliability; Responsiveness	55	Patients with complete (Frankel A) tetraplegia within 30 d from SCI who were admitted from 1985 to 1990.	Mean age, 25 yr; age range, 16–40 yr; males/females, 52/3	Level of SCI • Cervical = 48 • Thoracic = 4 • 2 vertebrae = 3 Cause of SCI • MVA = 21 • Gunshot = 17 • Fall = 4 • Diving = 4 • Other = 9	1990 ASIA Standards	4
Cohen and Bartko, 1994	Inter-rater/intra-rater reliability	32	NR	Age range, 18–65 yr; males/females, 32/0	Level & severity of SCI • Complete tetraplegia = 9 • Incomplete tetraplegia = 8 • Complete paraplegia = 9 • Incomplete paraplegia = 7 Time since injury = 3 mo–7 yr	1992 ASIA Standards	4
Waters et al., 1994a	Inter-rater reliability; Responsiveness	50	Consecutive patients with traumatic tetraplegia admitted from 1985 to 1990.	Mean age, 32.2 yr; age range, 18–59 yr; males/females, 41/9	Cause of SCI • MVA = 16 • Motorcycle = 4 • Fall = 9 • Gunshot = 11 • Other = 10	1992 ASIA Standards	4
Waters et al., 1994b	Convergent construct validity (gait performance and energy expenditure)	36	NR	Mean age, 29 yr; males/females, 30/6	Level & severity of SCI • Incomplete tetraplegia = 12 • Complete paraplegia = 4 • Incomplete paraplegia = 20 • Mean time since SCI = 0.5 yr	1992 ASIA Standards	4

(*continued*)

Table 2. (Continued)

Reference	*Psychometric property*	*Sample size (no.)*	*Inclusion and exclusion criteria*	*Study population*	*Injury features*	*Version of ASIA Standards*	*LOE*
Wells and Nicosia, 1995	Convergent construct validity (Neuro-trauma scale, Yale scale, MBI and FIM)	35	Consecutive patients with acute SCI were included.	NR	Level of SC • Cervical = 25 • Thoracic = 7 • Lumbar = 3 Severity of SCI • Complete = 16 • Incomplete = 19 • Cause of SCI • MVA = 17 • Fall = 10 • Sport = 6 • Other = 2	1982 ASIA Standards (Frankel grading)	4
Clifton et al., 1996	Intra-rater reliability	19	NR	Mean age, 30.4 yr; males/females, 14/5	Level of SCI • Cervical = 16 • Thoracic = 3 Severity of SCI • AIS A = 5 • AIS B = 11 • AIS C = 3 Mean time since SCI = 66.4 mo Time since SCI = 21–202 mo	1992 ASIA Standards	4
El Masry et al., 1996	Convergent construct validity (NASCIS motor score)	62	Only adult patients admitted within 7 d of acute SCI from Apr 1983 to Sept 1992 were evaluated.	Mean age, 34.1 yr; age range, 16–76 yr; males/females, 48/14	Level of SCI • Cervical/thoracic = 38 • Lumbar = 24 Mean time since SCI = 40.6 mo Time since SCI = 1–119 mo	1982/1984 ASIA Standards	2b
Ota et al., 1996	Convergent construct validity (FIM)	20	Included patients with complete (Frankel A/B) tetraplegia or paraplegia admitted from Jan 1990 to July 1995.	Mean age, 35 yr; males/females, 84/16	Level of SCI • Cervical = 48 • Thoracic = 52 Mean time since SCI = 29 mo	1992 ASIA Standards	4

Curt and Dietz, 1996	Convergent construct validity (SSEP)	69	Patients with acute/chronic traumatic tetraplegia who were admitted from 1992 to 1993 were included. Pts with TBI or lesions of the peripheral nervous system of the upper limbs (traumatic or nontraumatic) were excluded.	Acute-SCI group (n = 23): mean age, 40.2 yr; age range, 17–76 yr; males/females, 20/3. Chronic-SCI (n = 46): mean age, 39.7 yr; age range, 20–72 yr; males/females, 37/9	Acute-SCI group • Complete/incomplete SCI = 15:8 • Chronic-SCI group • Complete/incomplete SCI = 26:20	1992 ASIA Standards	4
Curt and Dietz, 1997	Convergent construct validity (SSEP)	104	Patients with acute SCI hospitalized for rehabilitation and outpatients with chronic SCI from 1992 to 1994 were included. Pts with nontraumatic diseases of the peripheral nervous system and cerebral lesions were excluded.	Acute-SCI group (n = 70): mean age, 42.6 yr (tetraplegics), 40.3 yr (paraplegics); males/females, 57/13. Chronic-SCI group (n = 34): mean age, 38.9 yr; males/females, 26/8	Level of SCI • Tetraplegia (acute-SCI group) = 31 • Paraplegia (acute-SCI group) = 39 Severity of SCI • Complete/incomplete SCI = 29:41 (acute-SCI group) and 15:19 (chronic-SCI group)	1992 ASIA Standards	4
Donovan et al., 1997	Inter-rater reliability	2	NR	Ages, 32 and 44 yr; males/females, 2/0	Level of SCI • Cervical = 1 • Lumbar = 1 Cause of SCI • MVA = 1 • Bike struck by car = 1	ASIA 1992 Standards	4
Ramon et al., 1997	Convergent construct validity (MRI parameters)	55	Subjects with acute traumatic SCI who were admitted from Jan 1990 to Dec 1993 and who underwent MRI within 15 d after trauma were included.	Mean age, 32.4 yr; age range, 14–76 yr; male, 80%	Severity of SCI • AIS A = 28 • AIS B = 7 • AIS C = 13 • AIS D = 7 Level of SCI • Cervical = 18 • Thoracic = 27 • T12 or lower = 10 Cause of SCI • MVA = 32 • Fall = 13	ASIA 1992 Standards (AIS)	4

(*continued*)

Table 2. (Continued)

Reference	*Psychometric property*	*Sample size (no.)*	*Inclusion and exclusion criteria*	*Study population*	*Injury features*	*Version of ASIA Standards*	*LOE*
Weinstein et al., 1997	Convergent construct validity (delayed plantar reflex)	36	Only patients with SCI admitted from July to Dec 1991, who were evaluated within 1 wk of injury, were included. Pts with lower extremity fractures, pre-existing neurologic deficits in the lower extremity, or lower motor neuron lesions were excluded.	Mean age, 36.1 yr; age range, 13–83 yr; males/females, 31/5	Severity of SCI • AIS A = 19 • AIS B = 6 • AIS C = 5 • AIS D = 6 Cause of SCI • MVA = 11 • Gunshot = 8 • Fall = 5 • Diving = 6 • Other = 6 Mean time since SCI = 1.2 days	ASIA 1992 Standards (AIS)	2b
Cohen et al., 1998	Inter-rater reliability	2	NR	NR	Case 1: complete tetraplegia Case 2: incomplete paraplegia	1992 ASIA Standards	4
Curt et al., 1998	Convergent construct validity (SSEP)	70	Only individuals with acute cervical (C2 to T1) SCI who were hospitalized and outpatients with chronic cervical SCI from 1993 to 1996 were selected. Individuals with diseases of the peripheral nervous system or cerebral lesions were excluded.	Acute-SCI group (n = 36): median age, 40.5 yr; age range, 17–77 yr; males/females, 31/5. Chronic-SCI group (n = 34): median age, 32 yr; age range, 18–73 yr; males/females, 26/8	Acute-stage group • Median time since injury = 25 d • Time since SCI = 1–110 d Chronic-stage group • Median time since SCI = 20.5 mo • Time since SCI = 6–310 d	1992 ASIA Standards	2b
Marino et al., 1998	Convergent construct validity (FIM); Intra-rater reliability; Internal consistency	154	Included patients age 16–70 yr, at least 1 yr after SCI, with motor level between C5 and T1, and followed by a regional SCI center.	Mean age, 36.7 yr; male, 91% White = 64%; African American = 31%; Hispanic = 3%; Other = 2%	Severity of SCI • AIS A = 60% • AIS B = 8% • AIS C = 16% • AIS D = 16%	1992 ASIA Standards	4

Toh et al., 1998	Convergent construct validity (Zancolli's classification)	70	Only patients with cervical SCI admitted from 1993 to 1995 were included.	Mean age, 42.2 yr; age range, 12–69 yr; males/females, 5/5	Severity of SCI • AIS A = 28 • AIS B = 16 • AIS C = 26 Mean time since SCI = 4.5 yr Time range = 2–24 yr	1992 ASIA Standards (Frankel grading)	4
Yavuz et al., 1998	Convergent construct validity (QIF and FIM)	29	Only patients with traumatic cervical SCI admitted May 1994–January 1996.	Mean age, 37 yr; age range, 14–66 yr; males/females, 20/9	Levels of SCI • Cervical = 28 • Thoracic = 1 Severity of SCI • Complete = 18 • Incomplete = 11 Cause of SCI • MVA = 51.7% • Falls = 13.8%	1992 ASIA Standards	4
Fujiwara et al., 1999	Convergent construct validity (FIM)	14	Only patients with complete C6 SCI discharged from 1995 to 1997 were included.	Mean age, 30.7 yr; age range, 13–62 yr; males/females, 12/2	Level of SCI • C6 = 14 Severity of SCI • Complete = 14 Mean time since SCI = 462 d Time since SCI = 169–1080 yr	1992 ASIA Standards	4
Iseli et al., 1999	Convergent construct validity (SSEP)	67	Patients with acute traumatic SCI between T1-L5 who were admitted from 1992 to 1994 and pts with acute ischemic myelopathic SCI admitted from 1985 to 1997. In both pt groups accompanying nontraumatic diseases of the peripheral nervous system and cerebral lesions were excluded.	Trauma group (n = 39): Mean age, 40.01 yr; males/females, 30/9. Non-trauma group (n = 28): mean age, 56.07 yr; males/females, 24/4	Trauma group • Complete/incomplete = 1:1.29 Non-trauma group • Complete/incomplete ratio = 1:1.33	1992 ASIA Standards	2b
Marino and Goin, 1999	Convergent construct validity (QIF)	95	Consecutive patients with tetraplegia, nonambulatory at 6 mo, who were admitted from Dec 1987 to Aug 1992, were included.	Mean age, 31.2 yr; age range, 16–86 yr; males/females, 85/10	Severity of SCI • Frankel A = 60 • Frankel B = 23 • Frankel C = 7 • Frankel D = 12	1992 ASIA Standards	4

(*continued*)

Table 2. (Continued)

Reference	*Psychometric property*	*Sample size (no.)*	*Inclusion and exclusion criteria*	*Study population*	*Injury features*	*Version of ASIA Standards*	*LOE*
Marino et al., 1999	Responsiveness	3585	Patients with SCI admitted within 1 wk of injury from Jan 1988 to Dec 1997 were included.	Mean age, 32.1 yr; male, 82.2%. White = 53.2%; African American = 28.9%; Hispanic = 15%; Other = 2.9%	Level and severity of SCI • Tetraplegia−complete = 19.8% • Tetraplegia−incomplete = 28.4% • Paraplegia−complete = 30% • Paraplegia−incomplete = 21.8% Cause of SCI • MVA = 36.9% • Violence = 29.3% • Fall = 21.9% • Sports = 7.8% • Pedestrian = 2.2% • Other = 1.9%	1992 ASIA Standards (AIS)	4
Shimada and Tokioka, 1999	Convergent construct validity (MRI parameters)	75	NR	Mean age, 54.7 yr; age range, 19–89 yr; males/females, 66/9	Severity of SCI • AIS A = 22 • AIS B = 32 • AIS C = 16 • AIS D = 7	1992 ASIA Standards (AIS)	4
Jonsson et al., 2000	Inter-rater reliability	23	Only patients classified as SCI through magnetic resonance tomography were selected. Pts must also be able to communicate adequately to participate. Malignant or other progressive lesion was an exclusion criterion.	Males/females, 15/8	Level of SCI • Cervical = 12 • Thoracic = 6 • Lumbar = 5 Severity of SCI • Complete = 3 • Incomplete = 20 Cause of SCI • Traumatic = 17 • Nontraumatic = 6 Mean time since injury = 7.8 d Time range = 1–14 d	1992 ASIA Standards	4

Kucukdeveci et al., 2000	Convergent construct validity (MBI)	100 (50 SCI, 50 stroke)	Included consecutive patients with stroke or SCI admitted from 1993 to 1997.	SCI group: mean age, 31.5 yr; male, 44%. Stroke group: mean age, 58 yr; male, 26%	Level of SCI • Cervical = 22% • Thoracic = 46% • Lumbar = 32% Mean time since SCI = 3.6 mo Time since SCI = 1–24 mo	1992 ASIA Standards	4
Geisler et al., 2001	Responsiveness	760	Included all patients with SCI admitted from Apr 1992 to Jan 1997 who were enrolled in the Sygen trial. Excluded pts with SCI rostral to the T10 bony level, that at least one lower extremity has ASIA motor score <15 of 25, and anatomical transactions.	Mean age, 32.6 yr; median age, 30 yr; age range, 11–69 yr; males/females, 609/151. White = 529; Black = 160; Asian = 10; Other = 59	Level of SCI • Cervical = 579 • Thoracic = 181 Severity of SCI • AIS A = 482 • AIS B = 131 • AIS C/D = 147 Cause of SCI • MVA = 411 • Fall = 123 • Water related = 83 • Gunshot = 35 • Other = 108	1992 ASIA Standards	2b
Kirshblum et al., 2002	Content validity	94	All patients with traumatic SCI admitted since 1992. Subjects with concomitant injuries who did not allow a complete and accurate neurologic examination, initial examinations >7 d after SCI and follow-up neurologic exams <1yr or >2 yr after SCI were excluded.	Males/females, 87/7	Level of SCI • Tetraplegia = 47 • Paraplegia = 47 Severity of SCI • Complete = 50 • Incomplete = 44	1996 & 2000 ASIA Standards	4

(*continued*)

Table 2. (Continued)

Reference	*Psychometric property*	*Sample size (no.)*	*Inclusion and exclusion criteria*	*Study population*	*Injury features*	*Version of ASIA Standards*	*LOE*
Takahashi et al., 2002	Convergent construct validity (MRI parameters)	43	Subjects with traumatic C3-4 SCI without radiographic abnormalities who were admitted from Jan 1993 to Dec 2000 were included.	Mean age, 63.4 yr; age range, 26–82 yr; males/females, 41/2	Severity of SCI • AIS A = 9 • AIS B = 25 • AIS C = 9 Cause of SCI • Fall = 25 • MVA = 13 • Other = 5	1996 Standards (AIS)	4
Burns et al., 2003	Responsiveness	103	Only patients with traumatic motor complete (AIS A/B) SCI who were admitted from 1995 to 1997 and had baseline exam within 48 h after injury and follow-up exam prior to discharge were included.	Mean age, 36.2 yr; median age, 30 yr; males/females, 90/13	Severity of SCI • AIS A = 81 • AIS B = 22 Cause of SCI • Fall = 32 • MVA = 29 • Gunshot = 28 • Sports = 14	1992 ASIA Standards	2b
Kirshblum et al., 2004	Responsiveness	987	Included patients with traumatic SCI who were admitted from 1988–1997.	Mean age, 31 yr	Severity of SCI (at 1 yr post-trauma) • AIS A = 571 • AIS B = 114 • AIS C = 121 • AIS D = 181	1989, 1992, 1996 & 2000 ASIA Standards	4
Marino and Graves, 2004	Convergent construct validity	4338	Subjects with traumatic SCI, AIS A-D, discharged between 1/1/1994 to 3/31/2003 were included.	Median age, 33 yr Males/females, 3443/895 White = 60.6%; African American = 25.8%; Other = 13.6%	Level & severity of SCI • Tetraplegia−complete = 19.7% • Tetraplegia−incomplete = 33.8% • Paraplegia−complete = 27.5% • Paraplegia−incomplete = 19% Cause of SCI • MVA = 43.9% • Falls = 24.7% • Violence = 18.5% • Other/unknown = 12.9% Median time since SCI = 15 d	1992 ASIA Standards	4

Johnston et al., 2005	Convergent and divergent construct validity (Short Form-12, Satisfaction with Life Scale, Craig Handicap Assessment and Reporting Technique, and Test of Functional, Health Literacy in Adults)	107	Only community-living adult (18 yr or older) people with traumatic SCI (AIS A-D) living in NJ area were included. Subjects with <6 mo since SCI, inability to read, inability to speak English or Spanish, unintelligible speech, uncontrolled psychiatric disease, and uncooperative were excluded.	Mean age, 39.1 yr; median age, 38 yr; male, 82.2%. White = 66.4%; African American = 26.2%; Asian/Pacific Islander = 2.8%; Other = 4.7%	Level & severity of SCI • Tetraplegia−motor complete = 38.7% • Tetraplegia−incomplete = 15.1% • Paraplegia−motor complete = 37.6% • Paraplegia−incomplete = 8.6% Severity of SCI • AIS A = 56.4% • AIS B = 20.2% • AIS C = 14.9% • AIS D = 8.5% Mean time since SCI = 11.36 yr Median time since SCI = 9.56 yr	2000 ASIA Standards	4
Oleson et al., 2005	Convergent construct validity (Benzel grading)	131	All patients with AIS-B SCI who were enrolled in Sygen trial were included.	Mean age, 31.6 yr; males/females, 106/25	Level of SCI • Cervical = 113 • Thoracic = 18 Cause of SCI • MVA = 60 • Water related = 26 • Fall = 19 • Other = 26	1992 ASIA Standards	4
Tewari et al., 2005	Convergent construct validity (MRI parameters)	40	Only patients with SCI without radiographic abnormality who were admitted from Jan 1999 to Dec 2000 were included.	Mean age, 42.1 yr; age range, 16–70 yr; male-female, 3.4:1	Severity of SCI • Frankel A = 7 • Frankel B = 9 • Frankel C = 20 • Frankel D = 4 Cause of SCI • MVA = 60% • Fall = 32.5% • Work = 7.5%	1982 ASIA Standards (Frankel grading)	4

(continued)

Table 2. (Continued)

Reference	*Psychometric property*	*Sample size (no.)*	*Inclusion and exclusion criteria*	*Study population*	*Injury features*	*Version of ASIA Standards*	*LOE*
Boldin et al., 2006	Convergent construct validity (MRI parameters)	29	Patients with traumatic, closed cervical SCI admitted from Sept 1996 to Sept 2001 were included. Pts with normal neurological examination were excluded.	Mean age, 43.5 yr; age range, 18–86 yr; males/females, 19/10	Cause of SCI • MVA = 13 • Fall = 11 • Sports = 3 • Diving = 2	1992 ASIA Standards	2b
Graves et al., 2006	Content validity	6116	Only records from National Spinal Cord Injury Statistical Center Database from 1993 to 2003 were included.	Mean age, 36 yr; male, 80%. White = 62%; African American = 26%; Hispanic = 10%; Other = 2%	48% paraplegia at the time of discharge from rehabilitation	1992 ASIA Standards	4
Ditunno et al., 2007	Convergent construct validity (WISCI II)	146	Included patients with incomplete (AIS B/C/D) SCI at C4 to L3 levels admitted to inpatient rehabilitation, who were enrolled in the SCI Locomotor Trial.	Mean age, 32 yr; age range, 16–69 yr; male, 78%	Level of SCI • Cervical = 58% • Thoracic = 18% • Lumbar = 24% Severity of SCI • AIS B = 36 • AIS C = 90 • AIS D = 20	2002 ASIA Standards	4
Mulcahey et al., 2007a	Inter-rater reliability	5	Subjects represented a convenience sample between 15 and 18 yr and at least 1 yr post-SCI.	Mean and median ages, 17 yr; age range, 15–19 yr	Level of SCI • Cervical = 3 • Thoracic = 2 Severity of SCI • AIS A = 2 • AIS B = 2 • AIS C = 1	2000 ASIA Standards	4

Mulcahey et al., 2007b	Intra-rater reliability	74	Only children and youths with stable SCI were included. Children with a TBI and other co-morbidities that interfered with the cognitive ability to follow standard testing instructions were excluded.	Age range, 8 mo–21 yr: 8 mo–5 yr (n = 13); 6–11 yr (n = 19); 12–15 yr (n = 18); 16–21yr (n = 24)	Level & severity of SCI • Tetraplegia−complete = 16 • Tetraplegia−incomplete = 9 • Paraplegia−complete = 37 • Paraplegia−incomplete = 8 • Unknown = 6	2000 ASIA Standards	2b
Miyanji et al., 2007	Convergent construct validity (MRI parameters)	100	Consecutive patients with cervical spine trauma admitted from Mar 2000 to Mar 2005 were included. Pts with TBI and a Glasgow coma score <15 were excluded.	Mean age, 45 yr; age range, 17–96 yr; males/females, 79/21	Severity of spine trauma • Complete SCI (AIS A) = 26 • Incomplete SCI (AIS B-D) = 51 • Normal (AIS E) = 22 • Unknown = 1 Level of spine trauma • C1-C2 = 2 • C2-C3 = 1 • C3-C4 = 6 • C4-C5 = 12 • C5 = 5 • C5-C6 = 25 • C6 = 3 • C6-C7 = 8 • Multiple levels = 17 • Unknown = 2 Cause of spine trauma • MVA = 42 • Fall = 34 • Sports/leisure = 16 • Other = 8	1996 ASIA Standards	2b
Savic et al., 2007	Inter-rater reliability	45	NR	Mean age, 40.3 yr; age range, 18–72 yr; males/females, 38/7	Level of SCI • Cervical = 15 • Thoracic = 29 • Lumbar = 1 Severity of SCI • AIS A = 24 • AIS B = 4 • AIS C = 4 • AIS D = 13 Time since SCI = 3 mo–43 yr	2000 ASIA Standards	4

(*continued*)

Table 2. (Continued)

Reference	Psychometric property	Sample size (no.)	Inclusion and exclusion criteria	Study population	Injury features	Version of ASIA Standards	LOE
Ditunno et al., 2008	Convergent construct validity (WISCI II and locomotor FIM)	150	Included patients with acute traumatic SCI at C2 to L3 levels who were admitted within 1 mo of injury and followed 6–12 mo after hospital discharge. Excluded patients with significant TBI, upper/lower extremity fracture, an immobilization device that precluded complete neurological examination, and those with WISCI = 20 on the initial evaluation.	NR	Severity of SCI • AIS A = 59 • AIS B = 19 • AIS C = 32 • AIS D = 40 Level of SCI • Tetraplegia = 84 • Paraplegia = 66	1992 ASIA Standards	4
Wirth et al., 2008	Convergent construct validity (SCIM)	100	Included only patients with traumatic, persistent motor complete (AIS A/B) SCI during a 1-year follow-up examination after injury.	Mean age, 37.7 yr; males/females, 74/26	Level of SCI • Tetraplegia = 36 • Paraplegia = 64	1996 ASIA Standards	4

AIS, ASIA impairment scale; ASIA, American Spinal Injury Association; CT, computed tomography; FIM, functional independence measure; LOE, level of evidence; MBI, modified Barthel index; MRI, magnetic resonance imaging; MVA, motor vehicle accident; NASCIS, National Acute Spinal Cord Injury Study; NR, not reported; pt(s), patient(s); QIF, quadriplegia index of function; SCI, spinal cord injury; SCIM, spinal cord independence measure; SSEP, somatosensory evoked potentials; TBI, traumatic brain injury; WISCI, walking index for spinal cord injury.

TABLE 3. SUMMARY OF QUALITY ASSESSMENT OF EACH INSTRUMENT[a]

Reference	*Instrument*	*Content validity*	*Internal consistency*	*Construct validity*	*Agreement*	*Reliability*	*Responsiveness*	*Floor/ceiling effect*	*Interpretability*	*Setting*
Lazar et al., 1989	1982 ASIA Standards			(+)						Rehabilitation
Schaefer et al., 1989	1982/1984 ASIA Standards (Frankel grading)			(?)						Acute care
Donovan et al., 1990	1984 ASIA Standards					(−) Inter-rater				Rehabilitation
Flanders et al., 1990	1982/1984 ASIA Standards (Frankel grading)			(+)						Acute care
Brown et al., 1991	1982 ASIA Standards						(?) (24 h vs. 72 h)			Acute care
Priebe and Waring, 1991	1982/1989 ASIA Standards (Frankel grading)					(−) Inter-rater				NR
Herbison et al., 1992	1989 ASIA Standards						(+) (24 h vs. 72 h vs. 1 wk)			Acute care
Silberstein et al., 1992	1982/1984 ASIA Standards (Frankel grading)			(+)						Acute care
Waters et al., 1992	1989 ASIA Standards						(+)			Rehabilitation
Bednarczyk and Sanderson, 1993	1989 ASIA Standards			(+)						Rehabilitation & community
Blaustein et al., 1993	1982 ASIA Standards						(+) (24 h = 72 h)			Acute care
Marciello et al., 1993	1982 ASIA Standards (Frankel grading)			(+)						Acute care
Marino et al., 1993	1982 ASIA Standards			(+)						Acute care & rehabilitation
Waters et al., 1993	1990 ASIA Standards					(?) Intra-rater	(+)			Acute care & rehabilitation
Cohen and Bartko, 1994	1992 ASIA Standards					(+) Intra rater for motor, LT, PP (+ to −) inter rater for motor, LT, PP				Rehabilitation & community
Waters et al., 1994a	1992 ASIA Standards					(?) Intra-rater	(+)			Acute care & rehabilitation

(*continued*)

Table 3. (Continued)

Reference	*Instrument*	*Content validity*	*Internal consistency*	*Construct validity*	*Agreement*	*Reliability*	*Responsiveness*	*Floor/ ceiling effect*	*Interpretability*	*Setting*
Waters et al., 1994b	1992 ASIA Standards			(+)						Rehabilitation
Wells and Nicosia, 1995	1982 ASIA Standards (Frankel grading)			(+)						Acute care
Clifton et al., 1996	1992 ASIA Standards					(?) Intra-rater				Rehabilitation
Curt and Dietz, 1996	1992 ASIA Standards			(+)						Acute care & rehabilitation
El Masry et al., 1996	1982/1984 ASIA Standards			(+)						Rehabilitation
Ota et al., 1996	1992 ASIA Standards			(?)						Rehabilitation
Curt and Dietz, 1997	1992 ASIA Standards			(+)						Acute care & rehabilitation
Donovan et al., 1997	1992 ASIA Standards					(0) Inter-rater				Acute care
Ramon et al., 1997	1992 ASIA Standards (AIS)			(+)						Acute care
Weinstein et al., 1997	1992 ASIA Standards (AIS)			(+)						Acute care
Cohen et al., 1998	1992 ASIA Standards					(?)				NR
Curt et al., 1998	1992 ASIA Standards			(+)						Rehabilitation
Marino et al., 1998	1992 ASIA Standards		(−)	(+)		(+) Intra-rater				Rehabilitation
Toh et al., 1998	1992 ASIA Standards (Frankel grading)			(+)						Rehabilitation
Yavuz et al., 1998	1992 ASIA Standards			(+)						Rehabilitation
Fujiwara et al., 1999	1992 ASIA Standards			(+)						Rehabilitation
Iseli et al., 1999	1992 ASIA Standards			(+)						Rehabilitation
Marino et al., 1999	1992 ASIA Standards (AIS)						(+)			Rehabilitation
Marino and Goin, 1999	1992 ASIA Standards			(+)						Rehabilitation
Shimada and Tokioka, 1999	1992 ASIA Standards			(+)						Acute care
Jonsson et al., 2000	1992 ASIA Standards					Inter-rater: (+to −) pin-prick (+to −) light touch (+to −) motor				Rehabilitation

Kucukdeveci et al., 2000	1992 ASIA Standards		(+)					Rehabilitation
Geisler et al., 2001	1992 ASIA Standards					(+)		Acute care & rehabilitation
Kirshblum et al., 2002	1996/2000 ASIA Standards	(+)						Rehabilitation
Takahashi et al., 2002	1992 ASIA Standards (AIS)		(+)					Acute care & rehabilitation
Burns et al., 2003	1992 ASIA Standards					(+) (≤48 h vs. > 48 h)		Acute care
Kirshblum et al., 2004	1989, 1992, 1996, 2000 ASIA Standards					(+) (1 yr = 5 yr)		Rehabilitation & community
Marino and Graves, 2004	1992 ASIA Standards		(+)				(−) for motor subscores	Rehabilitation
Johnston et al., 2005	2000 ASIA Standards		(+)					Community
Oleson et al., 2005	1992 ASIA Standards		(+)					Acute care & rehabilitation
Tewari et al., 2005	1982 ASIA Standards (Frankel grading)		(+)					Acute care
Boldin et al., 2006	1992 ASIA Standards		(+)					Acute care
Graves et al., 2006	1992 ASIA Standards	(+)						Rehabilitation
Ditunno et al., 2007	2002 ASIA Standards		(+)					Rehabilitation
Mulcahey et al., 2007a	2000 ASIA Standards				(+) Inter-rater			Community
Mulcahey et al., 2007b	2000 ASIA Standards				(+) Intra-rater			NR
Miyanji et al., 2007	1996 ASIA Standards		(+)					Acute care
Savic et al., 2007	2000 ASIA Standards			(+)	(+) Inter-rater			Rehabilitation
Ditunno et al., 2008	1992 ASIA Standards		(+)					Acute care
Wirth et al., 2008	1996 ASIA Standards		(+)					Rehabilitation

[a]According to the criteria of Terwee and associates.
(+) positive rating; (−) negative rating; (?) indeterminate rating due to lack of information or poor study design/method; NA, not applicable; NR, not reported.

Table 4. Summary of Articles on Pain Assessment with Level of Evidence Included in Systematic Review

Reference	Psychometric property	Sample size (no.)	Inclusion and exclusion criteria	Study population	Injury features	Instrument	LOE
Davidoff et al., 1987	Convergent construct validity	166 total DPS = 19 MRSCICS = 147	Patients with DPS of at least 1 mo, who failed to respond to conventional treatments, and had: disturbance of sleep-wake cycle, inability to perform self-care activities, or inability to fully comply with a therapeutic exercise program. Pts with traumatic myelopathy were excluded.	Mean age (DPS), 36.6 yr; mean age (MRSCICS), 32 yr	Level of injury • Tetraplegia (DPS) = 15.8% • Tetraplegia (MRSCICS) = 54.4% Severity of injury • Complete (DPS) = 26.3% • Complete (MRSCICS) = 48.6%	MPQ, Sternbach Pain Intensity, Zung Pain, and Distress Index	4
Cohen et al., 1988	Convergent construct validity	147 total SCI = 49	Patients with at least 6-mo history of chronic pain were included.	Mean age (SCI), 47.2 yr; male (SCI), 95%	NR	MPQ	4
Song et al., 1993	Convergent construct validity	47 total SCI = 31	Included individuals with traumatic SCI at T1 or below, without central or peripheral nerve disease, and without recent history of ethanol abuse. In addition, a SCI subgroup included individuals with DPS after SCI. Control group included healthy volunteers.	SCI & pain: mean age, 57 yr; range, 32 – 70 yr; SCI, no pain: mean age, 57 yr; range, 33–73 yr; Controls: mean age, 50 yr; range, 30–73 yr	SCI & pain: level of SCI = T1-L4 SCI, no pain: level of SCI = T1-L3	VAS	4
Curtis et al., 1995	Internal consistency	64 total SCI = 57	Patients with wheelchairs as their primary means of mobility for at least 1 yr were included.	Mean age, 42.9 yr; males/females, 62/2	Level of injury • Cervical = 13 • Thoracic = 38 • Lumbar = 6	Wheelchair Users Shoulder Pain Index	4
Quigley and Veit, 1996	Convergent construct validity	27	All SCI patients with complete data were included.	Mean age, 47 yr; males/females, 26/1	Level of injury • Tetraplegia = 9 • Paraplegia = 18	McGill-Melzack Pain Questionnaire	4
Kennedy et al., 1997	Convergent construct validity	76	Included all patients with traumatic SCI between 16 and 65 yr	Male, 76%	Level of injury • Tetraplegia = 32% • Paraplegia = 68%	6-point Likert scale	4

Widerstrom-Noga et al., 2001	Convergent construct validity	217	Included all SCI individuals with chronic pain who had complete data in the Miami Project Database and answered survey.	Mean age, 39 yr; male, 75.4%	Level of injury • Tetraplegia = 54% • Paraplegia = 46% Mean time since SCI = 8.2 yr	VAS	4
Defrin et al., 2001	Convergent construct validity	39 total SCI = 21	Included individuals with incomplete traumatic SCI at L3-T4 and healthy volunteers.	SCI & pain: mean age, 38.9 yr SCI, no pain: mean age, 37.6 yr Controls: mean age, 35.6 yr	NR	VAS	4
Cardenas et al., 2002	Inter-rater reliability	163	Included SCI patients age 18 or older whose data were collected in the Northwest Regional Spinal Cord Injury System.	Mean age, 40.6 yr (males), 43.9 yr (females); male, 69.9%	Cause of injury • MVA = 49.1% • Fall = 19.6% Mean years since SCI = 8.3	Pain classification	4
Putzke et al., 2002	Convergent construct validity	29	Adults with traumatic SCI who experienced at least one pain site.	Mean age, 45.2 yr; males/females, 24/5	Level of injury • Paraplegia = 22 • Tetraplegia = 7 Severity of injury • Complete = 14 • Incomplete = 15	Verbal descriptors	4
Richards et al., 2002	Inter-rater reliability	28	Adults with traumatic SCI who developed chronic pain in 1 or more sites at 1 yr after SCI were included. Pts with a fourth grade reading level or lower or history of TBI or chronic pain prior to SCI were excluded.	Mean age, 45.5 yr; males/females, 23/5	Level of injury Paraplegia = 21 • Tetraplegia = 7 Severity of injury • Complete = 13 • Incomplete = 15	Donovan Pain Classification Scheme	4
Turner et al., 2002	Convergent construct validity	174	Included SCI individuals with chronic pain who had data collected in the Northwest Regional SCI System and answered survey.	Mean age, 41.5 yr; male, 70.7%	Level of injury • Tetraplegia = 54% • Paraplegia = 46% Time since SCI = 8.1 yr	VAS	4
Putzke et al., 2003a	Test-retest reliability; Inter-rater reliability	28	Adults with traumatic SCI and chronic pain were included. Pts with fourth grade reading level or lower or history of TBI or chronic pain prior to SCI were excluded.	Mean age, 45.5 yr; males/females, 23/5	Level of injury • Paraplegia = 21 • Tetraplegia = 7 Severity of injury • Complete = 13 • Incomplete = 15	Donovan Pain Classification Scheme	4

(*continued*)

Table 4. (Continued)

Reference	Psychometric property	Sample size (no.)	Inclusion and exclusion criteria	Study population	Injury features	Instrument	LOE
Putzke et al., 2003b	Inter-rater reliability	29	Adults with traumatic SCI and chronic pain were included. Pts with fourth grade reading level or lower or history of TBI orchronic pain prior to SCI were excluded.	Mean age, 45.2 yr; males/females, 24/5	Level of injury • Paraplegia = 22 • Tetraplegia = 7 Severity of injury • Complete = 14 • Incomplete = 15	International Assoc. for the Study of Pain and Tunks SCI pain classification	4
Samuelsson et al., 2004	Convergent construct validity	66	Only individuals with paraplegia for more than 1 yr were included.	Mean age, 49 yr; males/females, 44/12	All paraplegics, mean time since SCI = 13.9 yr	Constant Murley Scale	4
Roth et al., 2004	Convergent construct validity	69 total SCI = 12	Only hospital inpatients, outpatients, or nursing home residents with chronic stage 2, 3, or 4 pressure sores were included. Patients with mental incompetence were excluded.	Mean age, 59 yr; male, 100%	NR	MPQ	4
Hanley et al., 2006a	Convergent construct validity	481	Included adults (18 yr or older) with a chronic SCI (>6 mo since injury).	Mean age, 42.6 yr; male, 72%	NR	VAS	4
Bryce et al., 2006	Inter-rater reliability	39	NR	NR	NR	Bryce/Ragnarsson SCI Pain Taxonomy	4
Raichle et al., 2006	Convergent construct validity	127	SCI patients with pain were included.	Mean age, 48.6 yr; males/female, 92/35	Level of injury • Cervical = 58 • Thoracic = 56 • Lumbosacral = 1 • Other = 13	VAS	4
Salisbury et al., 2006	Convergent construct validity	27	Individuals with tetraplegia between 2 and 4 yr post-SCI under rehabilitation.	Mean age, 42.5 yr; males/females, 20/7	All tetraplegics	VAS, MPQ, and Wheelchair Users Shoulder Pain Index	4

Widerstrom-Noga et al., 2006	Convergent construct validity	161	Adults with traumatic SCI and chronic pain were included.	Mean age, 43.5 yr; males/females, 138/23	Level of Injury • Cervical = 76 • Below cervical = 84 • Unknown = 1 Severity of injury • Complete = 93 • Incomplete = 50 • Unknown = 18	Multidimensional Pain Inventory-SCI version	4
Budh and Osteraker, 2007							
Attal et al., 2008	Content validity	482 total SCI = 78	Included adults with pain due to primary lesion of the peripheral or central nervous system.	Mean age, 57 yr; males/females, 258/224	NR	Neuropathic Pain Symptom Inventory	4
Hanley et al., 2008	Convergent construct validity	40	Adults with traumatic SCI and chronic pain were included.	Mean age, 49.3 yr; male, 70%	Level of injury • Cervical = 48% • Thoracic = 42% • Lumbosacral = 10% Severity of injury • Complete = 40% • Incomplete = 50% • Unknown = 10% Cause of injury • MVA = 30% • Fall = 18% • Diving = 10% • Sports = 8% • Gunshot = 8% • Other = 36%	VAS	4

DPS, dysestheic pain syndrome; LOE, level of evidence; MPQ, McGill Pain Questionnaire; MRSCICS, Midwest Regional Spinal Cord Injury Care System; MVA, motor vehicle accident; NR, not reported; pt(s), patient(s); SCI, spinal cord injury; TBI, traumatic brain injury; VAS, visual analog scale.

Table 5. Summary of Quality Assessment of Pain Intensity Instrument[a]

Reference	*Instrument*	*Content validity*	*Internal consistency*	*Construct validity*	*Agreement*	*Reliability*	*Responsiveness*	*Floor/ ceiling effect*	*Interpretability*	*Setting*
Davidoff et al., 1987	McGill Pain Questionnaire			(?)					(−)	Rehabilitation & community
Cohen et al., 1988	McGill Pain Questionnaire			(+)					(−)	Rehabilitation
Roth et al., 2004	McGill Pain Questionnaire			(+)						Rehabilitation
Salisbury et al., 2006	McGill Pain Questionnaire			(+)						Community
Quigley and Veit, 1996	McGill-Melzack Pain Questionnaire			(+)					(−)	Rehabilitation & community
Davidoff et al., 1987	Zung Pain and Distress Index			(?)					(−)	Rehabilitation & community
Kennedy et al., 1997	6-point Likert scale			(+to −)						Rehabilitation
Samuelsson et al., 2004	Constant Murley Scale			(+)						Community
Widerstrom-Noga et al., 2006	Modified West Haven-Yale Multi-dimensional Pain Inventory		(+to −)	(+)		(+to −) Test-retest				Rehabilitation & community
Attal et al., 2008	Neuropathic Pain Symptom Inventory		(+)	(+)					(?)	Rehabilitation
Davidoff et al., 1987	VAS (0 to 100)			(?)					(−)	Rehabilitation & community
Song et al., 1993	VAS (0 to 100)			(+)						Rehabilitation
Budh and Osteraker, 2007	VAS (0 to 100)			(+)						Rehabilitation
Defrin et al., 2001	VAS (0 to 10)			(+)						NR
Widerstrom-Noga et al., 2001	VAS (0 to 10)			(+)						Community
Turner et al., 2002	VAS (0 to 10)			(+)						Community
Roth et al., 2004	VAS (0 to 10)			(+)						Rehabilitation
Raichle et al., 2006	VAS (0 to 10)			(?)						Community
Salisbury et al., 2006	VAS (0 to 10)			(+)						Community
Hanley et al., 2006b	VAS (0 to 10)			(+to -)						Community
Hanley et al., 2008	VAS (0 to 10)			(+)						Community
Curtis et al., 1995	WUSPI	(+)	(+)							Community
Samuelsson et al., 2004	WUSPI			(+)						Community
Salisbury et al., 2006	WUSPI			(+)						Community

[a]According to the criteria of Terwee and associates (2007).
(+) positive rating; (−) negative rating; (?) indeterminate rating due to lack of information or poor study design/method; NA, not applicable; NR, not reported; VAS, visual analog scale; WUSPI, Wheelchair User Shoulder Pain Index.

Table 6. Summary of Quality Assessment of Pain Classification Instrument[a]

Reference	*Instrument*	*Content validity*	*Internal consistency*	*Construct validity*	*Agreement*	*Reliability*	*Responsiveness*	*Floor/ ceiling effect*	*Interpretability*	*Setting*
Cardenas et al., 2002	Cardenas Pain classification					(−) Inter-rater				Community
Putzke et al., 2002	IASP classification			(−)						Rehabilitation & community
Putzke et al., 2003b	IASP classification					(−) Inter-rater				Rehabilitation & community
Putzke et al., 2002	Tunks SCI pain classification			(−)						Rehabilitation & community
Putzke et al., 2003b	Tunks SCI pain classification					(−) Inter-rater				Rehabilitation & community
Richards et al., 2002	Donovan Classification Scheme					(−) Inter-rater				Rehabilitation & community
Putzke et al., 2002	Donovan Classification Scheme			(−)						Rehabilitation & community
Putzke et al., 2003a	Donovan Classification Scheme					(?) Inter-rater				Rehabilitation & community
Bryce et al., 2006	Bryce/Ragnarsson SCI pain taxonomy					(+to −) Inter-rater				NR

[a]According to the criteria of Terwee and associates (2007).

(+) positive rating; (−) negative rating; (?) indeterminate rating due to lack of information or poor study design/method; IASP, International Association for the Study of Pain; NA, not applicable; NR, not reported.

Pain assessment

Our systematic review also examined the psychometric properties of pain assessments in the SCI population based on 24 studies that were captured in our search. None of these examined pain assessment in an acute care setting, but all studies were carried out in spinal cord injured individuals in the community or rehabilitation setting. While 75% of the studies were focused on assessment of pain intensity, the remaining 25% examined classification of pain in the SCI population. The VAS is the most commonly used instrument of assessment of pain intensity in the SCI population. However, there was no classification of pain with confirmed reliability, validity, and responsiveness for use among spinal cord injured individuals.

Clinical assessment of pain associated with SCI is difficult because spinal cord injured individuals commonly develop complex and multiple pain syndromes with varied characteristics and occurring simultaneously in different parts of the body. Prior taxonomies of pain after SCI usually classify pain according to the type of pain (neuropathic or nociceptive) as well as level and severity of SCI (Bryce et al., 2007; Siddall et al., 1997). Those premises should be taken into consideration in the classification of pain following SCI. However, it is difficult to accurately link particular pain features to specific mechanisms because individuals with SCI can develop several types of pain that often persist, can worsen over time, and usually interfere with patient's cognitive, emotional, and physical function (Siddall et al., 1997). Unlike the classification of pain, the instruments of assessment of pain intensity are commonly used in the research and clinical fields. Although there are different instruments of assessment of pain intensity in the literature, the VAS from 0 to 10 (or 0 to 100) is the most commonly used. Our results also suggest that while the construct validity of the VAS has been shown in several prior studies, further investigation is required with regard to its reliability and responsiveness in the SCI population.

Recommendations

In the Delphi process, a panel of scientific experts in the field of acute SCI (including basic scientists, clinician-scientists, surgeons, rehabilitation specialists, nurses, and clinical epidemiologists) consensually endorsed the recommendation for use of ASIA Standards for assessment of motor and sensory function (based on pin-prick and light-touch sensation) and VAS for assessment of pain intensity in patients with acute SCI. However, the expert panel also recognized the need for further investigations to confirm the performance of both instruments in the acute care setting.

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