Review

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Diagnostic tests to assess balance in patients with spinal cord injury: a systematic review of their validity and reliability

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Abstract

Background: Sophisticated biomechanical instruments can assess balance in patients with spinal cord injury (SCI) with accuracy and precision; however, they are costly and time consuming to use. Clinical diagnostic tests to assess balance in patients with SCI are less costly and easier to use, but there is limited literature available regarding their reliability and validity.

Objectives: To review systematically articles reporting the validity and reliability of diagnostic tests used to assess balance function in patients with SCI.

Methods: We searched for articles in the English language from the earliest record to December 15, 2020, which reported validity or reliability of any clinical instrument or diagnostic test used to assess balance in patients with SCI. Articles assessing balance in paraplegic patients with causes other than SCI were excluded. Databases included MEDLINE, AMED, EMBASE, HMIC, PsycINFO, CINAHL, Scopus, and Google Scholar. The COSMIN Risk of Bias checklist was used to assess the studies included and PRISMA-DTA guidelines were applied.

Results: We included 16 articles that assessed the validity or reliability of 10 diagnostic tests. The Functional Reach Test (FRT), Berg Balance Scale (BBS), and Mini-Balance Evaluation Systems Test (Mini-BESTest) were assessed by more than 1 study, while the remaining 7 diagnostic tests including the Function in Sitting Test, T-Shirt Test, Motor Assessment Scale item 3, Sitting Balance Score, 5 Times Sit-to-Stand Test, Tinetti scale, and Sitting Balance Measure were assessed by 1 study each. The FRT has good-to-excellent test–retest reliability, excellent inter-rater reliability, and good construct, concurrent, and convergent validity. The BBS has excellent inter-rater and intra-rater reliability, high internal consistency, and good concurrent and construct validity. The Mini-BESTest has excellent test–retest reliability, excellent inter-rater reliability, high internal consistency, and good concurrent, convergent, and construct validity.

Conclusions: The FRT, BBS, and Mini-BESTest appear to be valid and reliable clinical instruments to assess balance function in patients with SCI.

Keywords: diagnostic test; outcome assessment, health care; postural balance; reproducibility of results; spinal cord injuries

Balance function or postural stability is important for performing activities of daily living [1]. Balance function is necessary, even for performing simple tasks such as sitting, standing, and walking. Similarly, complex motor skills, such as running, jumping, and dancing, also depend on efficient balance control [2]. Balance control is achieved through the

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integration of sensory inputs, the central processing system, and neuromuscular response. Sensory inputs include visual, vestibular, and proprioceptive inputs; the central processing system includes the brain and spinal cord, while neuromuscular responses include motor control [3]. Disturbance in any of the systems that maintain normal balance function will result in impaired balance [4].

Neurological disorders almost always result in impaired balance. Although the main disturbance in these neurological conditions is present in central processing system, the neuromuscular response and sensory inputs are also disturbed to some extent in these disorders [5]. Like those with other neurological disorders, individuals with spinal cord injury (SCI) also have poor balance function. In individuals with SCI, proprioception, the central processing system, and neuromuscular response are disturbed, which leads to an array of complications [6]. Although individuals with complete SCI remain wheel chair bound and only sitting balance is important for them, individuals with incomplete SCI need balance for both standing and sitting [7].

Because balance problems are known to disrupt rehabilitation and prevent patients with neurological conditions from performing activities of daily living, rehabilitation specialists always focus on balance function [8, 9]. Without appropriate balance training, individuals with SCI mostly remain bed bound and never function as productive members of society [10]. Many interventions and exercises are applied to manage balance problems in patients with SCI and almost all of them improve balance function to some extent [11]. Clinicians are always interested in making objective measurements of the improvement occurring as a result of therapeutic intervention and for this purpose they use clinical assessment or diagnostic tools [12].

Assessment of balance function in clinical settings is a daunting task. Many biomechanical instruments are available to assess balance function with accuracy and precision in patients with SCI; however, these sophisticated biomechanical instruments are usually not appropriate for use in clinical settings [13]. For research purposes, balance assessment is performed by measuring the center of pressure, forces, torques, and joint angles using a force plate analysis system or other instruments [14]. These biomechanical instruments can be used in laboratory settings, but they may not be applicable in clinical environments on a routine basis. The biomechanical instruments are costly, and the tests are time consuming. Moreover, use of the instruments may require highly trained personnel [15].

In contrast to biomechanical measures, nonbiomechanical measures in the form of clinical assessment tools or diagnostic tests are widely used in clinical settings [16]. Many clinical assessment tools are available to assess balance function in

patients with SCI. Although clinical tools and tests are easier to administer than biomechanical tests [17], there is limited literature available regarding their reliability and validity. Therefore, the present review was conducted to systematically review articles reporting the validity and reliability of clinical instruments used to assess balance function in individuals with SCI.

Methods

A systematic review of diagnostic tests or clinical assessment tools was conducted according to PRISMA-DTA guidelines to the extent they apply [18]. Various databases including MEDLINE, Allied and Complementary Medicine (AMED), EMBASE for Excerpta Medica dataBASE, The Healthcare Management Information Consortium (HMIC), PsycINFO, Cumulative Index to Nursing and Allied Health Literature (CINAHL) from EBSCO, and Scopus were searched. The search terms “spinal cord (injury, damage, compression, ischemia, trauma, contusion, laceration, transaction, syndrome),” OR “spinal (fracture, subluxation, dislocation, injury, trauma),” OR “cervical vertebrae injuries,” OR “lumbar vertebrae injuries,” OR “thoracic vertebrae injuries,” OR “SCI,” or “paraplegia,” OR “quadriplegia,” OR “tetraplegia,” AND “balance” OR “postural balance” OR “stability” OR “static balance” OR “dynamic balance” OR “walking balance” OR “sitting balance” OR “standing balance” OR “posture” OR “body equilibrium” OR “body posture” AND “clinical (assessment tools, instruments, scales, measurement tools, measures)” OR “nonbiomechanical (assessment tools, instruments, scales, measurement tools, measures)” OR “outcome (instruments, scales, tools, measures)” AND “reliability” OR “psychometric properties” OR “consistency” OR “validity” were used for the literature search, where AND and OR are logical operators. Truncations were used when they were appropriate.

The search results were imported into reference manager software. After removal of duplicates, 2 authors scanned the reference lists of the retrieved articles. Additionally, Google Scholar was searched to locate other relevant research articles. Research studies published in the English language from the earliest record to December 15, 2020, which reported validity and/or reliability of any of the clinical instrument used for the assessment of balance function in SCI individuals, were included. We excluded studies that reported psychometric properties of biomechanical measures such as force plate analysis, which are not used in clinical settings. Research articles that included paraplegic patients with causes other than SCI were excluded. Letter to editors, review articles, expert opinion, conference papers, brief communications, and commentaries were also excluded.

Two reviewers independently screened the articles to exclude those research articles that did not fulfill the eligibility criteria. After excluding irrelevant studies, the full text of the remaining articles was studied by 2 independent reviewers and necessary data from all these studies were extracted. The COSMIN Risk of Bias checklist was used to assess risk of bias in the studies included [19, 20]. Any disagreements between 2 reviewers were resolved by consensus with a third reviewer, who was consulted to confirm the extracted data. Discrepancies between the reviewers were resolved by consensus.

Results

A preliminary literature search identified 248 research articles; however, after removal of duplicates, only 93 studies remained. These 93 research articles were evaluated thoroughly

for eligibility criteria, and only 16 articles fulfilled the inclusion criteria, while the remaining 77 articles were excluded (**Figure 1**). The articles reported validity and/or reliability of 10 clinical instruments including the Functional Reach Test (FRT), Berg balance scale (BBS), Mini-Balance Evaluation Systems Test (Mini-BESTest), Function in Sitting Test, T-Shirt Test, Motor Assessment Scale item 3, Sitting Balance Score, 5 Times Sit-to-Stand Test, Tinetti scale, and Sitting Balance Measure. Eleven articles assessed individual clinical instruments, while the remaining 5 articles assessed more than one clinical instrument.

Good-to-excellent test-retest reliability of the FRT was reported by 6 articles [21–26], while 1 article reported excellent inter-rater reliability (FRT) [27]. Construct, concurrent, and convergent validities of the FRT were reported by 1 article each [22, 23, 25]. Excellent inter-rater reliability of the BBS was reported by 2 articles [27, 28] and 1 article reported excellent intra-rater reliability [29], while 1 article

Figure 1. PRISMA flow diagram for record triage through the different phases of systematic review.

reported high internal consistency [30]. Two articles reported concurrent validity of the BBS [28, 31] and 1 article reported construct validity [30]. The Mini-BESTest was assessed by 3 included articles [30, 32, 33]. These articles reported excellent test–retest reliability [32, 33], excellent inter-rater reliability [33], high internal consistency [30], and good concurrent, convergent [32], and construct validity [30] of the Mini-BESTest.

Excellent test–retest reliability and construct validity of the T-Shirt Test has been reported [22]. Excellent test–retest

reliability, internal consistency, and concurrent validity of the Function in Sitting Test [34], good-to-excellent inter-rater reliability and criterion validity of the Motor Assessment Scale item 3 and Sitting Balance Score [35], excellent inter-rater reliability of the 5 Times Sit-to-Stand Test [27], good-to-excellent intra-rater reliability of the Tinetti scale [29], and high internal consistency and content validity of the Sitting Balance Measure [36] have been reported in 1 article each. Methodological quality varied across the studies (**Table 1**).

Table 1. Summary of studies that assessed the validity or reliability of 10 clinical instruments

Article	Methodological quality	Patient characteristics	Balance measure	Validity	Reliability
Adegoke et al. [21]	Inadequate	20 adult nonambulatory patients with SCI	FRT		Test–retest reliability was assessed. ICC ranged from 0.98 to 0.99 in individuals with different levels of injuries
Boswell-Ruys et al. [22]	Doubtful	30 adult patients with SCI	FRT and T-Shirt Test	Construct validity was assessed using ASIA scores, level of injury, and duration of injury. The tests had good construct validity in that they distinguished between subjects with higher (C6–T7) and lower (T8–L2) levels of injuries and between patients with acute and chronic SCI. The tests correlated with ASIA motor and sensory scores	Test–retest reliability was assessed. ICC for the reach test ranged from 0.80 to 0.89 in different directions while ICC for T-Shirt Test ranged from 0.85 to 0.91 with different tasks of the test
Field-Fote and Ray [23]	Adequate	32 adult patients with motor incomplete SCI	FRT	Concurrent validity was tested with center of pressure excursion. The correlation of forward, backward, right and left reach with center of pressure excursion were 0.71, 0.72, 0.95, and 0.61, respectively	Test–retest reliability was assessed. ICCs ranged from 0.78 to 0.95 in different directions
Lynch et al. [24]	Inadequate	30 adult patients with motor complete SCI	FRT		Test–retest reliability was assessed. ICC ranged from 0.85 to 0.94 in patients with different levels of injuries
Sprigle et al. [25]	Doubtful	20 adult patients with SCI and injury duration less than 6 months	FRT	Convergent validity was assessed. The correlation of FRT with activities of daily living score was 0.46	Test–retest reliability was assessed. ICC was 0.85
Sprigle et al. [26]	Inadequate	22 adult patients with chronic SCI	FRT		Test–retest reliability was assessed. ICC was 0.87
Srisim et al. [27]	Inadequate	25 adult ambulatory patients with SCI	BBS, FRT and Five Times Sit-to-Stand Test		Inter-rater reliability was assessed. ICC for BBS, FRT, and Five Times Sit-to-Stand Test were 0.99, 1.00, and 0.99, respectively

(continued)

Table 1. (Continued)

Article	Methodological quality	Patient characteristics	Balance measure	Validity	Reliability
Wirz et al. [28]	Doubtful	42 adult patients with SCI	BBS	Concurrent validity was assessed. The correlation of BBS with SCIM mobility score, Walking Index for SCI, Falls Efficacy Scale, motor scores, and number of falls was 0.89, 0.82, 0.93, 0.81, 0.62, and 0.17, respectively	Inter-rater reliability was assessed. ICC was 0.953
Tamburella et al. [29]	Doubtful	23 adult patients with incomplete SCI	BBS, Tinetti (total), Tinetti (equilibrium), Tinetti (locomotion)		Intra-rater reliability was assessed. ICC for BBS, Tinetti (total), Tinetti (equilibrium), and Tinetti (locomotion) were 0.97, 0.22, 0.87, and 0.78, respectively
Jørgensen et al. [30]	Adequate	46 adult patients with chronic SCI	BBS and Mini-BESTest	Construct validity was assessed. Strong correlations between both scales ($r = 0.90$) and between both scales and Timed Up and Go ($r > 0.70$), SCIM mobility scores ($r > 0.80$), and 10-Meter Walk Test ($r > 0.80$) support high construct validity	Internal consistency was assessed. Cronbach α for BBS was 0.94 while α for Mini-BESTest was 0.95
Lemay and Nadeau [31]	Inadequate	32 adult patients with motor incomplete SCI	BBS	Concurrent validity was assessed. The correlation of BBS with 2-minute walk test, Walking Index for SCI, 10-Meter Walk Test, and Timed Up and Go were 0.78, 0.81, 0.79, and -0.81 , respectively, while its correlation with Functional Ambulation Inventory (SCI-FAI) ranged 0.71–0.74	
Chan et al. [32]	Adequate	21 adult patients with chronic motor incomplete SCI	Mini-BESTest	Concurrent and convergent validity was tested with measures of center of pressure velocity during eye open and eye closed standing and lower extremity muscle strength, respectively. The correlation of Mini-BESTest scores with center of pressure velocity during standing with eye open ranged from -0.48 to -0.76 and during standing with eye closed ranged from -0.04 to 0.07 . The correlation of Mini-BESTest scores with lower extremity muscle strength was 0.73	Test–retest reliability was assessed. ICC for the total score of Mini-BESTest was 0.98
Roy et al. [33]	Very good	23 adult patients with SCI	Mini-BESTest		Test–retest and inter-rater reliability was assessed. ICC for test–retest and inter-rater reliability were 0.94 and 0.96, respectively
Abou et al. [34]	Adequate	26 adult nonambulatory patients with chronic SCI	Function in Sitting Test	Concurrent validity was tested with modified FRT (forward and lateral) and posturography assessment (virtual time)	Test–retest reliability and internal consistency was assessed.

(continued)

Table 1. (Continued)

Article	Methodological quality	Patient characteristics	Balance measure	Validity	Reliability
				to contact). The correlation of function in sitting test with lateral reach was 0.64 while its correlation with forward reach and virtual time to contact was 0.16 and 0.23, respectively.	ICC was 0.95 Cronbach α was 0.81
Jørgensen et al. [35]	Adequate	48 adult patients with SCI	Motor Assessment Scale item 3 and Sitting Balance Score	Criterion validity was assessed. The correlation between the scales were in relation to neurological injury level ($r = 0.19-0.51$), extent of injury ($r = 0.57-0.68$), functional independence measure ($r = 0.13-0.68$), and 5 additional mobility and locomotor items ($r = 0.10-0.49$)	Inter-rater reliability was assessed. For Motor Assessment Scale item 3 k with linear weights (k_w) ranged from 0.83 to 0.91 with different raters while for Sitting Balance Score k with linear weights (k_w) ranged from 0.69 to 0.96 with different raters
Wadhwa and Aikat [36]	Doubtful	30 adult patients with SCI	Sitting Balance Measure	Content validity of Sitting Balance Measure was established through qualitative review by experts and by calculating content validity ratio.	Internal consistency was assessed. Cronbach α was 0.96

ASIA, American Spinal Injury Association; BBS, Berg Balance Scale; FRT, Functional Reach Test; ICC, intraclass correlation coefficient; Mini-BESTest, Mini-Balance Evaluation Systems Test; SCI, Spinal Cord Injury; SCIM, Spinal Cord Independence Measure.

Discussion

SCI and its sequelae in the form of paralysis and impaired sensations result in a wide range of physical and psychological disorders [37]. SCI usually results in lifelong disability and rehabilitation interventions aim to minimize complications and maximize independence of individuals with SCI [38]. Mobility training, transfer training, wheelchair maneuverability, gait training, and balance training are important components of rehabilitation for individuals with SCI [39]. Among these components, rehabilitation specialists always give more focus to balance training because without good balance function, patients with SCI cannot achieve maximum independence [40]. Almost all other rehabilitation components depend on proper postural stability and that is why clinicians start balance training from the first day of rehabilitation and continue this training until the rehabilitation protocols are complete [41].

Many outcome measures are available to assess balance function in patients with neurological disorders. These outcome measures range from highly complicated biomechanical measures requiring sophisticated instrumentation to simple and easily administered clinical tests [42]. Owing to the complexity and cost of biomechanical measures, they are seldom used in clinical practice; however, they are frequently used by researchers. By contrast, clinical tests are frequently

used by clinicians to assess balance function [43]. A variety of outcome measures is used in clinical practice, each of which assesses different aspects of balance function [44]. Ten clinical instruments that can be used to assess balance function of individuals with SCI in clinical settings were identified in the current systematic review. These include the FRT, BBS, Mini-BESTest, Function in Sitting Test, T-Shirt Test, Motor Assessment Scale item 3, Sitting Balance Score, 5 Times Sit-to-Stand Test, Tinetti scale, and Sitting Balance Measure. Most of these clinical instruments are not specific to individuals with SCI, and they can be used to assess balance function in the elderly and in patients with other neurological diseases [45].

The present search retrieved 16 research articles that reported validity and/or reliability of clinical instruments to assess balance function in patients with SCI. This clearly highlights the scarcity of literature regarding these clinical instruments. The instruments are widely used in clinical settings; however, the limited literature shows that they have not received robust attention from researchers. There is a need for high quality research regarding the validity and reliability of these clinical instruments because without high quality evidence, clinicians may not be confident to use these clinical instruments. The present review systematically evaluated available literature that assessed the clinical instruments used to assess balance function in patients with SCI.

FRT, BBS, and Mini-BESTest are the most commonly used clinical instruments used to assess balance function [27, 30] and can be used for a variety of conditions. Patients with musculoskeletal disorders, such as chronic low back pain, and patients with neurological conditions, such as stroke, can be assessed with these instruments, which can be used in the geriatric population [46]. Most articles in current review reported good-to-excellent reliability and good validity of the FRT, BBS, and Mini-BESTest to assess balance function in patients with SCI. These clinical instruments provide valid and reliable outcome measures for assessing balance in patients with balance disorders [47, 48]. Apart from these 3 instruments, the validity and reliability of other clinical instruments are rarely described in the literature. The available literature reported that the T-Shirt Test has excellent test–retest and construct validity, while the Function in the Sitting Test has excellent test–retest reliability, internal consistency, and concurrent validity.

Despite that the current review assimilates the available literature regarding outcome measures used in clinical settings to assess balance function in patients with SCI, it has some limitations. First, due to heterogeneity in the data, it was not feasible to conduct a meta-analysis and so only descriptive results are presented. Second, due to the scarce and limited literature it was difficult to draw firm conclusions regarding the reliability and validity of various clinical instruments. The protocols used to conduct the systematic review were not registered, for example in PROSPERO [49].

Conclusion

Few research studies determined the reliability and validity of clinical instruments in the assessment of balance function in SCI individuals. From the available literature, it appears that FRT, BBS, and Mini-BESTest are valid and reliable clinical instruments for the assessment of balance function in individuals with SCI. Due to scarcity of literature regarding the validity and reliability of other clinical instruments, no firm conclusions can be drawn regarding their use in clinical settings. Large multicenter studies are recommended to determine the validity and reliability of clinical instruments.

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