Clinical Instruments for Measuring Unsupported Sitting Balance in Subjects with Spinal Cord Injury: A Systematic Review

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Background: Evidence of intervention effectiveness depends on, among other things, the use of a common set of valid and reliable measures that are responsive to change and reflect clinically important outcomes. **Objective:** To identify clinical assessment instruments with properties for measuring unsupported sitting balance in subjects with spinal cord injury (SCI). **Methods:** Bibliographic databases (PubMed, Science Direct, CINAHL, and Central) were searched for articles with the key words "spinal cord injury," "unsupported sitting," and "outcome assessment" in combination with a specific methodological search filter for each database. Studies describing the application of any assessment instrument for measuring unsupported sitting balance in subjects with SCI, which had the evaluation of any measurement property, were included in the review. Publication details, measure's name, setting, summary statistics, measurement properties (reliability, validity, responsiveness), and statistical significance (*p* values) were extracted. **Results:** Eight hundred forty publications were identified; 8 articles were included in the systematic review. Twelve instruments were identified and analyzed, showing limited and incomplete measurement properties. Among them, 10 addressed activity, 1 addressed structures/body functions, and 1 addressed both activity and structures/body functions domains of the International Classification of Functioning, Disability and Health (ICF). **Conclusion:** Based mainly on the measurement properties and the development of the instruments analyzed in this review, the Sitting Balance Measure, the Trunk Control Test, and the Set of Assessment Tools for Measuring Unsupported Sitting seem to be the most appropriate and recommended measures to assess unsupported sitting in subjects with SCI. **Key words:** outcome assessment, spinal cord injury, systematic review, unsupported sitting

In the able-bodied population, the ability to sit unsupported requires the coordinated use of the whole body, the lower limbs, the trunk, the arms, and the head, along with inputs from the sensory systems.¹ Because of paralysis and sensory loss, people with spinal cord injury (SCI) have an impaired ability to sit unsupported. This gross motor activity is therefore important for people with paraplegia because they perform most activities of daily living from a seated position.² Anderson et al² showed that more than 60% of people with SCI and tetraplegia rated trunk stability with arm/hand function as priorities to improve their quality of life. Physical therapy typically involves exercises and practice of functional activities in a seated position following the principles of motor re-learning in people with SCI.^{3,4} In this context, a massive practice of unsupported sitting for 1 hour a day three

times a week with head and arm movements to promote trunk stability over a 6-week period demonstrated changes in the ability of people with chronic paraplegia to sit unsupported^{3,4} but did not improve this ability in people with recently acquired paraplegia compared to the performance of activities of daily living.³ Despite the time and effort devoted by physical therapists to train unsupported sitting in clinical practice, there are no standardized training guidelines, so the clinical and real-life implications of unsupported sitting training are yet to be clarified.⁵

Assessment of unsupported sitting evaluates the individual's ability to maintain a posture (static), to keep control of balance during voluntary movements (proactive), and to regain control after unforeseen loss of balance (reactive) in a sitting position without upper extremity support.^{6,7} Assessment in clinical settings is difficult because

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Top Spinal Cord Inj Rehabil 2018;24(2):177-193
© 2018 Thomas Land Publishers, Inc.
www.thomasland.com
Published online ahead of print February 12, 2018
doi: 10.1310/sci17-00027

unsupported sitting is complex, involves ongoing postural adjustments,⁸ and cannot be separated from the environment in which it is performed.

Evidence of an intervention's effectiveness depends on, among other things, the use of a common set of valid and reliable instruments that are responsive to change and reflect clinically important outcomes.⁹ In the literature, some measures, instruments, and tools have been used to assess unsupported sitting in SCI in the laboratory, such as force plate transducers,¹⁰⁻¹² piezo-resistive pressure systems,¹³ and limits of stability,¹⁴ and in clinical settings, such as the modified Functional Reach Test (mFRT).¹⁵ The instruments used for this purpose in clinical practice are quick and easy to administer, but the assessment of the measurements' properties to confirm their use is scarce. Moreover, the equipment used in the laboratory is costly and unsuitable for use in clinical settings. There is a need for assessment instruments that are quick and easy to administer, are suitable for clinical practice, and have an analysis of their measurement properties. Therefore, the main objective of this systematic review was to identify clinical instruments with properties for measuring unsupported sitting balance in subjects with SCI. The study also aims to classify the instruments according to the International Classification of Functioning, Disability and Health (ICF) framework.

Methods

We performed the systematic review as described below. The review methodology is published and registered on the PROSPERO registry (CRD42016029579), Centre for Reviews and Dissemination, University of York. The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement provides guidance on the most appropriate methods of presenting systematic review data, the principles of which were adopted in the presentation of the results.¹⁶

Eligibility criteria

The selection criteria were studies (1) with the application of any assessment instrument for measuring unsupported sitting balance in

subjects with SCI; (2) with the development of any instrument, test, or tool for measuring unsupported sitting that addresses any measurement property described by the CONsensus-based Standards for the selection of health status Measurement Instruments (COSMIN)¹⁷; (3) including participants older than 16 years, either chronic or acute SCI, any injury level, and complete or incomplete severity level; and (4) published in English.

Exclusion criteria were (1) studies not evaluating any aspect of unsupported sitting balance, (2) instruments not specific for SCI subjects, and (3) measurement property evaluation for the instruments not able to be identified in the literature.

Search strategy

The search process was performed on the selected databases by one researcher who reported a list with all the titles and abstracts of the articles for further review process. The following databases were searched from the beginning of each database to April 2016: MEDLINE (PubMed), Science Direct, CINAHL, and Central.

Combinations of the following key words and derivations were used: spinal cord injury, paraplegia, tetraplegia, postural balance, trunk control, unsupported sitting, outcome assessments, test, scale, evaluation. Search terms were entered into each database using either MeSH or key word headings specific to the requirements of the database. The full search strategies for each database are available in the Appendix.

Review process

In accordance with the PRISMA guidelines for systematic reviews, the review process was performed by 2 independent reviewers who screened all the titles and abstracts from the previously listed articles. The abstract was reviewed if the title was found to be relevant. Then potentially relevant articles were retrieved for full-text assessment. Two members of the research team independently evaluated all the methodology applied in the retrieved full-text articles with the aim of identifying potentially eligible studies in

accordance with the previously described eligibility criteria. The selected studies were compared, and differences were resolved by discussion with a third member until a joint consensus was reached.

Data extraction and synthesis

After consensus, selected studies were obtained and fully analyzed. Publication details (author, year), instruments, setting, summary statistics (mean, *SD*), measurement properties (reliability, validity, and responsiveness domains), and statistical significance (*p* values) were extracted. The identified instruments were classified according to the ICF framework. The ICF is a comprehensive representation of health and health-related domains based on the relationships among health conditions, body functions and structures, activities, and participation.¹⁸

Quality assessment

Two reviewers independently assessed and rated each study's methodological quality using the scoring system from the COSMIN checklist.¹⁹ Disagreements were settled through discussion, with a third reviewer making the final decision. The COSMIN checklist is made up of 12 sections, each of which has between 5 and 18 items. Nine of these sections evaluate study quality with respect to specific measurement properties. Studies are rated as poor, fair, good, or excellent for each measurement property.

The remaining sections are general, and interpretability and generalizability boxes are used to extract related information to each section. The 9 measurement properties fit into one of 3 domains, namely reliability, validity, and responsiveness, as described below.

Reliability

Reliability is the degree to which the measurement is free from measurement error. It reflects the extent to which scores for patients who have not changed are the same for repeated measurement under several conditions. Reliability includes test-retest reliability designed to take into account the variation over time in stable patients, internal

consistency that assesses the use of different sets of items from the same instrument, interrater reliability that assesses different persons on the same occasion, and intrarater reliability that assesses the same person on different occasions.²⁰

Validity

Validity is the degree to which an instrument measures the construct(s) it purports to measure. It includes content, construct, and criterion validities as measurement properties. Content validity is the degree to which the content of an instrument is an adequate reflection of the construct to be measured. Evidence of content validity was considered when patients, caregivers, or experts had been consulted regarding the initial selection of items (eg, through focus groups or surveys) or had provided evaluation or feedback as part of the development. Construct validity originates from the idea that the new measure evaluates the construct it has been designed to measure. Evidence was considered if the measure was based on hypothetical constructs, which had been tested and supported during its evaluation. Criterion validity refers to the assessment of an instrument against a true value for the measure, a "gold standard."²⁰

Responsiveness

Responsiveness is the ability of an instrument to detect change over time in the construct to be measured.¹⁷ This property is particularly important for instruments applied in clinical trials. Responsiveness needs to be assessed in a prospective study, where change in the health status is likely to occur for the majority. Here, effect sizes are commonly used; this is a method of calculating the magnitude of change measured by an instrument in a standardized way that allows direct comparisons to be made between different instruments and scales.²¹

Interpretability

Interpretability can be defined as the degree to which qualitative meaning can be assigned to quantitative scores. This includes information

about clinically meaningful differences in scores between subgroups, floor and ceiling effects, and minimal important change (MIC).^{22,23} Interpretability is not a measurement property, but it is an important characteristic of a measurement instrument.²⁰

We ensured that all applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed in all the studies selected for this systematic review.

Results

Data sources

A summary of the stages of the review, according to the PRISMA instrument selection flow diagram, is given in **Figure 1**. The search yielded 840 studies, 839 of which were identified through the database search and 1 was found by manual search. After removing duplicate records, we screened 806 studies by reviewing their titles and abstracts. Sixteen studies were retained for full-text assessment of eligibility. After studies that failed to meet the eligibility criteria were removed, 8 studies were included in the qualitative analysis.

Instruments

The following 12 instruments were identified: Sitting Balance Measure (SBM),²⁴ modified Motor Assessment Scale (mMAS),⁶ modified Sitting Balance Score (mSBS),⁶ Hand-Held Dynamometry (HHD),⁷ Set of Assessment Tools for Measuring Unsupported Sitting,⁵ Functional Reach (FR),²⁵ Reach Area (RA),²⁵ Bilateral Reach (BR),²⁵ modified Functional Reach Test (mFRT),¹⁵ Limits of Stability (LOS),¹⁴ Sequential Weight Shifting (SWS),¹⁴ and Trunk Control Test.²⁶ Among the instruments, the HHD addresses structures/body functions, 10 address the activity domain, and the Trunk Control Test addresses both the activity and structures/body function of the ICF.

Participants

Only 2 studies originally proposed the development of instruments for assessing unsupported sitting balance in subjects with SCI.^{24,26} The remaining studies adapted and validated measures developed in other populations to people with SCI.^{5-7,14,15,25} In total, 414 subjects participated in the studies, and 404 of them were

Figure 1. PRISMA instrument selection flow diagram.

subjects with SCI; the number of subjects in each of the 8 studies ranged from 9 to 177. Ten rehabilitation professionals participated in the planning phase of the SBM.²⁴ The neurologic level ranged from C2 to L2 and the American Spinal Injury Association Impairment Scale (AIS) ranged from A to D. Participant ages ranged from 15 to 81 years. Regarding the time of injury, only 4 studies^{5,6,25,26} specified this parameter and included subjects in the acute (injury time <1 year) and chronic stages of SCI (injury time >1 year), with the maximum injury time being 48 years.

Study quality

The measurement properties of the studies included in this review were rated as poor to fair quality, with the exception of one study²⁶ in which the measurement properties were rated as poor to excellent (see **Table 1**). **Table 2** provides details of the measurement properties reported by the studies included in this systematic review.

Reliability

For this domain, at least one measurement property had been reported for all the instruments found in the studies. Internal consistency was reported in only 2 studies^{24,26} showing evidence of optimal internal consistency, Cronbach's coefficient $\alpha = 0.967$ and 0.979 for SBM and Trunk Control Test, respectively. Test-retest reliability had not been assessed for SBM, mMAS, mSBS, and HHD. However, according to the studies, test-retest assessment for the other instruments (using pondered kappa [K_w] or ICC) was considered excellent for the Trunk Control Test ($K_w = 0.999$)²⁶; adequate to excellent for LOS (ICC = 0.817 - 0.947),¹⁴ SWS (ICC = 0.788 - 0.846),¹⁴ mFRT (ICC = 0.85 - 0.94),¹⁵ FR (ICC = 0.858),²⁵ RA (ICC = 0.705),²⁵ and BR (ICC = 0.725)²⁵; and good to excellent for the Set of Assessment Tools for Measuring Unsupported Sitting (ICC = 0.51 - 0.91).⁵

Evidence for intra- or interrater reliability was not found for SBM, the Set of Assessment Tools for Measuring Unsupported Sitting, FR, RA, BR, mFRT, LOS, or SWS. Interrater reliability was found to be excellent for the Trunk Control Test and HHD

($K_w = 0.987$,²⁶ and ICC = 0.97 - 0.99 ,⁷ respectively) and adequate to excellent for mMAS and mSBS ($K_w = 0.83$ - 0.91 and 0.69 - 0.96 , respectively).⁶ Only one study presented evidence regarding intrarater reliability and found a good to excellent pondered kappa for HHD for unsupported sitting ranged from 0.80 to 0.98 .⁷ None of the studies reported measurement error.

Validity

No evidence of this domain assessment could be found for HHD in this review. Evidence of adequate content validity was found for SBM and the Trunk Control Test, with the face validity analyzed by a panel of experts and then by content validity ratio (CVR) calculation²⁴ and by factorial analysis,²⁶ respectively.

Only one study assessed construct validity through hypothesis testing and found that the Trunk Control Test presented a strong and positive correlation with Spinal Cord Independence Measure (SCIM; $r = 0.873$, $p < .001$) and weak and positive correlation with time of evolution ($r = 0.437$, $p = .001$).²⁶

Evidence of criterion validity (discriminant validity) was found for the Set of Assessment Tools for Measuring Unsupported Sitting and mFRT, distinguishing injury levels (higher or lower)^{5,15} and time since injury (acute or chronic).⁵ Correlation tests were also used to show evidence of this measurement property for FR, RA, and BR, presenting significant but weak correlations with percentage of activities of daily living (% ADL; $p < .01$)²⁵; for LOS and SWS unsupported sitting correlating with SCIM III ($r > 0.8$, $p < .05$) for both instruments¹⁴; for mMAS and mSBS presenting a good correlation between both ($r > 0.7$); fair to moderate correlations with neurological levels of injury, FIM, and bed transfers ($r < 0.7$); fair correlations with time since injury and other functional tests ($r < 0.3$); and moderate correlations with AIS ($r = 0.58$ - 0.68).⁶

Responsiveness and interpretability

None of the studies included in this review assessed responsiveness and interpretability.

Table 1. Evaluation of the methodological quality of the measurement properties of instruments described by each study through the Consensus-based Standard for the selection of health Measurement INstruments (COSMIN) checklist with 4-point rating scale

Instrument	Study	Internal consistency	Reliability	Measurement error	Content validity	Structural validity	Hypotheses testing	Cross-cultural validity	Criterion validity	Responsiveness
Sitting Balance Measure (SBM)	Wadhwa & Aikat (2016) ²⁴	Poor	Poor	Poor	Fair	Poor	Poor	—	Poor	Poor
modified Motor Assessment Scale (mMAS), modified Sitting Balance Score (mSBS)	Jørgensen et al (2011) ⁶	Poor	Poor	Poor	Fair	Poor	Fair	—	Poor	Poor
Hand-Held Dynamometry (HHD)	Larson et al (2010) ⁷	Poor	Poor	Poor	Fair	Poor	Poor	—	Poor	Poor
Set of Assessment Tools for Measurements Unsupported Sitting	Boswell-Ruys et al (2009) ⁵	Poor	Poor	Poor	Fair	Poor	Fair	—	Poor	Poor
Functional Reach (FR), Reach Area (RA), Bilateral Reach (BR)	Sprigle et al (2007) ²⁵	Poor	Poor	Poor	Fair	Poor	Poor	—	Poor	Poor
modified Functional Reach Test (mFRT)	Lynch et al (1998) ¹⁵	Poor	Poor	Poor	Poor	Poor	Poor	—	Poor	Poor
Trunk Control Test	Quinzaños et al (2014) ²⁶	Fair	Fair	Fair	Excellent	Poor	Fair	—	Fair	Fair
Limits of stability (LOS), Sequential Weight Shifting (SWS)	Gao et al (2015) ¹⁴	Poor	Poor	Poor	Fair	Poor	Poor	—	Poor	Poor

Table 2. Description of the instruments for assessing unsupported sitting in subjects with spinal cord injury (SCI)

Study	Instrument(s)	Setting(s)/study population(s) (<i>n</i> , sex, mean age)	ICF domains: no./types of items and scoring strategy	Validity	Reliability
Wadhwa & Aikat (2016) ²⁴	Sitting Balance Measure (SBM)	Planning phase: 22 participants; 12 subjects with SCI, 5 caretakers of subjects with SCI, 5 health care professionals dealing with SCI. Quantitative evaluation phase: 30 participants	ICF domains: Activity 16 items Ordinal scale of 0-3 with 0 = minimum balance ability and 3 = maximum balance ability	Content Face validity: Analyzed by a panel of experts including 10 rehabilitation professionals (5 OT and 5 PT) and 10 subjects with SCI. They rated each item of the scale and the content validity ratio (CVR) was calculated. Items with CVR > 0.42 were retained, resulting in 24-item scale. Construct Not reported Criterion Not reported	Internal consistency Inter-item correlation: Pearson's correlation coefficient ranged from 0.35 to 0.99 (8 items with inter-item correlations very high [>0.8] were considered redundant and removed, resulting in 16-item scale.) Cronbach's coefficient alpha of 16-item SBM: 0.967 Test-retest Not reported Intra-/interrater or interobserver Not reported Measurement error (MDC) Not reported
Jørgensen et al (2011) ⁶	modified Motor Assessment Scale (mMAS), modified Sitting Balance Score (mSBS)	48 in-patients with SCI Cross-sectional study Median age: 47 y (range, 18-69) Median time since injury: 6 y (range, 3 m-48 y)	ICF domains: Activity mMAS: 6-point ordinal scale with 0 = minimum balance ability and 6 = maximum balance ability mSBS: 4-point ordinal scale with 0 = minimum balance ability and 4 = maximum balance ability	Content Not reported Construct Not reported Criterion Between mMAS and mSBS ($r = 0.78$; 0.85 and 0.77) Between neurological levels of injury and mMAS ($r = 0.43$ -0.51) and mSBS ($r = 0.19$ -0.37) Between AIS, mMAS, and mSBS ($r = 0.57$ -0.68) With time since injury: mMAS ($r = 0.14$ -0.21) and mSBS ($r = 0.24$ -0.26) With FIM: mMAS and mSBS ($r = 0.34$ -0.50) for bed transfers, and ($r = 0.60$ -0.68) for stairs management Other functional tests ($r = 0.13$ -0.49)	Internal consistency Not reported Test-retest Not reported Intra-/interrater or interobserver Interrater reliability: mMAS: $K_w = 0.83$ -0.91 mSBS: $K_w = 0.69$ -0.96 Measurement error (MDC) Not reported

(Continued)

Table 2. Description of the instruments for assessing unsupported sitting in subjects with spinal cord injury (SCI) (CONT.)

Study	Instrument(s)	Setting(s)/study population(s) (n, sex, mean age)	ICF domains: no./types of items and scoring strategy	Validity	Reliability
Larson et al (2010) ⁷	Hand-Held Dynamometry (HHD)	29 subjects with SCI Mean age: 32.4 ± 11 y Injury level: C4-L1 AIS: A-D	ICF domains: Structures/body function Trunk strength (Newton-N)	<p>Content Not reported</p> <p>Construct Not reported</p> <p>Criterion Not reported</p>	<p>Internal consistency Not reported</p> <p>Test-retest Not reported</p> <p>Intra-/ interrater or interobserver Intrater reliability: Unsupported sitting ICC = 0.80-0.98 Supported sitting ICC = 0.79-0.99; for all raters in the 4 directions of force application. Interrater reliability: Unsupported sitting ICC = 0.97-0.99 Supported sitting ICC = 0.96-0.98 for all directions.</p> <p>Measurement error (MDC) Not reported</p>
Boswell-Ruys et al (2009) ⁵	Set of Assessment Tools for Measuring Unsupported Sitting	30 subjects with SCI Cross-sectional comparisons Injury level: C2-L2 Time since injury: 2 m to 37 y	ICF domains: Activity Six activities: upper body sway, maximal balance range, coordinated stability, alternating reach test, seated reach test, t-shirt test	<p>Content Not reported</p> <p>Construct Not reported</p> <p>Criterion In relation to: -Lesion level: good, distinguishing between participants with higher (C6-T7) and lower (T8-L2) -Time since injury: good, distinguishing between participants with acute (<1 y) and chronic (>1 y) -AIS: The majority of tests correlated with motor and sensory scores^a</p>	<p>Internal consistency Not reported</p> <p>Test-retest ICC = 0.51-0.91</p> <p>Intra-/interrater or interobserver Not reported</p> <p>Measurement error (MDC) Not reported</p>

(Continued)

Table 2. Description of the instruments for assessing unsupported sitting in subjects with spinal cord injury (SCI)

Study	Instrument(s)	Setting(s)/study population(s) (<i>n</i> , sex, mean age)	ICF domains: no./types of items and scoring strategy	Validity	Reliability
Sprigle et al (2007) ²⁵	Functional Reach (FR), Reach Area (RA), Bilateral Reach (BR)	2 groups of 39 subjects with SCI (paraplegia and tetraplegia in both groups) Group 1: 19 subjects, near or greater than 12 m post injury, ranging from 11 to 242 m (median 51.5 m); age 15 to 58 y (median 33 y) Group 2: 20 subjects, approximately 6 m or less ranging from 41 to 213 days (median 51.5 m); age 16 to 32 y (median 23.5 y)	ICF domains: Activity 12 ADLs Maximum score: 53 points Scoring varies according each activity	Content Not reported	Internal consistency Not reported
				Construct Not reported	Test-retest Not reported
				Criterion Correlations % ADL with: FR ($r = 0.468$, $p = .0031$) RA ($r = 0.434$, $p = .0061$) BR ($r = 0.583$, $p = .000$)	Intra-/interrater or interobserver ICC for uncompensated reach: FR = 0.858; good RA = 0.705; fair BR = 0.702; fair
				Pelvic tilt with: FR ($r = 0.315$, $p = .061$) RA ($r = 0.176$, $p = .305$) BR ($r = 0.127$, $p = .460$) %ADL ($r = 0.096$, $p = .577$)	Measurement error (MDC) Not reported
Lynch et al (1998) ¹⁵	modified Functional Reach Test (mFRT)	30 male subjects with SCI C5-6, T1-4, T10-12 Age: 18 to 45 years (mean = 30.8, $SD = 7.2$) AIS A or B	ICF domains: Activity 1 item measured by distance reached	Content Not reported	Internal consistency Not reported
				Construct Not reported	Test-retest ICC: Group 1 = 0.94 Group 2 = 0.85 Group 3 = 0.93
				Criterion The mFRT distinguishes level of lesion. Mean maximal reach for: C5-6 (tetraplegia), 14.7 ± 7.6 cm T1-4 (paraplegia), 15.5 ± 4.3 cm T10-12 (paraplegia), 22.9 ± 5.6 cm	Intra-/interrater or interobserver Not reported
					Measurement error (MDC) Not reported

(Continued)

Table 2. Description of the instruments for assessing unsupported sitting in subjects with spinal cord injury (SCI) (CONT.)

Study	Instrument(s)	Setting(s)/study population(s) (<i>n</i> , sex, mean age)	ICF domains: no./types of items and scoring strategy	Validity	Reliability
Gao et al (2015) ¹⁴	Limits of stability (LOS), Sequential Weight Shifting (SWS)	9 subjects with SCI Age: 35 to 63 y (mean 50.6 ± 10.7 y) Level of injury: C6 to L1	ICF domains: Activity	<p>Content Not reported</p> <p>Construct Not reported</p> <p>Criterion Supported sitting: No correlation between LOS test and SCIM III ($r = -0.489$, $p > .05$) For SWS test, total time ($r = -0.829$, $p = .011$) and directional control ($r = 0.849$, $p = .033$) correlated significantly with the SCIM III scores. Unsupported sitting: For LOS test, reaction times ($r = -0.852$, $p = .015$), maximum excursion ($r = 0.813$, $p = .026$), and directional control ($r = 0.889$, $p = .007$) showed significant correlation with SCIM III. For SWS test, total time ($r = -0.823$, $p = .044$) and directional control ($r = 0.927$, $p = .024$) correlated significantly with the SCIM III scores.</p>	<p>Internal consistency Not reported</p> <p>Test-retest Supported sitting ($n = 9$) For LOS test: reaction time ICC = 0.751, maximum excursion ICC = 0.99, directional control ICC = 0.863 For SWS test: movement time ICC = 0.688, directional control ICC = 0.952 Unsupported sitting ($n = 7$) For LOS test: reaction time ICC = 0.885, maximum excursion ICC = 0.817, directional control ICC = 0.947 For SWS test: movement time ICC = 0.788, directional control ICC = 0.846</p> <p>Intra-/interrater or interobserver Not reported</p> <p>Measurement error (MDC) Not reported</p>

(Continued)

Table 2. Description of the instruments for assessing unsupported sitting in subjects with spinal cord injury (SCI) (CONT.)

Study	Instrument(s)	Setting(s)/study population(s) (<i>n</i> , sex, mean age)	ICF domains: no./types of items and scoring strategy	Validity	Reliability
Quinzaños et al (2014) ²⁶	Trunk Control Test	177 subjects with SCI Age: 16 to 81 y (mean, 38.1 ± 14.29) AIS A, B, C, D Time of evolution: 0 to 60 m (mean, 6.65 ± 8.38 m)	ICF domains: Structures/body function and activity 13 items Ordinal scale of 0–2 with 0 = minimum balance ability and 2 = maximum balance ability	<p>Content Explanatory and confirmatory factorial analyses were carried out. All items were consistent, resulting in 13 items.</p> <p>Construct Strong and positive correlation with SCIM ($r = 0.873, p = .000$) Weak and positive correlation with time of evolution ($r = 0.437, p = .001$)</p> <p>Criterion Differentiates adequate and inadequate trunk control ($r = 0.613, p = .001$)</p>	<p>Internal consistency Cronbach's coefficient alpha = 0.979</p> <p>Test-retest $K_w = 0.999$</p> <p>Intra-/interrater or interobserver Interrater reliability: $K_w = 0.987$</p> <p>Measurement error (MDC) Not reported</p>

Note: ADL = activities of daily living; AIS = American Spinal Injury Association Impairment Scale; C = cervical; FIM = functional independence measure; ICC = intraclass coefficient correlation; ICF = International Classification of Functioning, Disability and Health; L = lumbar; m = month; MDC = minimal detectable change; *n* = number of participants; OT = occupational therapist; PT = physical therapist; *r* = Pearson's correlation; SCIM III = Spinal Cord Independence Measure III; T = thoracic; y = year.

* Originally described as construct validity by the authors, but we considered as criterion validity as referred by the Consensus-based Standard for the selection of health Measurement Instruments (COSMIN).

Discussion

This systematic review aimed to identify clinical instruments with measurement properties used for measuring unsupported sitting balance in subjects with SCI. Twelve instruments were identified: 1 addresses structures/body functions, 10 address the activity domain, and 1 addresses both the activity and structures/body function of the ICF for measuring this specific function in SCI.¹⁸

The instruments identified in this systematic review presented validity and reliability assessment, but none explored responsiveness and/or interpretability. According to the studies, the Trunk Control Test presented all and the best measurement properties assessment relating to the reliability domain in a varying population of people with SCI (AIS A, B, C, and D).²⁶ The other studies assessed one measurement property of the reliability domain of the instruments. Among these, only the SBM presented internal consistency, which is an important reliability property showing the consistency of the instrument items.²⁴

Regarding the validity of the instruments, the Trunk Control Test presented all the measurement properties and assessed them all showing the instrument development phases. Its overall validity was demonstrated with the assessment of the content, construct, and criterion validities presenting very high specificity (92.2%) and sensitivity (98%) scores, which indicate that subjects with a score of 13 or more in the test have adequate trunk control.²⁶ The other 10 instruments presented one measurement property of the validity domain, principally criterion validity, that is to distinguish injury levels, except the SBM that assessed the content validity showing also the development phases of the instrument. The content validity lacking for the other instruments is due to the fact that these instruments were not originally developed for unsupported sitting balance assessment in people with SCI and were adapted for this purpose in this population. The mMAS and the mSBS showed fair to moderate validity, because of the difficulty of distinguishing between different levels of unsupported sitting, and consequently scoring the test was troublesome. The correlations of both tests with neurological injury level, time since injury, and functional testing were inconsistent.⁶

Concerning the assessment of sitting balance components, the SBM addressed all of them and the 3 other identified instruments assessed more than one component. The Trunk Control Test and the mMAS assessed the static and proactive balance control and the mSBS assessed the static and reactive balance control of sitting balance.^{6,26} The Trunk Control Test was originally developed for measuring unsupported sitting balance in SCI patients and was described from the planning phase to the evaluations of the measurement properties. Although mMAS and mSBS were regarded as quick to administer and easy to perform in clinical settings, they failed to present some evaluations of measurement properties and were somewhat difficult to score.⁶ Both tests need major revisions before their consideration for the assessment of unsupported sitting balance in subjects with SCI.

The remaining instruments primarily assessed the proactive balance control. The SBM, based mainly on daily activities, appears to be easily applicable and the equipment required for its administration is generally available in clinical settings.²⁴ Even though some important measurement properties such as test-retest reliability, intra- and interrater reliability, and measurement error, which might confirm the SBM's reliability, are missing, the test seems simple and appropriate for assessing unsupported sitting balance in subjects with SCI. Likewise, the Set of Assessment Tools for Measuring Unsupported Sitting,⁵ which also addresses proactive balance control, is a set of simple, inexpensive, and portable tests suitable for use in the clinical setting. Although this study lacks some assessment of measurement properties such as measurement error and responsiveness, the combination of tests showed high sensitivity and specificity and the tests have been proven to have criterion validity in that they could discriminate between people with acute and chronic injuries and people with higher and lower lesions. Boswell-Ruys et al⁵ recommended the following tests as a minimum set for comprehensively assessing unsupported sitting in people with SCI: upper-body sway test total length, seated reach distance (45° to the left and/or right), supported alternating reach test, coordinated stability test A, and t-shirt put-on test. These tests can be routinely used in clinical settings

because each takes less than 3 minutes to administer and requires a minimal amount of equipment.

The FR, RA, and BR are used to assess daily activities and address only proactive balance control. They present fair to moderate measurement properties; rather than being used to assess unsupported sitting in subjects with SCI in order to plan or monitor a physical therapy intervention, they may be better applied in studies designed to assess postural control and stability during functional tasks.²⁵ The mFRT, which was adapted to the SCI population from the FRT originally designed for stroke populations,²⁷ also assesses the proactive balance control component. It is a simple test that measures forward reach in a sitting position and can be performed with equipment generally available in the clinical setting. The test was able to distinguish level of lesion (between tetraplegia and paraplegia and higher and lower paraplegia but not tetraplegia and higher paraplegia), showing a relatively good discriminant validity. However, Gao et al¹⁴ found no correlation ($p > .05$) between the mFRT and the mobility scale of the SCIM III in people with complete and incomplete SCI, which suggests some validity limitation. Considering all this, we found there were insufficient arguments to confirm the validity of the test. More studies are needed to affirm that the mFRT is a valid and reliable instrument to assess unsupported sitting balance in subjects with SCI.

The HHD provides an objective means of quantifying the forces generated by the postural muscles in the upright sitting posture; this instrument addresses structures/body functions of the ICF and the proactive balance control. Trunk strength may not directly correlate with sitting balance, which is a multifaceted skill^{28,29}; therefore this instrument cannot be recommended for use as a measure of unsupported sitting balance. The HHD can be used to quantify postural muscle strength in sitting in subjects with SCI, however the relationship between postural muscle strength and sitting balance needs to be understood.

The remaining tests identified in this review, the LOS and the SWS, involved the use of a tailor-made force platform and an adjustable-height screen placed in front of the participants on which the center of pressure (COP) was displayed.¹⁴ Even though

both instruments presented good measurement properties evaluations, they are complex, relatively slow to administer, and require equipment that is not suitable for use in clinical settings.

Future studies are required to confirm the suitability of the instruments and evaluate their validity, reliability measurements, and other important properties such as responsiveness and interpretability. Longitudinal studies are needed on a similar cohort of patients (lesion level, AIS classification, chronicity, age) to determine minimal detectable change (MDCs) and/or minimally clinical important differences (MCIDs) for specific tools. These instruments need to be modified or new instruments need to be developed that include all the sitting balance control components (static, proactive, and reactive) to better assess unsupported sitting balance in people with SCI.

Implications for rehabilitation practice and research

Relevant instruments specifically developed to assess unsupported sitting activity are lacking. Consequently, the evidence to support the strategies applied to train unsupported sitting balance and their effectiveness in subjects with SCI is weak in the literature. Future randomized clinical trials are warranted for training unsupported sitting balance in subjects with SCI using the instruments found and discussed in this review. These instruments can also be used in clinical practice to plan or monitor physical therapy interventions directed at enhancing sitting balance and thus increasing functional independence in subjects with SCI.

Limitations and strength

To the best of our knowledge, this is the first systematic review to address clinical instruments for assessing unsupported sitting balance in subjects with SCI. The discussions and conclusions contained in this review are based on studies that are poor in terms of methodological quality. The fact that the search was restricted to English-language studies must be considered a limitation of this review. However, this work can be used as a base to guide future studies regarding the evaluations of measurement properties that were found to be lacking in the identified instruments

and so contribute to improving the assessment of unsupported sitting balance in subjects with SCI.

Conclusion

In this review, we analyzed clinical instruments available to assess unsupported sitting balance in subjects with SCI. Of those found, the SBM, the Trunk Control Test, and the Set of Assessment Tools for Measuring Unsupported Sitting seem to be the best suited for the task. Although the SBM and the Trunk Control Test have recently

been developed, they showed good measurement property scores and their items are relevant to assess the unsupported sitting balance necessary to achieve functional performance and independence. They are simple, easy, quick to administer in clinical settings, and applicable to every type of patient regardless of their neurological level and type of injury.

Acknowledgments

The authors declare no conflicts of interest.

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APPENDIX

Search Strategy of the Systematic Review

MEDLINE (Pubmed)

1. "Spinal Cord Injury"
2. Spinal Cord Injury
3. Spinal Cord Injur*
4. Spinal injury
5. Spinal Injur*
6. Paraplegia
7. Paraplegic
8. Paraplegic*
9. Tetraplegia
10. Tetraplegic
11. Tetraplegic*
12. OR / 1 – 11
13. "Postural balance"
14. Balance
15. Trunk control
16. Trunk
17. OR / 13 - 16
18. Unsupported sitting
19. Sitting
20. Sit
21. Sit*
22. Seated
23. OR / 18 – 22
24. "Outcome assessments"
25. Outcome
26. Outcom*
27. Assessment
28. Asses*
29. Test

30. Scale

31. Evaluation

32. OR / 24 - 31

33. 12 AND 17 AND 23 AND 32

[("Spinal Cord Injury" OR Spinal Cord Injury OR Spinal Cord Injur* OR Spinal injury OR Spinal Injur* OR Paraplegia OR Paraplegic OR Paraplegic* OR Tetraplegia OR Tetraplegic OR Tetraplegic*) AND ("Postural balance" OR Balance OR Trunk control OR Trunk) AND (Unsupported sitting OR Sitting OR Sit OR Sit* OR Seated) AND ("Outcome assessments" OR Outcome OR Outcom* OR Assessment OR Asses* OR test OR scale OR Evaluation)]

CINAHL

1. Spinal Cord Injury
2. Spinal injury
3. Paraplegia
4. Paraplegic
5. Tetraplegia
6. Tetraplegic
7. OR / 1 – 6
8. Postural balance
9. Balance
10. Trunk control
11. Trunk
12. OR / 8 - 11
13. Unsupported sitting
14. Sitting
15. Sit
16. Seated
17. OR / 13 – 16
18. Outcome assessments

19. Outcome
20. Assessment
21. Test
22. Scale
23. Evaluation
24. OR / 18 - 23
25. 7 AND 12 AND 17 AND 24

[(Spinal cord injury OR Spinal injury OR Paraplegia OR Paraplegic OR Tetraplegia OR Tetraplegic) AND (Postural balance OR Balance OR Trunk control OR Trunk) AND (Unsupported sitting OR Sitting OR Sit OR Seated) AND (Outcome assessments OR Outcome OR Assessment OR test OR scale OR Evaluation)]

CENTRAL

1. Spinal Cord Injury (Key word, Title and Abstract)
2. Sitting (Key word, Title and Abstract)
3. Unsupported sitting (Key word, Title and Abstract)
4. Seated (Key word, Title and Abstract)
5. Outcome assessments (Key word, Title and Abstract)
6. Outcome (Key word, Title and Abstract)
7. Assessment (Key word, Title and Abstract)

SCIENCE DIRECT

1. "Spinal Cord Injury" OR { Spinal Cord Injury}
2. Spinal Cord Injury
3. Spinal injury
4. Spinal Injur*
5. Spinal Cord Injur*
6. Paraplegia
7. Paraplegic*
8. Paraplegia

9. Tetraplegia
10. Tetraplegic
11. OR / 1 – 10
12. "Postural balance" OR {Postural balance}
13. Balance
14. Trunk control
15. Trunk
16. OR / 12 - 15
17. Unsupported sitting
18. Sitting
19. Sit
20. Sit*
21. Seated
22. OR / 17 – 21
23. "Outcome assessments" OR {Outcome assessments}
24. Outcome
25. Outcom*
26. Assessment
27. Asses*
28. Test
29. Scale
30. Evaluation
31. OR / 23 – 30
32. 11 AND 16 AND 22 AND 31

[({Spinal Cord Injury} OR Spinal Cord Injury OR Spinal injury OR Spinal Injur* OR Spinal Cord Injur* OR Paraplegia OR Paraplegic* OR Paraplegia OR Tetraplegia OR Tetraplegic) AND ({Postural balance} OR Balance OR Trunk control OR Trunk) AND (Unsupported sitting OR Sitting OR Sit OR Sit* OR Seated) AND ({Outcome assessments} OR Outcome OR Outcom* OR Assessment OR Asses* OR Test OR Scale OR Evaluation)]