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REVIEW ARTICLE (META-ANALYSES)

Using the Systems Framework for Postural Control to Analyze the Components of Balance Evaluated in Standardized Balance Measures: A Scoping Review

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Abstract

Objective: To identify components of postural control included in standardized balance measures for adult populations.

Data Sources: Electronic searches of MEDLINE, EMBASE, and CINAHL databases using keyword combinations of postural balance/equilibrium, psychometrics/reproducibility of results/predictive value of tests/validation studies, instrument construction/instrument validation, geriatric assessment/disability evaluation, gray literature, and hand searches.

Study Selection: Inclusion criteria were measures with a stated objective to assess balance, adult populations (18y and older), at least 1 psychometric evaluation, 1 standing task, a standardized protocol and evaluation criteria, and published in English. Two reviewers independently identified studies for inclusion. Sixty-six measures were included.

Data Extraction: A research assistant extracted descriptive characteristics and 2 reviewers independently coded components of balance in each measure using the Systems Framework for Postural Control, a widely recognized model of balance.

Data Synthesis: Components of balance evaluated in these measures were underlying motor systems (100% of measures), anticipatory postural control (71%), dynamic stability (67%), static stability (64%), sensory integration (48%), functional stability limits (27%), reactive postural control (23%), cognitive influences (17%), and verticality (8%). Thirty-four measures evaluated 3 or fewer components of balance, and 1 measure—the Balance Evaluation Systems Test—evaluated all components of balance.

Conclusions: Several standardized balance measures provide only partial information on postural control and omit important components of balance related to avoiding falls. As such, the choice of measure(s) may limit the overall interpretation of an individual's balance ability. Continued work is necessary to increase the implementation of comprehensive balance assessment in research and practice.

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Balance is a critical skill for fall avoidance,[1] and balance impairment is common in both older adults and people living with chronic health conditions.[2-4] Balance exercise can reduce falls,[5-7] and comprehensive assessment is recommended for identifying impairments in postural control and informing the design of optimal balance exercise programs for fall prevention.[8] However, a plethora of standardized balance measures exist,[9] and extensive variation in their use has limited the ability to synthesize data on the effects of balance interventions. For example, a systematic review on the effectiveness of exercise interventions to improve balance in older adults identified 95 eligible trials[6] but was able to pool <50% of included studies because more than 25 different standardized balance measures were used across individual trials. Varied use of balance measures is also seen in clinical practice, as

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Table 1 Components of balance operational definitions

Domains in Systems Framework for Postural Control[8]	Scoping Review Adaptation of Component of Balance and Operational Definition
1. Biomechanical constraints: degrees of freedom, strength, limits of stability	1. Functional stability limits: Ability to move the center of mass as far as possible in the anteroposterior or mediolateral directions within the base of support 2. Underlying motor systems: eg, strength and coordination 3. Static stability: Ability to maintain position of the center of mass in unsupported stance when the base of the support does not change (may include wide stance, narrow, 1-legged stance, tandem—any standing condition)
2. Orientation in space: perception of gravity, verticality	4. Verticality: Ability to orient appropriately with respect to gravity (eg, evaluation of lean)
3. Movement strategies: reactive, anticipatory, voluntary	5. Reactive postural control: Ability to recover stability after an external perturbation to bring the center of mass within the base of support through corrective movements (eg, ankle, hip, and stepping strategies) 6. Anticipatory postural control: Ability to shift the center of mass before a discrete voluntary movement (eg, stepping-lifting leg, arm raise, head turn)
4. Control of dynamics: gait, proactive	7. Dynamic stability: Ability to exert ongoing control of center of mass when the base of the support is changing (eg, during gait and postural transitions)
5. Sensory strategies: integration, reweighting	8. Sensory integration: Ability to reweight sensory information (vision, vestibular, somatosensory) when input altered
6. Cognitive processing: attention, learning	9. Cognitive influences: Ability to maintain stability while responding to commands during the task or attend to additional tasks (eg, dual-tasking)

illustrated in a survey of balance assessment practices among Canadian physical therapists that reported use of more than 20 different measures.[10] These issues emphasize the need for consensus on the use of outcome measures to increase understanding of the most effective components of exercise interventions.[11]

Direction is needed to inform balance measurement recommendations, and given the absence of a criterion standard method for evaluating balance,[12] content validity should be a primary consideration. However, previous systematic reviews on standardized balance measures are limited by focusing only on clinical utility, task, and environment issues in a restricted subset of measures[13,14] or narrow population.[12] As such, there is a need to systematically examine the theoretical basis underlying existing balance measures.[12] Contemporary postural control theory views balance as the product of integrated inputs and the body as a mechanical system that interacts with the nervous system in a continuously changing environment.[15-17] Support for this theory has been provided by evidence from multiple laboratories that have demonstrated how imposed constraints or deficits in the underlying systems impair balance.[18] Based on this view, the Systems Framework for Postural Control was proposed.[8] It describes 6 major components required for the maintenance of postural control—(1) constraints on the biomechanical system, (2) movement strategies, (3) sensory strategies, (4) orientation in space, (5) dynamic control, and (6) cognitive processing (table 1, column 1)—and highlights that each underlying component and type of control could independently lead to a balance impairment. As such, this framework emphasizes the need for individual assessment of each component and treatment on a case-by-case basis.[8]

Given its conceptual basis, comprehensive nature, and support from the physiological and biomechanical literature, the Systems Framework for Postural Control can help clarify the components of balance captured in existing measures and inform decisions when selecting measures for evaluating balance and informing rehabilitative interventions. The objectives of this study were to (1) identify existing validated standardized measures of standing balance in adult populations and (2) determine the components of postural control captured in each tool, as outlined by the Systems Framework for Postural Control. The review question was "What components of postural control are included in standardized balance measures whose validity and reliability are established in adult populations (18y and older)?"

List of Abbreviations:

BESTest Balance Evaluation Systems Test

Methods

Study design

A scoping review—a rigorous approach useful for identifying gaps in the existing literature[19]—was conducted. We applied Arksey and O'Malley's 5-stage framework for conducting scoping reviews[19,20] and incorporated recent recommendations for enhancing this methodology,[20,21] such as using an iterative approach to develop the research question, defining relevant concepts, and including quality indicators in the eligibility criteria. The steps are outlined below. Preferred Reporting Items for Systematic Reviews and Meta-Analyses recommendations for systematic review conduct and reporting[22] also informed the methodology and were adopted where appropriate.

Develop a research question

What components of postural control are included in standardized balance measures whose validity and reliability are established in adult populations (18y and older)?

Search for relevant material

A professional librarian searched published literature indexed in MEDLINE (from 1946 to February week 4, 2014), EMBASE (from 1974 to March 10, 2014), and CINAHL (from 1981 to

March 11, 2014), and the search strategies were reviewed by a second librarian. Combinations of the following terms were used: postural balance/equilibrium, psychometrics/reproducibility of results/predictive value of tests/validation studies, instrument construction/instrument validation, geriatric assessment/disability evaluation. A sample search strategy for MEDLINE is presented in supplemental appendix S1 (available online only at http://www.archives-pmr.org/). A comprehensive gray literature search was also conducted to identify measures not captured by the database searches, including the Canadian Agency for Drugs and Technologies in Health gray literature search checklist,[23] as well as a hand search of published narrative review articles describing balance measures identified in the database search, and a search of the Physiotherapy Evidence Database, a database of randomized trials, systematic reviews, and clinical practice guidelines for physiotherapy, to identify additional measures.

Define study selection

Level 1 title and abstract screening criteria included descriptive studies (1) focused on balance measurement, (2) in adult populations (18y and older), and (3) published in the English language. Screening criteria were piloted on a random 10% sample of abstracts and clarified where necessary. We were specifically searching for the "index" publication—a measure's first publication presenting its development and/or initial psychometric evaluation—as the definitive reference for the measure. However, in anticipation that not all measures would be published in a way that it would be possible to identify the first publication from the abstract, the names of all balance measures identified in the abstract screen were recorded for manual cross-checking and hand search for the index publication. Two research assistants independently screened the abstracts of studies identified in the database search using the screening criteria. Disagreements were resolved by the primary investigator (K.M.S.), who also reviewed the list of all measures identified in the abstract screening and flagged relevant abstracts for a follow-up hand search.

Level 2 full-text screening criteria included (1) index publication, (2) having a stated objective or commonly used to assess balance, (3) including at least 1 standing task, (4) having both a standardized testing protocol *and* a standardized evaluation criteria, and (5) having a minimum of 1 psychometric property (validity or reliability) evaluated. The last criterion (minimum of 1 psychometric property evaluated) was included for quality assessment purposes to prevent measures with no empirical support from being considered. Hand searches were triggered at this phase if (1) no psychometric data were reported in the index publication (to determine whether companion articles existed that would support the inclusion of the measure in the review) or (2) it was not clear from the full text whether the identified article was the index publication. Full-text screening was performed by 2 research assistants, with disagreements resolved by the primary investigator. Two coinvestigators (M.K.B. and K.V.O.) reviewed and approved the final list of included measures to confirm that all known relevant measures were included.

Chart the data

Descriptive data abstraction was performed by a research assistant and reviewed by the primary investigator. The research assistant used a standardized template to extract the measures' stated purpose and development methods, characteristics (evaluation parameters and number of items), and results of preliminary psychometric testing (reliability and/or validity data).

The components of balance evaluated in each measure were explored by coding the individual items and tasks according to the Systems Framework for Postural Control. Review of the framework by the research team suggested that in some cases, multiple constructs were captured in the original 6 domains (eg, reactive and anticipatory postural control under "movement strategies"). As such, the 6 domains were adapted by the primary investigator into 9 operational definitions of balance components that may be uniquely evaluated. These operational definitions were reviewed and revised by two coinvestigators (M.K.B. and K.V.O.) both before and iteratively during coding and validated by an external reviewer with expertise in neurophysiology of postural control. The final operational definitions are presented in table 1. Two investigators (K.M.S. and M.K.B.) independently reviewed the tasks and scoring criteria of each measure and identified on a binary scale (yes/no) which balance components were included in each measure. Individual components were defined as included if they were inherent to task performance, even if not explicitly part of the measure's evaluation criteria. Disagreements were resolved through consensus discussion with a third investigator (K.V.O.).

Collate, summarize, and report results

Data abstraction and mapping results were tabulated and descriptive statistics (frequencies and percentages) were calculated for all variables using SAS (version 9.2).[a]

Results

Data synthesis

The study selection process is illustrated in figure 1. The MEDLINE, CINAHL, and EMBASE searches yielded a total of 1213 records. The hand search and gray literature search yielded an additional 18 records, and the Physiotherapy Evidence Database search did not produce any additional results. After duplicates were removed, and 974 abstracts were identified for review. Of these, 847 records were excluded after the abstract screening and 128 articles were selected for full-text review. After full-text screening, 66 articles representing the index publication of a standardized balance measure for adults were included. Full references for the index publication of all included measures are provided in supplemental appendix S2 (available online only at http://www.archives-pmr.org/).

Measure characteristics

Supplemental Table S1 (available online only at http://www.archives-pmr.org/) presents selected characteristics of each measure. The 66 included measures were published between 1986 and 2014. Thirty-seven measures (56%) stated at least 1 component of balance included in the Systems Framework for Postural Control. Reported development methods for each measure ranged from no description (n=33, 50%), to expert or clinician consultation (n=12, 18%), to statistical analysis (eg, Rasch analysis and item response theory; n=13, 20%). The number of items in each measure ranged between 1 and 53, with a median of 9 items. Twelve measures (18%) included some graded progression in which participants must meet specific criteria to complete additional items. Thirty-eight measures (58%) were evaluated on a categorical scale (ranging between 2 and 9 categories), 26 (39%) used a continuous scale, and 2 (3%) used a combination.

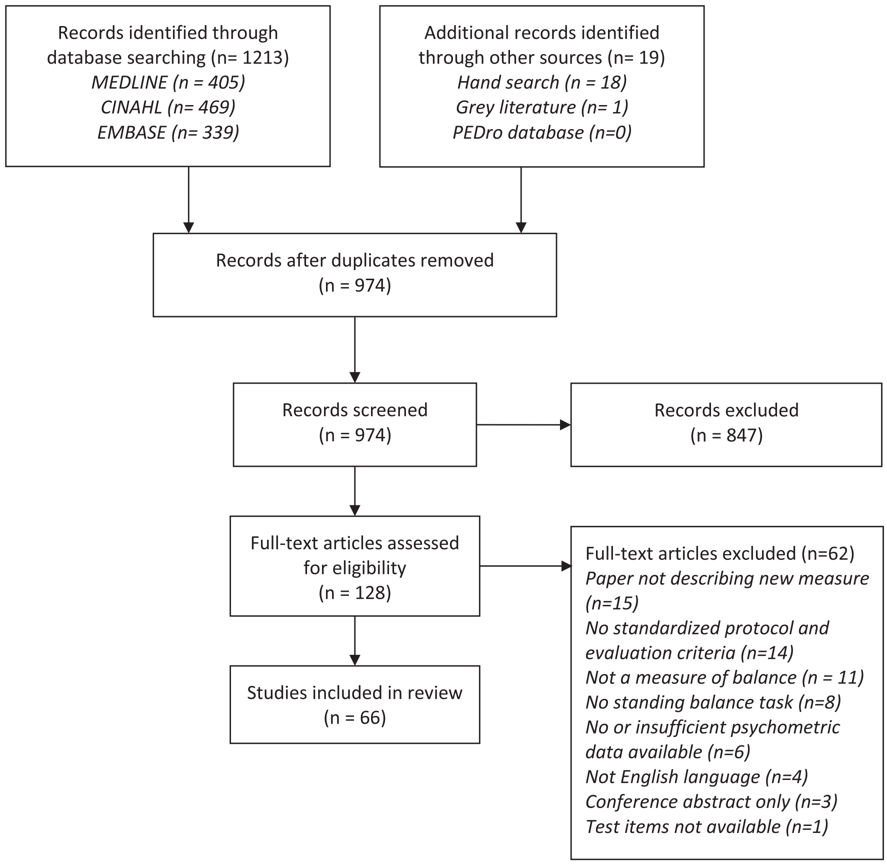

Fig 1 Study flow diagram.

Psychometric data published with the index publication are presented in supplemental table S2 (available online only at http://www.archives-pmr.org/).

Components of balance evaluated in each measure

Coding agreement by the 2 independent reviewers was 87%, and 100% agreement was achieved after consensus discussion with the third investigator. Coding results identifying the components of balance included in each measure are presented in table 2. Underlying motor systems were evaluated in all 66 measures (100%), anticipatory postural control in 47 measures (71%), dynamic stability in 44 measures (67%), static stability in 42 measures (64%), sensory integration in 32 measures (48%), functional stability limits in 18 measures (27%), reactive postural control in 15 measures (23%), cognitive influences in 11 measures (17%), and verticality in 5 measures (8%). Figure 2 illustrates the distribution of number of components evaluated in each measure. Thirty-four measures (52%) evaluated 3 or fewer components of balance, 22 measures (33%) evaluated between 4 and 6 components of balance, 9 measures (14%) evaluated 7 or 8 components of balance, and 1 measure evaluated all 9 components of balance (Balance Evaluation Systems Test [BESTest]).

Discussion

To our knowledge, this work represents the first attempt to synthesize the literature on standardized balance measures for adult populations and analyze the content of measures with respect to an established theoretical framework for postural control. The primary findings of this review are the large number of independently validated standardized measures available to assess balance in adults, and the high proportion of measures that assess only a few components of balance as identified by the Systems Framework for Postural Control. These findings highlight a number of issues relevant to selecting standardized balance measures, as well as broader issues related to the theoretical basis of postural control.

With respect to the high number of standardized balance measures, although 66 distinct measures were included in the present study, it is important to note that there was significant overlap in the specific balance tasks performed. For example, alternating steps onto a stool or platform were common across multiple measures (eg, Activity-based Balance Level Evaluation scale, BESTest, Berg Balance Scale, and Community Balance and Mobility scale). Moreover, some stand-alone measures were incorporated as tasks in larger tests, such as single leg stance and functional reach (included in BESTest and Berg Balance Scale), and several "new" measures were developed as combinations, adaptations, or evolutions of other balance measures (eg, Equiscale, Postural Assessment for Stroke Scale, and Unified Balance Scale). However, recent data on clinical balance assessment practices indicate that refined and/or newer standardized balance measures are yet to be widely adopted[10]; therefore, it is difficult to determine whether actual balance assessment is improving with these changes. Rather, the pool of balance measures continues to

Table 2 Components of balance evaluated by standardized measures

Measure	Static Stability	Underlying Motor Systems	Functional Stability Limits	Verticality	Reactive Postural Control	Anticipatory Postural Control	Dynamic Stability	Sensory Integration	Cognitive Influences	Other Constructs not Included in Systems Framework
Activity-based Balance Level Evaluation (ABLE) Scale[29]	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Sitting balance
Advanced Balance and Mobility Scale (ABMS)[30]	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	
Balance Computerized Adaptive Testing (CAT) system[31]	Yes	Yes	No	No	No	Yes	Yes	Yes	No	Supine to sitting, and sitting
Hierarchical Balance Short Forms (HBSF)[32]	Yes	Yes	No	No	No	Yes	Yes	Yes	No	Sitting balance
Balance Error Scoring System (BESS)[33]	Yes	Yes	No	No	No	No	No	Yes	No	
Modified Balance Error Scoring System (M-BESS)[34]	Yes	Yes	No	No	No	NO	No	Yes	No	
BESTest[18]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	
Brief Balance Evaluation Systems Test (Brief BESTest)[35]	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	
Mini Balance Evaluation Systems Test (Mini BESTest)[36]	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	
Balance Outcome Measure for Elder Rehabilitation (BOOMER)[37]	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	
Balance Screening Tool (BST)[38]	Yes	Yes	No	No	No	Yes	Yes	Yes	No	
BDL Balance Scale[39]	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	
Berg Balance Scale (BBS)[40]	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	Sitting balance
Short Form of the Berg Balance Scale (SFBBS)[41]	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	
Short Berg Balance Scale[42]	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	
Brunel Balance Assessment (BBA)[43]	Yes	Yes	Yes	No	No	Yes	Yes	No	No	Sitting balance
Clinical Gait and Balance Scale (GABS)[44]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	
Clinical Test of Sensory Interaction in Balance (CTSIB)[45]	Yes	Yes	No	No	No	No	No	Yes	No	
Community Balance and Mobility Scale (CB&M)[46]	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	
Dynamic Balance Assessment (DBA)[47]	Yes	Yes	No	No	No	Yes	No	Yes	Yes	
Dynamic Gait Index[48]	No	Yes	No	No	No	Yes	Yes	Yes	Yes	
Four-item Dynamic Gait Index (4-DGI)[49]	No	Yes	No	No	No	Yes	Yes	Yes	Yes	
Functional Gait Assessment (FGA)[50]	No	Yes	No	No	No	Yes	Yes	Yes	Yes	
Dynamic One Leg Stance (DOLS)[51]	Yes	Yes	No	No	No	Yes	No	Yes	No	
Equiscale[52]	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	
Fast Evaluation of Mobility, Balance and Fitness (FEMBAF)[54]	Yes	Yes	No	No	Yes	Yes	Yes	Yes	No	Sitting balance
Five Times Sit-to-Stand Test (5-STS)[55]	No	Yes	No	No	No	Yes	Yes	No	No	

(*continued on next page*)

Table 2 (*continued*)

Measure	Static Stability	Underlying Motor Systems	Functional Stability Limits	Verticality	Reactive Postural Control	Anticipatory Postural Control	Dynamic Stability	Sensory Integration	Cognitive Influences	Other Constructs not Included in Systems Framework
Four Square Step Test (FSST)[56]	No	Yes	No	No	No	Yes	Yes	No	No	
Fullerton Advanced Balance (FAB) Scale[57]	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	
Functional Reach Test[58]	No	Yes	Yes	No	No	Yes	No	No	No	
Multidirectional Reach Test[59]	No	Yes	Yes	No	No	Yes	No	No	No	
Hierarchical Assessment of Balance and Mobility (HABAM)[60]	Yes	Yes	No	No	Yes	Yes	Yes	No	No	
Kansas University Standing Balance Scale (KUSBS)[61]	Yes	Yes	No	No	No	Yes	No	No	No	
Limits of Stability Test (LOS)[62]	No	Yes	Yes	No	No	Yes	No	No	No	
Modified Figure of Eight Test[63]	No	Yes	No	No	No	No	Yes	No	No	
Parallel Walk Test (PWT)[64]	No	Yes	No	No	No	No	Yes	No	No	
Performance Oriented Mobility Assessment (POMA)[53]	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Sitting balance
Modified Performance Oriented Mobility Assessment[65]	Yes	Yes	No	No	No	Yes	Yes	Yes	No	
Postural Assessment Scale for Stroke Patients (PASS)[66]	Yes	Yes	No	No	No	Yes	Yes	No	No	Supine to sitting, and sitting
Short Form of Postural Assessment Scale for Stroke Patients (SFPASS)[67]	Yes	Yes	No	No	No	No	Yes	No	No	
Postural Control and Balance for Stroke Scale[68]	Yes	Yes	Yes	No	No	Yes	Yes	No	No	
Postural Stress Test (PST)[69]	No	Yes	No	No	Yes	No	No	No	No	
Pull/Retropulsion Test[70]	No	Yes	No	No	Yes	No	No	No	No	
Push and Release Test[71]	No	Yes	No	No	Yes	No	No	No	No	
Rapid Step Test (RST)[72]	No	Yes	No	No	No	Yes	Yes	No	No	
Sensory Organization Test (SOT)[73]	Yes	Yes	No	No	No	No	No	Yes	No	
Head-Shake Sensory Organization Test (HS-SOT)[74]	Yes	Yes	No	No	No	No	No	Yes	No	
Short Physical Performance Battery (SPPB)[75]	Yes	Yes	No	No	No	No	Yes	No	No	
Side-Step Test[76]	No	Yes	No	No	No	Yes	Yes	No	No	
Single Leg Hop Stabilization Test[77]	Yes	Yes	No	No	No	Yes	Yes	No	No	
Single Leg Stance Test[78]	Yes	Yes	No	No	No	No	No	No	No	
Spring Scale Test (SST)[79]	No	Yes	No	No	Yes	No	No	No	No	
Standing Test for Imbalance and Disequilibrium (SIDE)[80]	Yes	Yes	No	No	No	Yes	No	No	No	
Star Excursion Balance Test (SEBT)[81]	Yes	Yes	Yes	No	No	Yes	No	No	No	

(*continued on next page*)

Table 2 (*continued*)

Measure	Static Stability	Underlying Motor Systems	Functional Stability Limits	Verticality	Reactive Postural Control	Anticipatory Postural Control	Dynamic Stability	Sensory Integration	Cognitive Influences	Other Constructs not Included in Systems Framework
Step Test (ST)[82]	No	Yes	No	No	No	Yes	Yes	No	No	
Tandem Stance[83]	Yes	Yes	No	No	No	No	No	No	No	
Time on Ball Test[84]	Yes	Yes	No	No	No	No	No	Yes	No	
Timed Up-and-Go Test (TUG)[85]	No	Yes	No	No	No	Yes	Yes	No	No	
Expanded Timed Up-and-Go Test (ETUG)[86]	No	Yes	No	No	No	Yes	Yes	No	No	
TURN180[87]	No	Yes	No	No	No	No	Yes	No	No	
Unified Balance Scale[88]	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	
Unilateral Forefoot Balance Test[89]	Yes	Yes	No	No	No	No	No	No	No	
Timed Up-and-Go Assessment of Biomechanical Strategies (TUG-ABS)[90]	No	Yes	No	No	No	Yes	Yes	No	No	
Posture and Posture Ability Scale (PPAS)[91]	Yes	Yes	No	Yes	No	No	No	No	No	Sitting balance
High Level Mobility Assessment Tool (HiMAT)[92,93]	No	Yes	No	No	No	Yes	Yes	No	No	
Cross Step Moving on Four Spots Test (CSFT)[94]	No	Yes	No	No	No	Yes	Yes	No	No	

widen with additional combinations of tasks in a circuitous fashion.

Although several components of balance were included in a high proportion of measures (such as underlying motor systems, anticipatory postural control, static stability, and dynamic stability in more than two thirds of measures), certain functionally relevant components were not included in most measures. For example, reactive postural control—corrective responses after instability—was included in only 23% of the measures. The lack of measures evaluating reactive control is concerning because the ability to successfully recover from instability is the most critical component of balance for fall avoidance.[24] Impaired reactive control is independently associated with falls, resulting in as much as a 6-fold increase in fall incidence.[25] Similarly, cognitive contributions to postural control and fall risk are well established, yet only 17% of the measures included a secondary cognitive task.[1,26] Finally, vertically was the least commonly included component (8% of the measures). Verticality and appropriate orientation to gravity are important for establishing an efficient stable "starting position" for balance,[27] the absence of which may put an individual in an inherently less stable position, which could lessen the likelihood of successful balance recovery, and for whom individuals with sensory or neurological conditions may be particularly at risk.[18]

Half of the measures included in this review evaluated 3 or fewer components of postural control. Some of these tests are commonly used in clinical practice, such as the Single Leg Stance test,[10] and as such, users need to be aware of what balance information they are getting when they choose a limited-scope measure. These types of tests may be appropriate for screening or risk assessment, but not for treatment planning and intervention selection. For a comprehensive balance assessment, multiple measures can be combined, or users can select a measure that includes most or all components of balance. Only 1 measure contained an explicit evaluation of all 9 components of postural control: the BESTest. Published in 2009, it was developed with the goal of helping clinicians identify underlying postural control systems that may be responsible for poor functional balance—the only identified measure with this specific purpose. However, the BESTest developers also authored the most comprehensive description of the Systems Framework for Postural Control, so it is not unexpected that this measure is the closest match. Four measures included 8 components of balance (Clinical Gait and Balance Scale, Fullerton Advanced Balance Scale, Mini-BESTest, and Unified Balance Scale). From a theoretical perspective, these are the most complete standardized balance measures available to date. However, none of these measures has yet been widely adopted in clinical practice,[10] highlighting the need to study factors influencing balance assessment practices and use of standardized measures in more detail.

Study limitations

Although the focus of this review was on balance assessment for treatment planning and intervention selection, theoretical construct is only one characteristic of a measure. Consideration of measure purpose (eg, risk assessment versus outcome measurement) would be beneficial for evaluating the appropriateness of individual measures for their intended function. Examination of evaluation parameters would also be useful because quantitative measurements may provide more precise information than do observed behaviors. Furthermore, this review did not consider the difficulty of individual items related to a particular balance component, such as whether print & web 4C/FPO

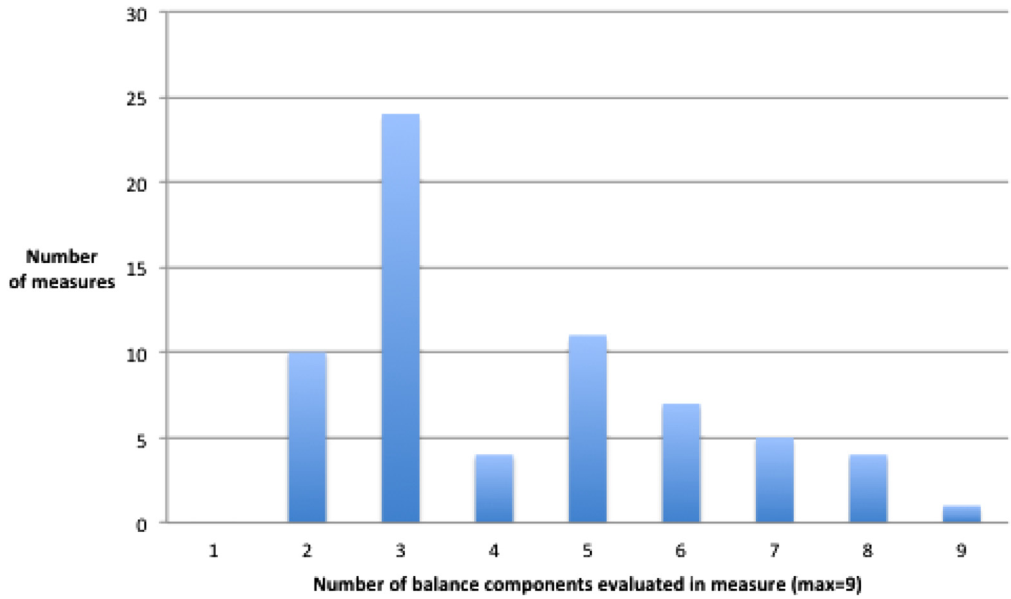

Fig 2 Number of balance components evaluated by measure.

static stability was assessed by normal or narrow stance, tandem stance, or single-leg stance. Nor did we consider how dual-task assessments were conducted and whether instructions were to prioritize the postural or cognitive task. These are important functional distinctions not reflected in the present analysis, and attempts to evaluate particular components of balance across the continuum of difficulty likely have contributed to the proliferation of so many measures. Given the complexities of standardized balance measurement, we suggest that readers interpret our findings in conjunction with the previous reviews that address some of these issues[13,14] and refer to the Rehabilitation Measures Database—a National Institute of Disability and Rehabilitation Research-funded, searchable Web site containing evidence-based summaries of more than 250 rehabilitation measures.[28]

In conducting this review, we identified a number of gaps in postural control theory that require attention to move the field forward. First, although the systems-based nature of postural control is accepted and supported throughout the literature, there is no criterion-standard description of all known components and their interactions. Second, the Systems Framework for Postural Control, the model selected for the current review, accounts for all balance components equally, without any hierarchy or order to the individual components. It also considers only standing balance, when sitting balance is an important functional task recognized in a number of the measures included in this review. Indeed, in this review we excluded measures that included only sitting balance (n=8) because they could not be captured in the model. Refinement of the theory to address such issues may more accurately reflect the nature of postural control in vivo as well as facilitate increased efficiency of balance assessment in time- and resource-constrained clinical environments. For example, reactive postural control may be considered a more challenging component than anticipatory control, and if an individual cannot effectively engage anticipatory strategies, it may not be appropriate to explicitly assess reactive control. Conversely, appropriate anticipatory actions do not necessarily indicate that reactive control is "normal," requiring continued probing. Incorporating such logic to more standardized assessment strategies may preserve the theoretical integrity of balance measures while optimizing efficiency. Two included measures, the Balance Computerized Adaptive Testing system and Hierarchical Balance Short Forms, did incorporate such a system into their approach but lacked consideration of all components of postural control in their models. Continued refinement of these systems from a comprehensive perspective may be a practical approach moving forward.

Conclusions

The theoretical components of postural control included in standardized balance measures for adults vary greatly, with some measures omitting important components relevant for avoiding falls. As such, the choice of the measure may limit the overall interpretation of an individual's balance ability. Continued work is necessary to increase implementation of comprehensive assessment in research and practice to facilitate individualized identification of balance deficits and customization of training programs.

Supplier

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Keywords

Accidental falls; Aging; Chronic disease; Postural balance; Psychometrics; Rehabilitation

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Supplemental Appendix S1. Sample Search Strategy

Database: Ovid MEDLINE(R), Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations, Ovid MEDLINE(R) Daily, and Ovid OLDMEDLINE(R) <from 1946 to February week 4, 2014>

Search Strategy:

1. Postural Balance/ (11,988)
2. Psychometrics/ (47,676)
3. 1 and 2 (75)
4. Disability Evaluation/ (31,007)
5. Geriatric Assessment/ (15,901)
6. "reproducibility of results"/ (230,959)
7. 5 or 6 (245,565)
8. 1 and 4 and 7 (98)
9. 3 or 8 (162)
10. limit 9 to English language (156)

Supplemental Table S1 Measure characteristics

Measure	Reference	Stated Purpose of Measure	Components of Balance Purportedly Assessed	Target Adult Population	Development Methods	Number of Items in Test	Evaluation Parameters	Number of Scoring Categories	Graded Progression
Activity-based Balance Level Evaluation (ABLE) Scale[29]	Ardolino et al. Phys Ther 2012;92: 1046-54	To assess changes in balance across the full spectrum of recovery in the spinal cord injury population	Balance in the domains of sitting, standing, and walking	Spinal cord injury	Literature review and clinical expertise, Delphi process, and Rasch analysis	28	Categorical	5	No
Advanced Balance and Mobility Scale (ABMS)[30]	Kairy et al. Disabil Rehabil 2003;25: 127-35	To address shortcomings of previous balance measures that do not address adaptive and reactive control and do not assess the interaction between impairment and disability components of the task used	Postural control in standing and walking	Not specified	Not specified	12	Categorical	4	No
Balance Computerized Adaptive Testing (CAT) system[31]	Hsueh et al. Phys Ther 2010;90: 1336-44	To assess balance function in people with stroke	Entire range of balance function (items with wide range and even distribution of difficulty)	Stroke	Pool of 41 items identified on the basis of predefined balance concepts, clinical expert consultation, and field testing to finalize item description and scoring; items administered by 5 raters to 764 patients and item response theory model fit to data and item parameters estimated	34	Categorical	26 items have 2 scoring categories, and 8 items have 3 scoring categories	No
Hierarchical Balance Short Forms (HBSF)[32]	Hou et al. Arch Phys Med Rehabil 2011;92:1119-25	To assess balance function precisely in people with stroke with limited assessment burden	Sitting, standing, and stepping balance	Stroke	34 items of the Balance CAT system[31] divided into 3 hierarchical function-related balance levels (sitting, standing, and stepping); simulation program used to make an item selection algorithm proposing 6 candidates (each with 6 items) for each balance level, simulation data used to select	16	Continuous (binary counts transformed into continuous measure)	NA	Yes, within each of 3 categories

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Supplemental Table S1 (*continued*)

Measure	Reference	Stated Purpose of Measure	Components of Balance Purportedly Assessed	Target Adult Population	Development Methods	Number of Items in Test	Evaluation Parameters	Number of Scoring Categories	Graded Progression
					candidates with highest reliability, adopted opinions of stroke-related clinicians and psychometricians to determine the final set of 6-item balance short form for each sitting, standing, and stepping level				
Balance Error Scoring System (BESS)[33]	Riemann et al. J Sport Rehabil 1999;8:71-82	To assess postural stability	Not specified	Not specified	Not specified	6	Continuous (number of errors)	NA	No
Modified Balance Error Scoring System (M-BESS)[34]	Hunt et al. Clin J Sport Med 2009;19:471-5	To easily administer an objective assessment tool in a cost-effective way	Postural stability	Concussion	Modified BESS[33] by eliminating double-leg stance and increasing number of trials per condition	4	Continuous (number of errors)	NA	No
Balance Evaluation Systems Test (BESTest)[18]	Horak et al. Phys Ther 2009;89:484-98	To help physical therapists identify underlying postural control systems that may be responsible for poor functional balance	Biomechanical constraints, stability limits/ verticality, anticipatory postural adjustments, postural responses, sensory integration, and stability of gait	Not specified	Initial test proposed by Horak and Frank, then clinicians provided feedback on clarity, sensitivity, and practicality at 38 workshops over 4y, interrater reliability evaluated, then test revised	36	Categorical	4	No
Brief Balance Evaluation Systems Test (Brief BESTest)[35]	Padgett et al. Phys Ther 2012;92: 1197-207	To assess balance performance in 6 specific contexts of postural control to allow for identification of specific balance systems responsible for poor balance	Mechanical constraints, limits of stability, anticipatory postural adjustments, postural responses to induced loss of balance, sensory	Not specified	Evaluated internal consistency of items in each section of the BESTest[18] and used item-total correlations to identify each section's most representative item	8	Categorical	4	No

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Supplemental Table S1 (*continued*)

Measure	Reference	Stated Purpose of Measure	Components of Balance Purportedly Assessed	Target Adult Population	Development Methods	Number of Items in Test	Evaluation Parameters	Number of Scoring Categories	Graded Progression
			orientation, and gait						
Mini Balance Evaluation Systems Test (Mini BESTest)[36]	Franchignoni et al. J Rehabil Med 2010;42: 323-31	To comprehensively assess balance in a short time period	Dynamic balance	Not specified	Expert review and Rasch analysis of BESTest[18] to remove redundant items	14	Categorical	3	No
Balance Outcome Measure for Elder Rehabilitation (BOOMER)[37]	Haines et al. Arch Phys Med Rehabil 2007;88:1614-21	To be a global standing balance outcome measure for elder rehabilitation	Global standing balance (static, dynamic, and function)	Older adults undergoing rehabilitation	Cross-sectional survey with expert panel, selection of 4 stand-alone tests, multicenter prospective cohort randomly divided into development and validation data sets to perform item scaling	4	Categorical	5	No
Balance Screening Tool (BST)[38]	Mackintosh et al. Int J Ther Rehabil 2006;13:558-61	To screen balance in older adults to identify impairments requiring further investigation and intervention	Static and dynamic standing balance	Not specified	Developed by expert physiotherapists on the basis of published evidence and clinical experience	6	Categorical	2	No
BDL Balance Scale[39]	Lindmark et al. Adv Physiother 2012;14:3-9	To quantitatively measure balance at a relatively high level	Not specified	People of working age with neurological impairment and mild-moderate balance disturbance	Not specified	10	Categorical	5	No
Berg Balance Scale (BBS)[40]	Berg et al. Physiother Canada 1989;41:304-11	To measure balance in healthy individuals	Not specified	Geriatric (60y and older)	Interviews with clinicians and participants, literature review, ranking of items (modified Delphi process)	14	Categorical	5	No
Short Form of the Berg Balance Scale (SFBBS)[41]	Chou et al. Phys Ther 2006;86:195-204	To evaluate balance performance in people with stroke	Not specified	Not specified (validated in stroke)	Selected items from BBS[40] with highest internal consistency and greatest responsiveness in development cohort of patients, and compared 4, 5,	7	Categorical	3	No

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Supplemental Table S1 (*continued*)

Measure	Reference	Stated Purpose of Measure	Components of Balance Purportedly Assessed	Target Adult Population	Development Methods	Number of Items in Test	Evaluation Parameters	Number of Scoring Categories	Graded Progression
					6, and 7-item versions of the SFBBS with 3 and 5 assessment levels				
Short Berg Balance Scale[42]	Hohtari-Kivimaki et al. Aging Clin Exp Res 2012;24:42-6	To assess functional balance among community-dwelling aged people with moderate or good physical functioning	Static and dynamic balance	Community-dwelling older adults	Factor analysis of BBS,[40] removing 5 items	9	Categorical	5	No
Brunel Balance Assessment (BBA)[43]	Tyson and DeSouza. Clin Rehabil 2004;18:801-10	To assess the effects of specific stroke physiotherapy interventions for balance disability poststroke	Not specified	Stroke	14-point hierarchical prototype test proposed with progressively difficult tasks, validated by decreasing pass rates for each item, acceptable coefficients of stability and reproducibility	12	Categorical	2	Yes
Clinical Gait and Balance Scale (GABS)[44]	Thomas et al. J Neurol Sci 2004;217:89-99	To comprehensively measure all essential elements of gait and balance	Balance and posture	Not specified	Not specified	18	Categorical	10 items have 5 levels, 4 items have 3 levels, 2 items have 2 levels, and 2 items have subgroups with multiple categories	No
Clinical Test of Sensory Interaction in Balance (CTSIB)[45]	Shumway-Cook and Horak. Phys Ther 1986;66:1548-50	To assess the influence of sensory interaction on postural stability in the standing patient with neurologic problems	Sensory interactions while standing	People with neurologic problems	Not specified	6	Suggests continuous (time) or categorical (subjective numeric ranking system for sway)	NA	No
Community Balance and Mobility (CB&M) Scale[46]	Howe et al. Clin Rehabil 2006;20:8 85-95	To identify postural instability, evaluate change after intervention, and inform rehabilitation team about balance and	Multitasking, sequencing of movement components, complex motor skills	Ambulatory people with traumatic brain injury	Literature review, interviews with physical and occupational therapists, ambulatory people with brain injury living in community over multiple phases	19	Categorical	6	No

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Supplemental Table S1 (*continued*)

Measure	Reference	Stated Purpose of Measure	Components of Balance Purportedly Assessed	Target Adult Population	Development Methods	Number of Items in Test	Evaluation Parameters	Number of Scoring Categories	Graded Progression
		mobility status of ambulatory individuals with traumatic brain injury returning to community environment							
Dynamic Balance Assessment (DBA)[47]	Desai et al. Phys Ther 2010;90:748-60	Not specified	Dynamic balance	Community-dwelling older adults	Not specified, but notes it incorporates features of modified CTSIB[45]	12	Categorical (continuous data collapsed into categories)	5	No
Dynamic Gait Index[48]	Shumway-Cook et al. Phys Ther 1997;77:812-9	To evaluate and document a patient's ability to modify gait in response to changing task demands	Not specified	Not specified	Not specified	8	Categorical	4	No
Four-item Dynamic Gait Index (4-DGI)[49]	Marchetti et al. Phys Ther 2006; 86:1651-60	To measure walking function in people with balance and vestibular disorders	Not specified	People with balance and vestibular disorders	Rasch analysis of DGI[48]	4	Categorical	4	No
Functional Gait Assessment (FGA)[50]	Wrisley et al. Phys Ther 2004; 84:906-18	To assess postural stability during gait with higher-level tasks	Not specified	Not specified	Revised DGI[48] and added 3 new items	10	Categorical	4	No
Dynamic One Leg Stance (DOLS)[51]	Blomqvist and Rehn. Adv Physiother 2007;9:129-35	To investigate different aspects of balance	Dynamic body actions during 1-legged stance, sensory subsystems	Not specified	Not specified	5	Categorical	2	Yes
Equiscale[52]	Tesio et al. Funct Neurol 1997;12:255-65	To evaluate balance in people with multiple sclerosis	Not specified	Multiple sclerosis and people with unilateral motor or sensory impairments	Preliminary 10-item instrument derived from POMA[53] and BBS [40]; trial-and-error procedure: administered to 55 patients 1—3 times and Rasch analysis used to explore psychometric validity; 2 items deleted	8	Categorical	3	No

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Supplemental Table S1 (*continued*)

Measure	Reference	Stated Purpose of Measure	Components of Balance Purportedly Assessed	Target Adult Population	Development Methods	Number of Items in Test	Evaluation Parameters	Number of Scoring Categories	Graded Progression
					because too easy and uninformative				
Fast Evaluation of Mobility, Balance and Fitness (FEMBAF)[54]	Di Fabio and Seay. Phys Ther 1997; 77:904-17	To assess risk of falling, ability to complete functional tasks, and assess reports of fear, pain, mobility, difficulty, and perception of strength deficits	Not specified	Not specified	Not specified	18	Categorical	3	No
Five Times Sit-to-Stand (5-STS) Test [55]	Whitney et al. Phys Ther 2005; 85:1034-45	To measure balance dysfunction	Not specified	Not specified	Not specified	1	Continuous (time)	NA	No
Four Square Step Test (FSST) [56]	Dite and Temple. Arch Phys Med Rehabil 2002;83: 1566-71	Not specified	Dynamic standing balance, rapid stepping, obstacle avoidance	Older adults	Not specified	1	Continuous (time)	NA	No
Fullerton Advanced Balance (FAB) Scale [57]	Rose et al. Arch Phys Med Rehabil 2006;87:1478-85	To identify balance problems of varying severity in functionally independent older adults and evaluate system(s) that might be contributing to balance problems	Sensory systems and strategies, internal representations, musculoskeletal components, and anticipatory and adaptive mechanisms	Functionally independent older adults	Review of conceptual frameworks, scientific literature, and previously published tests; developed test items and evaluated appropriateness of items, clarity of instructions, and scoring by clinical experts; pilot test of preliminary scale with older adults to establish appropriate test protocols, scoring procedures, and better instructions	10	Categorical	5	No
Functional Reach Test[58]	Duncan et al. J Gerontol 1990;45: M192-7	To assess anterior and posterior dynamic stability	Dynamic stability	Not specified	Not specified	1	Continuous (distance)	NA	No
Multidirectional Reach Test[59]	Newton. J Gerontol A	To measure limits of stability in 4 reaching directions	Limits of stability	Not specified	Not specified	4	Continuous (distance)	NA	No

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Supplemental Table S1 (*continued*)

Measure	Reference	Stated Purpose of Measure	Components of Balance Purportedly Assessed	Target Adult Population	Development Methods	Number of Items in Test	Evaluation Parameters	Number of Scoring Categories	Graded Progression
	Biol Sci Med Sci 2001; 56:M248-52								
Hierarchical Assessment of Balance and Mobility (HABAM)[60]	MacKnight and Rockwood. Age Ageing 1995;24:126-30	Not specified	Static and dynamic balance	Not specified	Not specified	24	Categorical	2	Yes
Kansas University Standing Balance Scale (KUSBS)[61]	Kluding et al. J Geriatr Phys Ther 2006;29:93-9	To measure balance in lower levels of function in more severely impaired people	Standing balance	Not specified	Developed over 2y by physical therapists; scale developed for lower-functioning patients, to document progress in an objective and quantifiable way, quick to use, no math, no equipment; during development, therapists were encouraged to talk to each other about experiences with scale; script of therapist instruction to patients subsequently developed	4	Categorical	10	Yes
Limits of Stability (LOS) Test[62]	Clark et al. Arch Phys Med Rehabil 1997;78:1078-84	To assess multiple indices of dynamic balance performance by evaluating individual's ability to volitionally move the center of gravity to 8 predetermined positions	Dynamic balance	Not specified	Not specified	8	Continuous (center of gravity velocity, excursion, endpoint, directional control)	NA	No
Modified Figure of Eight Test[63]	Jarnlo and Nordell. Phys Theory Pract 2003;19:35-43	To measure the ability to walk slightly in lateral direction to both sides in an 8 in combination with a narrow step width	Not specified	Not specified	Modification of Figure of Eight Test[64]	1	Continuous (time and number of "oversteps")	NA	No
Parallel Walk Test (PWT)[65]	Lark et al. Arch Phys Med Rehabil 2011;92:812-7	To measure dynamic balance during gait	Dynamic balance during gait	Older adults	Not specified	3	Continuous (time and "footfall score" [+1 when part of foot placed on line, +2 when foot falls	NA	No

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Supplemental Table S1 (*continued*)

Measure	Reference	Stated Purpose of Measure	Components of Balance Purportedly Assessed	Target Adult Population	Development Methods	Number of Items in Test	Evaluation Parameters	Number of Scoring Categories	Graded Progression
							outside line or reached for something to maintain balance])		
Performance Oriented Mobility Assessment (POMA)[53]	Tinetti. J Am Geriatr Soc 1986;34:119-26	To practically assess performance-oriented mobility tasks that incorporate useful feature of both disease-oriented and gait analytic approaches	Not specified	Not specified	Reviewed previous work by bioengineers, orthopedists, neurologists, rheumatologists, and physical therapists to identify what observations should be included and how they should be made; adapted this work to make instrument with 8 position changes for balance and 8 gait observations; 90% agreement between raters when tested in 15 ambulatory people; added 5 balance maneuvers	Balance-13, Gait-9	Categorical	3 for balance item and 2 for gait items	No
Modified Performance Oriented Mobility Assessment [66]	Fox et al. Arch Phys Med Rehabil 1996; 77:171-6	To characterize recovery in physical capacity and functional independence after hip fracture	Not specified	People aged 65y and older with a hip fracture	Not specified	13	Continuous (time, angle, distance, contact between thigh and abdomen)	NA	Yes for some tasks
Postural Assessment Scale for Stroke Patients (PASS)[67]	Benain et al. Stroke 1999; 30:1862-8	To assess and monitor postural control after stroke; to assess subject performance	Maintenance of a given posture and to ensure equilibrium in changing postures (lying, sitting, standing)	Stroke	Adapted items from Fugl-Meyer assessment[68]	14	Categorical only	4	No
Short Form of Postural Assessment Scale for Stroke Patients (SFPASS)[69]	Chien et al. Neurorehabil Neural Repair 2007;21:81-90	To measure balance function in people with stroke	Balance in lying, sitting, or standing position	Stroke	Selected items from PASS[67] with highest internal consistency and greatest responsiveness in development cohort of patients and compared 5, 6,	5	Categorical	3	No

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Supplemental Table S1 (*continued*)

Measure	Reference	Stated Purpose of Measure	Components of Balance Purportedly Assessed	Target Adult Population	Development Methods	Number of Items in Test	Evaluation Parameters	Number of Scoring Categories	Graded Progression
					and 7-item versions of the SFPASS with 3 and 5 assessment levels				
Postural Control and Balance for Stroke Scale[70]	Pyöriä et al. Archs Phys Med Rehabil 2005;86:296-302	To assess postural changes, sitting balance, and standing balance with items of varying difficulty in the same clinical instrument	Sitting balance, static standing balance, and postural change tasks	Stroke	Developed and refined by physical therapists	23	Categorical	2—4, depending on question	Yes (independent static sitting and standing as inclusion criteria for additional tasks)
Postural Stress Test (PST)[71]	Wolfson et al. J Am Geriatr Soc 1986; 34:845-50	To safely, quantitatively assess the postural response	Postural responses	Older adults	Not specified	3	Categorical	Number of trials with effective balance (4 levels) and balance strategy score (9-level grading scale)	Yes when using the number of trials effective balance approach
Pull/Retropulsion Test[72]	Visser et al. Arch Phys Med Rehabil 2003;84:1669-74	To assess the ability to maintain balance	Balance reactions	Not specified	Not specified	1	Categorical	4	No
Push and Release Test[73]	Jacobs et al. J Neurol 2006;253: 1404-13	To reliably assess postural stability with sensitivity to fall history and low balance confidence in Parkinson's disease	Postural response to a sudden release of a subject pressing backward on examiner's hands placed on the subject's back	Not specified; developed so that it is sensitive enough for people with Parkinson's disease	Not specified	1	Categorical	5	No
Rapid Step Test (RST)[74]	Medell et al. J Gerontol A Biol Sci Med Sci 2000;55: M429-33	To assess maximal and rapid stepping for balance and fall risk	Not specified	Not specified	Not specified	8	Continuous (step length, distance, and time)	NA	No

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Supplemental Table S1 (*continued*)

Measure	Reference	Stated Purpose of Measure	Components of Balance Purportedly Assessed	Target Adult Population	Development Methods	Number of Items in Test	Evaluation Parameters	Number of Scoring Categories	Graded Progression
Sensory Organization Test (SOT) [75]	Ford-Smith et al. Arch Phys Med Rehabil 1995; 76:77-81	To assess ability to make effective use of visual, vestibular, and proprioceptive inputs separately and the ability to suppress inaccurate sensory information	Postural control	Not specified	Not specified	6	Continuous (2 outcomes per condition)	NA	No
Head-Shake Sensory Organization Test (HS-SOT)[76]	Pang et al. Phys Ther 2011; 91:246-53	To enhance the SOT[75] to improve delineation of balance performance	Sensory interactions in standing balance with additional vestibular input and dual tasks	Not specified	Not specified	6	Continuous (equilibrium score as percentage from 0% to 100%)	NA	No
Short Physical Performance Battery (SPPB)[77]	Guralnik et al. J Gerontol 1994;49:M85-94	To assess lower extremity function	Not specified	Not specified	Adapted from previously used measures	6	Categorical for standing and walking items but continuous (time) for rise from sitting item	Timed standing: side-by-side stand = 2, semi-tandem = 5, tandem = 3 Walking item: 5 categories depending on time	Standing and rise from sitting items were graded
Side-Step Test[78]	Fujisawa and Takeda. Clin Rehabil 2006;20:340-6	To assess dynamic standing balance in the frontal plane	Dynamic standing balance ability in the frontal plane	Stroke	Not specified	1	Continuous (distance)	NA	No
Single Leg Hop Stabilization Test[79]	Riemann et al. J Sport Rehabil 1999;8:171-83	To assess postural control during a functional performance task	Postural control	Not specified	Adapted the modified Bass test described by Johnson and Nelson[80]	20	Categorical	2	Yes
Single leg Stance Test [81]	Bohannon. Top Geriatr Rehabil 2006;22:70-7	To quantify standing balance	Standing balance	Not specified	Not specified	1 or 2 (if one leg or both legs tested)	Continuous (time)	NA	No
Spring Scale Test (SST)[82]	DePasquale and Toscano. J Geriatr Phys	To assess and quantify effective limits of anterior-posterior	Reactive and proactive balance	Community-dwelling older adults	Not specified	2	Continuous (% body weight)	NA	Yes

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Supplemental Table S1 (*continued*)

Measure	Reference	Stated Purpose of Measure	Components of Balance Purportedly Assessed	Target Adult Population	Development Methods	Number of Items in Test	Evaluation Parameters	Number of Scoring Categories	Graded Progression
	Ther 2009;32:159-67	stepping for the purposes of fall risk assessment							
Standing Test for Imbalance and Disequilibrium (SIDE)[83]	Teranishi et al. Jpn J Compr Rehabil Sci 2010;1:11-6	To classify static standing balance ability for fall prevention	Static standing balance	Not specified	Not specified	4	Categorical	Task 1: 2, task 2: 2, task 3: 3, task 4: 2	Yes
Star Excursion Balance Test (SEBT) [84]	Hertel et al. J Sport Rehabil 2000;9:104-16	To challenge the postural control systems of well-conditioned, physically active individuals recovering from lower extremity injuries	Dynamic balance	Well-conditioned, physically active individuals	Not specified	8	Continuous (distance)	NA	No
Step Test (ST)[85]	Hill et al. Physiother Canada 1996;48:257-62	To meet the need for a clinically useful test of balance that incorporates dynamic single limb stance	Dynamic standing balance	Stroke	Not specified	6	Continuous (number of steps up to 7.5cm in 15 and 30s and up to 15cm in 15s on each leg)	NA	No
Tandem Stance[86]	Hile et al. Phys Ther 2012;92:1316-28	To assess postural stability by narrowing the base of support	Not specified	Not specified	Not specified	2	Continuous (time)	NA	No
Time on Ball Test[87]	Bruinsma et al. Clin Kinesiol 2008;62:1-3	Not specified	Dynamic balance	Not specified	Not specified	1	Continuous (time)	NA	No
Timed Up-and-Go Test (TUG) [88]	Podsiadlo and Richardson. J Am Geriatr Soc 1991;39:142-8	To quickly assess basic mobility skills	Not specified	Not specified	Modified the Get-Up and Go Test[89] by timing person rather than scoring them on scale from 1 to 5	1	Continuous (time)	NA	No
Expanded Timed Up-and-Go (ETUG) test [90]	Botolfsen et al. Physiother Res Int 2008;13:94-106	To address shortcomings of the Get-up-and-Go test[89] and the TUG test[88]	Not specified	Not specified	Not specified	5	Continuous (time)	NA	No
TURN180[91]	Simpson et al. Physiotherapy 2002; 88:342-53	To be a simple, clinically useful test of dynamic postural control in frail elderly people	Dynamic postural stability	Frail older adults	Not specified	2	Continuous (counting number of steps)	NA	No

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Supplemental Table S1 (*continued*)

Measure	Reference	Stated Purpose of Measure	Components of Balance Purportedly Assessed	Target Adult Population	Development Methods	Number of Items in Test	Evaluation Parameters	Number of Scoring Categories	Graded Progression
Unified Balance Scale[92]	La Porta et al. J Rehabil Med 2011; 43:435-44	To be a single tool with proven measurement properties, allowing the measurement of balance "from bed to community" regardless of the etiology of the neurological lesion causing the loss of balance	Quiet stance, anticipatory postural adjustments/ transitions, responses to external perturbations, sensory orientation, stability during gait	People with a neurological lesion	Literature review identifying the BBS,[40] POMA,[53] and FAB Scale,[57] classical psychometric methods, Rasch analysis	27	Categorical	2—5, depending on question	No
Unilateral Forefoot Balance Test[93]	Clark et al. NZ J Physiother 2007;35:110-8	Not specified	High-level balance	Postmenopausal women	Unpublished pilot study with 31 health volunteers (16 women, mean age, 35y) assessing interrater and test-retest reliability Pilot interrater ICC = .99 and test-retest ICC = .95	2	Continuous (time)	NA	No
Timed Up-and-Go Assessment of Biomechanical Strategies (TUG-ABS)[94]	Faria et al. J Rehabil Med 2013;45:232-240	To systematically evaluate biomechanical strategies used during performance of the TUG test	Not specified	Stroke	Literature review, opinions of physical therapists, observations of TUG performance, expert panel content validation	15	Categorical	3	No
Posture and Posture Ability Scale (PPAS)[95]	Rodby-Bousquet et al. Clin Rehabil 2014;28:82-90	To evaluate posture and postural ability in people with severe disabilities	Posture and postural ability in lying, sitting, and standing positions	Cerebral palsy	Adaptation of pediatric Physical Ability Scale	4 tasks, 53 items assessed	Categorical scale	7 categories for postural ability, 2 categories for quality of posture	No
High Level Mobility Assessment Tool (HiMAT)[96,97]	Williams et al. Brain Inj 2005;19:833-843	To assess people with high-level mobility and balance problems	High-level mobility	Brain injury	Item generation proposed by expert clinicians, internal consistency and Rasch analysis determined final set	9 tasks, 13 items assessed	Categorical	5 categories	No

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Supplemental Table S1 (*continued*)

Measure	Reference	Stated Purpose of Measure	Components of Balance Purportedly Assessed	Target Adult Population	Development Methods	Number of Items in Test	Evaluation Parameters	Number of Scoring Categories	Graded Progression
Cross Step Moving on Four Spots Test (CSFT) [98]	Yamaji and Demura. Arch Phys Med Rehabil 2013;94: 1312-9	To evaluate crossover steps in older adults	Crossover steps	Older adults (older than 65y)	Not reported	9	Continuous (time to complete 9 steps)	NA	No

NOTE. See supplemental appendix S2 for full list of references.
Abbreviations: ICC, intraclass correlation coefficient; NA, not applicable/available.

Supplemental Table S2 Preliminary psychometric characteristics evaluated in standardized balance measures with index publication

Measure	Reliability Tested	Reliability Type	Reliability Sample Size	Reliability Score	Validity Tested	Validity Type	Validity Method	Validity Sample Size	Validity Score
Activity-based Balance Level Evaluation (ABLE) Scale[29]	No	NA	NA	NA	Yes	1. Content validity 2. Discriminant validity	1. 3-round Delphi process 2. Compare scores across 3 functional groups (walker, stander, and wheelchair user)	104	2. $F_{2,101}$=258.37, P<.0001
Advanced Balance and Mobility Scale (ABMS)[30]	Yes	Interrater reliability	12 people with recent stroke (mean age, 65y), 6 healthy community-dwelling people (mean age, 71y), 5 physiotherapist raters	ICC=.97	Yes	Construct validity	Compared scores between high- and low-functioning people with stroke (based on gait speed cutoff of 0.7m/s), and healthy older adults	12 people diagnosed with recent stroke (mean age, 65y), 6 healthy community-dwelling people (mean age, 71y)	Significant differences in scores across groups (P<.05)
Balance Computerized Adaptive Testing (CAT) system[31]	Yes	1. Interrater reliability 2. Item reliability	1. 5 raters administered 41 items 2. 764 patients with stroke and stimulation study using data of patients who had participated in item pool development	1. Raw sum score of initial 41 items ICC=.95 2. Item simulation study average reliability=.94	Yes	Concurrent validity	Correlated to Berg Balance Scale[40]	56 people with stroke (mean age, 62y)	Pearson r=.88
Hierarchical Balance Short Forms (HBSF)[32]	Yes	Item reliability	Simulation of data from 764 people with stroke	Average reliability ≥.93	Yes	Concurrent validity	Correlated to Berg Balance Scale[40]	85 people with stroke (mean age, 64y)	Spearman ρ=.97
Balance Error Scoring System (BESS)[33]	Yes	1. Interrater reliability 2. Test-retest reliability	1. 3 raters, 18 NCAA Division I varsity male athletes (mean age, 10y) 2. 12 NCAA Division I varsity male athletes (mean age, 20y)	1. ICC range=.78 to .93 2. Significant difference between repeated sessions for double-leg stance-foam target sway	Yes	Concurrent validity	Correlated to forceplate target sway	111 NCAA Division I varsity male athletes (mean age, 20y)	Pearson r range=.31 to .79

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Supplemental Table S2 (*continued*)

Measure	Reliability Tested	Reliability Type	Reliability Sample Size	Reliability Score	Validity Tested	Validity Type	Validity Method	Validity Sample Size	Validity Score
Modified Balance Error Scoring System (M-BESS)[34]	Yes	Internal consistency	144 high school football athletes (mean age, 16y)	Reliability = .88	No	NA	NA	NA	NA
Balance Evaluation Systems Test (BESTest)[18]	Yes	Interrater reliability (evaluated once, then test revised and evaluated again)	Reliability session 1: 12 ambulatory adults with a range of balance function (age, 50 to 80y) Reliability Session 2: 11 subjects, including 4 from first session (age, 67 to 88y)	Total score ICC = .91; subsection ICC range = .79 to .96	Yes	Concurrent validity	Correlated score of most experienced rater to Activity-Specific Balance Confidence Scale[99]	12	Total score r = .685, subsection r range = .41 to .78
Brief Balance Evaluation Systems Test (Brief BESTest)[35]	Yes	Interrater reliability	3 raters, 20 participants with and without diagnosed neurological disorders or injuries	Total score ICC = .99	Yes	Discriminant validity	Compared scores between people with and without neurological diagnosis and multiple sclerosis	20 participants with and without neurological diagnosis or injuries	Scores were significantly different between people with and without neurological diagnosis (P < .01)
Mini Balance Evaluation Systems Test (Mini BESTest)[36]	Yes	1. Item separation index 2. Person separation index	115 people with balance disorders (mean age, 63y)	1. Item separation index = 7.35, r = .98 2. Person separation index = 2.5, r = .86	Yes	Internal	Outlier-sensitive mean-square statistic	115 people with balance disorders (mean age, 63y)	Mean square statistic scores for all items ranged between 0.7 and 1.3
Balance Outcome Measure for Elder Rehabilitation (BOOMER)[37]	No	Internal consistency	784 people (mean age, 74y)	Internal consistency range = .87 to .89	Yes	Construct validity	Correlated to FIM,[100] Modified Elderly Mobility Scale (MEMS)[101]	272 people (mean age, 75y)	Admission FIM ρ = .73 Discharge FIM ρ = .72 MEMS admission ρ = .88 and discharge ρ = .83

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Supplemental Table S2 *(continued)*

Measure	Reliability Tested	Reliability Type	Reliability Sample Size	Reliability Score	Validity Tested	Validity Type	Validity Method	Validity Sample Size	Validity Score
Balance Screening Tool (BST)[38]	Yes	1. Intrarater reliability 2. Interrater reliability	1. 16 community-dwelling older adults (mean age, 70y) 2. 14 falls risk assessment community care clients (mean age, 77y)	1. Spearman rank ρ=.90, κ coefficients range=0.64 to 1.00 for individual items 2. r=.89, κ coefficients range=.58 to .71 for individual items	Yes	Concurrent validity	Correlated to Berg Balance Scale[40]	16 community-dwelling older adults and 14 falls risk assessment community care clients	Spearman r range=.87 to .92
BDL Balance Scale[39]	Yes	1. Interrater reliability 2. Test-retest reliability 3. Internal consistency	1. 2 raters 2 and 3. 30 people with mild- moderate balance problems (mean age, 53y), 35 people with no balance problems	1. κ coefficient range=0.56 to 1.0, total score ICC=.99 2. κ coefficient range=.39 to .73, total score ICC=.96 3. Cronbach α=.87	No	NA	NA	NA	NA
Berg Balance Scale (BBS)[40]	Yes	1. Interrater reliability 2. Internal consistency 3. Intrarater reliability	1. 5 experienced physical therapists 2 and 3. 14 people older than 65y	1. Interrater total score ICC=.98 2. Cronbach α=.96 3. Intrarater total score ICC=.99	Yes	1. Content validity 2.Criterion validity	1. Panel of 32 geriatric patients and health professionals 2. Correlated scores with 3 global ratings of balance (good, fair, and poor)	23	2. Significant association between global rating and BBS score (P<.0001)
Short Form of the Berg Balance Scale (SFBBS)[41]	Yes	Internal consistency	113 people with stroke	Cronbach α=.96	Yes	1. Concurrent validity 2. Convergent validity 3. Predictive validity	1. Compared with PASS[67] at 14d poststoke 2. Correlated to Fugl-Meyer motor test[68] and Barthel Index[102] 3. Correlated to Barthel Index[102] 90d poststroke	113 people with stroke (81 at 90d poststroke)	1. ICC=.99 2. Barthel Index r=.86 & Fugl Meyer r=.68 3. r=.60
Short Berg Balance Scale[42]	Yes	Internal consistency	519 people (mean age, 72y)	Cronbach α=.69	Yes	Concurrent validity	Correlated to static and dynamic balance outcomes assessed on a force platform	519 people (mean age, 72y)	Correlation range with static outcomes=−.32 to −.45 (all P<.0001), correlation range with dynamic outcomes=−.25 to −.41 (all P< .0001)

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Supplemental Table S2 (*continued*)

Measure	Reliability Tested	Reliability Type	Reliability Sample Size	Reliability Score	Validity Tested	Validity Type	Validity Method	Validity Sample Size	Validity Score
Brunel Balance Assessment (BBA)[43]	Yes	1. Internal consistency 2.Test-retest reliability 3. Interrater reliability	1. 80 people poststroke (mean age, 67y) 2. 37 people poststroke (mean age, 66y) 3. 2 raters	1. Cronbach α = .93 2. κ coefficient = 1 3. κ coefficient = 1	Yes	Criterion-related validity	Correlated with Motor Assessment Scale,[103] the BBS,[40] Rivermead Mobility Index[104]	55 people poststroke (mean age, 68y)	Motor Assessment Scale ICC = .83 BBS ICC = .97 Rivermead Mobility Index ICC = .95
Clinical Gait and Balance Scale (GABS)[44]	Yes	Intrarater reliability	10 people with Parkinson's disease	κ coefficient range = .315 to .839	Yes	Concurrent validity	Correlated to spatial and temporal gait characteristics and limits of stability test[62]	35 people with Parkinson's disease (age, 50 to 75y)	Correlation range = .43 to .66
Clinical Test of Sensory Interaction in Balance (CTSIB)[45]	Yes[105]	1. Test-retest reliability 2. Interrater reliability	1. 22 people (mean age, 21y) 2. 2 raters	1. Pearson r = .992. Pearson r = .99	No	NA	NA	NA	NA
Community Balance and Mobility (CB&M) Scale[46]	Yes	1. Interrater reliability 2. Intrarater reliability 3. Test-retest reliability	1. 4 teams of 2 physical therapists 2 and 3. 32 people with traumatic brain injury attending neurorehabilitation (mean age, 34y)	1. ICC = .98 2. ICC = .98 3. Immediate ICC = .98 and test-retest 5d apart ICC = .90	Yes	1. Content validity 2. Construct validity	1. Physical therapists' ratings of importance of scale items on 5-point scale from "not at all important" to "extremely important," correlation to global balance rating 2. Compared with gait velocity	36 people with traumatic brain injury attending neurorehabilitation (mean age, 31y)	1. Physical therapist global balance scale r = .62 2. Self-paced gait velocity r = .53, maximal gait velocity r = .64
Dynamic Balance Assessment (DBA)[47]	No	NA	NA	NA	Yes	Convergent validity	Correlated to gait speed, Six-Minute Walk Test,[106] the TUG test,[88] and the BBS[40]	72 community-dwelling adults older than 65y	Correlation range = 0.1 to 0.31
Dynamic Gait Index[48]	No	NA	NA	NA	Yes	1. Concurrent validity 2. Discriminant validity	1. Correlated to the BBS,[40] assistive device use, history of imbalance, self-perceived balance 2. Compared scores between fallers and nonfallers	44 community-dwelling people (mean age, 76y)	1. Correlation range = .44 to .76 2. Significant difference in score between groups (P < .001)

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Supplemental Table S2 (*continued*)

Measure	Reliability Tested	Reliability Type	Reliability Sample Size	Reliability Score	Validity Tested	Validity Type	Validity Method	Validity Sample Size	Validity Score
Four-item Dynamic Gait Index (4-DGI)[49]	Yes	1. Subject separation 2. Item difficulty separation 3. Internal consistency	131 people (with balance and vestibular disorders and healthy controls)	1. r=.79 2. r=.99 3. Internal consistency correlation range=.75 to .82	Yes	Discriminant validity	Compared scores between fallers and nonfallers	34 people who had reported falls in the past 6mo and 89 subjects who had not reported falls in the previous 6mo	Scores were significantly different between fallers and nonfallers ($P<.01$)
Functional Gait Assessment (FGA)[50]	Yes	1. Intrarater reliability 2. Interrater reliability 3. Internal consistency	1 and 3. 6 people with vestibular disorders (mean age, 59y) 2. 10 clinicians	1. ICC=.83 2. ICC=.84 3. Cronbach α=.79	Yes	Concurrent validity	Correlated to the DGI,[48] Activities-Specific Balance Confidence (ABC) Scale,[99] Dizziness Handicap Inventory,[107] perception of dizziness symptoms, number of falls, and the TUG test[88]	6 people with vestibular disorders (mean age, 59y)	Correlation range=0.1 to 0.8
Dynamic One Leg Stance (DOLS)[51]	Yes	Test-retest reliability	12 blind people aged 19 to 61y and 12 sighted people aged 26 to 60y	Weighted κ=.47 to .88 for blind people and .47 to .72 for sighted people	Yes	Concurrent validity	Correlated scores with single-leg stance test[81] and force plate assessment	12 blind people aged 19 to 61y and 12 sighted people aged 26 to 60y	Correlation with force plate assessment and single-leg stance test for blind subjects: −.13 and .77 for left leg and −.78 and .89 for the right leg, sighted people: correlation was −.56 (NS) and .93 for the left leg and −.61 and .71 for the right leg
Equiscale[52]	Yes	Item separation reliability	24 people with multiple sclerosis	r=.98	No	NA	NA	NA	NA
Fast Evaluation of Mobility, Balance and Fitness (FEMBAF)[54]	Yes	Interrater reliability	5 older adults, 2 raters	Mean risk factors κ=.95, task completion κ=.96	Yes	Concurrent validity	Correlated to the POMA,[53] the CTSIB,[45] and TUG[88] tests	35 older adults without cognitive impairment	POMA Spearman rank-order r range=−0.1 to 0.91, CTSIB range=−.18 to .56, TUG=−0.2 to 0.6

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Supplemental Table S2 (*continued*)

Measure	Reliability Tested	Reliability Type	Reliability Sample Size	Reliability Score	Validity Tested	Validity Type	Validity Method	Validity Sample Size	Validity Score
Five Times Sit-to-Stand (5-STS) Test[55]	No	NA	NA	NA	Yes	1. Concurrent validity 2. Discriminant validity	1. Compared scores between people with and without diagnosed balance disorders 2. Compared scores to the DGI[48] and the ABC scale[99]	81 healthy controls and 93 people with balance disorders	1: DGI Spearman $\rho=-.68$ ($P<.001$) and ABC Spearman $\rho=-.58$ ($P<.001$) 2. The FTSST correctly identified 65% of the subjects with balance dysfunction
Four Square Step Test (FSST)[56]	Yes	1. Interrater reliability 2. Test-retest reliability	1. 30 community-dwelling adults older than 65y 2. 20 community-dwelling adults older than 65y	1. ICC=.99 2. ICC=.98	Yes	Convergent validity	Correlated to the Step Test,[85] the TUG test,[88] and the Functional Reach Test[58]	81 community-dwelling older adults	Step Test $r=.83$, TUG test $r=.88$, Functional Reach Test $r=.47$
Fullerton Advanced Balance (FAB) Scale[57]	Yes	1. Test-retest reliability 2. Intrarater reliability 3. Interrater reliability	1. 31 older adults (mean age, 75y) with identified balance problems of varying severity 2 and 3. 10 older adults (61 to 81y), 4 raters	1. Spearman rank $r=.96$ 2. Correlation range=0.51 to 1.0 3. Correlation range=0.22 to 1.0	Yes	Convergent validity	Correlated to BBS[40] scores	31 older adults (mean age, 75y) with identified balance problems of varying severity	Spearman rank $r=.75$ ($P<.01$)
Functional Reach Test[58]	Yes	Test-retest reliability	14 people (age, 20 to 79y)	ICC=.92	Yes	Concurrent validity	Correlated with the COP excursion	128 people (age, 20 to 79y)	Pearson $r=.71$
Multidirectional Reach Test[59]	Yes	1. Internal consistency 2. Test-retest reliability	254 community-dwelling older adults (mean age, 74y)	1. Cronbach $\alpha=.842$ 2. ICC range=.93 to .94	Yes	Concurrent validity	Correlated to the BBS[40] and the TUG test[88]	254 community-dwelling older adults (mean age, 74y)	Correlation with BBS total score: forward reach $r=.476$, backward reach $r=.356$, right reach $r=.389$, and left reach $r=.39$ Correlation with TUG: forward reach $r=-.442$, backward reach $r=-.333$, right reach $r=-.26$, and left reach $r=-.31$

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Supplemental Table S2 (*continued*)

Measure	Reliability Tested	Reliability Type	Reliability Sample Size	Reliability Score	Validity Tested	Validity Type	Validity Method	Validity Sample Size	Validity Score
Hierarchical Assessment of Balance and Mobility (HABAM)[60]	Yes	Interrater reliability	2 raters, 30 people admitted to a general medicine service or geriatric assessment unit (mean age, 80y)	ICC=.94	Yes	1. Convergent construct validity 2. Discriminant construct validity	Correlated to the Barthel Index,[102] Folstein Mini Mental Status Exam (MMSE),[108] Lawton-Brody Instrumental Activities of Daily Living (ADL),[109] Spitzer Quality of Life Index[110]	30 people admitted to a general medicine service or geriatric assessment unit (mean age, 80y)	1. Barthel Index $r=.76$ 2. Folstein MMSE $r=.15$, Lawton-Brody ADL $r=.30$, Spitzer Quality of Life Index $r=.39$
Kansas University Standing Balance Scale (KUSBS)[61]	Yes	1. Intrarater reliability 2. Interrater reliability	23 people admitted to inpatient rehabilitation (mean age, 58y)	1. ICC=.89 for novice raters, ICC=.76 for experienced raters 2. ICC=.73	Yes	Concurrent validity	Correlated to FIM[100] transfer and walking scores	25 people admitted to inpatient rehabilitation (mean age, 63y)	FIM transfer $r=.49$, FIM walking $r=.38$
Limits of Stability Test (LOS)[62]	Yes	Test-retest reliability	38 community-dwelling healthy older adults (mean age, 68y)	Generalizability coefficient range=.69 to .89	No	NA	NA	NA	NA
Modified Figure of Eight Test[63]	Yes	1. Interrater reliability 2. Test-retest reliability	1. 2 raters 2. 30 community-dwelling women older than 70y (mean age, 76y)	1. ICC=0.94 to 1.0 at first session and 0.99 to 1.00 at second session, .79 to .93 for number of oversteps 2. ICC=.93 and ICC=.73 for oversteps value	Yes	Concurrent validity	Correlated to one-legged stance test,[81] tandem stance with eyes closed, preferred and maximal gait velocity	30 community-dwelling women older than 70y (mean age, 76y)	Correlation range=.05 to .52
Parallel Walk Test (PWT)[65]	Yes	1. Interrater reliability 2. Test-retest reliability	1. 2 raters 2. 36 elderly fallers (mean age, 81y)	1. ICC range=.71 to .99 2. ICC range=.70 to .90	Yes	1. Concurrent validity 2. Discriminative validity	1. Correlated to tandem[86] and parallel stance tests and tandem walk tests 2. Compared scores between fallers and nonfallers	61 older adult fallers and nonfallers	Correlation range=.28 to .49, significant differences in scores between fallers and nonfallers ($P<.05$)

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Supplemental Table S2 (*continued*)

Measure	Reliability Tested	Reliability Type	Reliability Sample Size	Reliability Score	Validity Tested	Validity Type	Validity Method	Validity Sample Size	Validity Score
Performance Oriented Mobility Assessment (POMA)[53]	Yes[111]	Interrater reliability	26 residents of a skilled nursing home (mean age, 80y), 3 student physical therapists (phase 1), 9 physical therapy clinicians (phase 2)	Phase 1: κ range=0.4 to 1.0; Phase 2: κ range=0.4 to 0.75	No	NA	NA	NA	NA
Modified Performance Oriented Mobility Assessment[66]	Yes	Interrater reliability	23 people after hip fracture (mean age, 81y), 4 raters	κ range=0.1 to 0.4 ICC range=.08 to .92	No	NA	NA	NA	NA
Postural Assessment Scale for Stroke Patients (PASS)[67]	Yes	1. Interrater reliability 2. Intrarater reliability	1. 2 unique raters 2. 12 people with stroke	1. Average κ coefficient= .72 (range= 0.45 to 1), Pearson r=.99 2. Average k-coefficient= .88 (range, 0.64 to 1), Pearson r=.98	Yes	1. Construct validity 2. Predictive validity	1. Correlated scores with motricity, somatosensory threshold, spatial inattention, spasticity, and functional status and instrumental measures of sitting balance, when available 2. Correlated with FIM score[100] at 3mo	70	"Strong correlations with the transferring and locomotion sections of FIM, with motricity, sensibility, and spatial neglect scores, negative correlations with postural stabilization (r=.48; P<.0001) and postural orientation with respect to gravity (r=.36; P=.05); strong correlation to total FIM score (r=.75; P<.0001)
Short Form of Postural Assessment Scale for Stroke Patients (SFPASS)[69]	Yes	Internal consistency	287 people with stroke (mean age, 65.5y)	Cronbach α=.93	Yes	1. Concurrent validity 2. Convergent validity 3. Predictive validity	1. Compared with PASS[67] at 14d poststoke 2. Correlated to Fugl-Meyer motor test[68] and Barthel Index[102] 3. Correlated to Barthel Index[102] 90d poststroke	287 people with stroke (mean age, 65.5y)	1. ICC=.98 2. Barthel Index r=.86 and Fugl Meyer r=.75 3. r=.48
Postural Control and Balance for Stroke Scale[70]	Yes	1. Internal consistency 2. Interrater reliability 3. Intrarater reliability	1 and 3. 19 people (1 to 8wk poststroke) 2. 5 raters	1. Cronbach α=.96 2. Total score ICC=.95 3. Total score ICC=.96	No	NA	NA	NA	NA

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Supplemental Table S2 (*continued*)

Measure	Reliability Tested	Reliability Type	Reliability Sample Size	Reliability Score	Validity Tested	Validity Type	Validity Method	Validity Sample Size	Validity Score
Postural Stress Test (PST)[71]	Yes	Interrater reliability	51 (22 nursing home residents with $\geq$2 unexplained falls in previous year, 18 age- and sex-matched, nonfalling control group, 21 young controls)	Cronbach α=.99	Yes	Discriminant validity	Compared scores between 3 groups	51 (22 nursing home residents with $\geq$2 unexplained falls in previous year, 18 age- and sex-matched, nonfalling control group, 21 young controls)	Significant difference in scores between groups (P<.05)
Pull/Retropulsion Test[72]	Yes	Interrater reliability	3 raters, 42 people with Parkinson's disease (mean age, 64y) and 15 healthy volunteers (mean age, 64y)	Weighted κ mean range=.57 to .98	Yes	1. Concurrent criterion validity 2. Predictive validity	1. Compared scores between unstable Parkinson's disease, stable Parkinson's disease, and health control groups 2. Sensitivity and specificity	42 people with Parkinson's disease (mean age, 64y) and 15 healthy volunteers (mean age, 64y)	1. Significant differences for all but 2 conditions (P<.05) 2. Predictive: sensitivity=.63, specificity=.88, positive predictive value=.86, negative predictive value=.69, and overall predictive accuracy=.75
Push and Release Test[73]	Yes	Interrater reliability	3 examiners, 3 healthy people (mean age, 62y), 8 people with Parkinson's disease (mean age, 62y)	ICC range=.83 to .84	Yes	Discriminant validity	Compared scores between people with and without Parkinson's disease	68 people with Parkinson's disease (mean age, 67y), 69 healthy people (mean age, 67y)	Significant differences in scores between people with and without Parkinson's disease (P<.001)
Rapid Step Test[74]	Yes	1. Test-retest reliability 2. Interrater reliability	34 women (12 healthy young, 12 healthy older, and 10 balance-impaired older adults)	1. ICC range=.71 to .97 2. ICC=.98 for primary session and .95 for follow-up	Yes	Convergent validity	Correlated to balance and fall risk measures	34 women (12 healthy young, 12 healthy older, and 10 balance-impaired older adults)	Correlation range=.60 to .84
Sensory Organization Test (SOT)[75]	Yes	Test-retest reliability (completed for each condition for first trial and average of 3 trials)	40 community-dwelling adults older than 65y	First-trial ICC range=.15 to .70, 3-trial average ICC range=.26 to .68	No	NA	NA	NA	NA

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Supplemental Table S2 (*continued*)

Measure	Reliability Tested	Reliability Type	Reliability Sample Size	Reliability Score	Validity Tested	Validity Type	Validity Method	Validity Sample Size	Validity Score
Head-Shake Sensory Organization Test (HS-SOT)[76]	Yes	Test-retest reliability	77 people (56 young adults [mean age, 24y] and 21 older adults [mean age, 58y])	Overall HS-SOT condition 2 ICC=.82, overall HS-SOT condition 5 ICC=.77	No	Discriminant validity	Compared scores between young and older adults	165 people (92 young adults [mean age, 28y], 73 older adults [mean age, 60y])	HS-SOT scores significantly lower in older adults ($P<.01$)
Short Physical Performance Battery (SPPB)[77]	Yes	Internal consistency	5104 community-dwelling people from 3 population studies (aged 65y and older)	Cronbach $\alpha=.76$	Yes	Concurrent validity	Correlated scores to performance of self-reported disability	5104 community-dwelling people from 3 population studies (65y and older)	Summary performance score showed a very strong association with measures of self-reported disability
Side-Step Test[78]	Yes	Test-retest reliability	28 people with hemiplegia (mean age, 67y)	ICC=.97 (for both affected and unaffected legs)	Yes	Convergent validity	Correlated to one-footed standing duration, walking speed, stride length, and cadence	28 people with hemiplegia (mean age, 67y)	Correlation range=.84 to .89
Single Leg Hop Stabilization Test[79]	Yes	Interrater reliability	3 testers, 15 people (mean age, 21y)	Landing score: ICC=.92 Balance scale: ICC=.70	No	NA	NA	NA	NA
Single-leg Stance Test[81]	Yes[112]	Interrater reliability	42 people (mean age, 42y)	ICC=.76	No	NA	NA	NA	NA
Spring Scale Test (SST)[82]	Yes	Test-retest reliability	58 community-dwelling adults older than 65y (29 fallers and 29 nonfallers)	ICC=.94	Yes	1. Convergent construct validity 2. Known groups validity	1. Correlated to gait speed, the TUG test,[88] the Single-leg Stance Test,[81] and Tandem Stance[86] 2. Known groups: Compared with gait speed, the TUG test,[88] the Single-leg Stance Test,[81] and Tandem Stance[86]	58 community-dwelling adults older than 65y (29 fallers and 29 nonfallers)	1. Gait speed $r=.53$, TUG $r=-.67$, Single limb stance $r=.54$, and Tandem stance $r=.55$ 2. Significant difference between fallers and nonfallers ($T=11.6$; $P=.001$)
Standing Test for Imbalance and Disequilibrium (SIDE)[83]	Yes	Interrater reliability	30 rehabilitation inpatients with neurological or musculoskeletal impairment (mean age, 57.4y), 2 physiotherapists	Cohen k=.76	Yes	Criterion-related validity	Correlated with the BBS[40]	30 rehabilitation inpatients with neurological or musculoskeletal impairment (mean age, 57.4y)	Spearman rank $r=.93$ ($P<.01$)

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Supplemental Table S2 (*continued*)

Measure	Reliability Tested	Reliability Type	Reliability Sample Size	Reliability Score	Validity Tested	Validity Type	Validity Method	Validity Sample Size	Validity Score
Star Excursion Balance Test (SEBT)[84]	Yes	1. Intrarater reliability 2. Interrater reliability	16 recreationally active, healthy young adults (mean age, 21y)	1. ICC range=.78 to .96 2. ICC range=.35 to .84 on day 1 and .81 to .93 on day 2	No	NA	NA	NA	NA
Step Test (ST)[85]	Yes	Test-retest reliability	14 healthy older adults (mean age, 72y) and 21 people with stroke (mean age, 76y)	Healthy elderly ICC range=.90 to .94; stroke ICC range=.88 to .97	Yes	Concurrent validity	Correlated to the Functional Reach Test,[58] gait velocity, and stride length	49 people (20 with stroke and 29 healthy elderly, mean age, 71y)	Correlation range=.68 to .83
Tandem Stance[86]	Yes[113]	1. Interrater reliability 2. Test-retest reliability	45 women (mean age, 63y), 2 observers	1. ICC=.99 2. ICC range=.76 to .91	Yes	Discriminant validity	Compared test performance by fall history	NA	NA
Time on Ball Test[87]	Yes	1. Intrasession reliability 2. Intersession reliability 3. Interrater reliability	1. 10 college-aged students (mean age, 20y) 2. 10 college-aged students (mean age, 20y) 3. 2 testers	1. ICC=.374 2. ICC=.203 3. ICC=>.98	No	NA	NA	NA	NA
Timed Up-and-Go (TUG) Test[88]	Yes	1. Interrater reliability 2. Intrarater reliability	22 medically stable people attending day hospital over a 2-mo period	1. ICC=.99 2. ICC=.99	Yes	Concurrent validity	Correlated to the BBS,[40] Barthel Index,[102] and gait speed	60 elderly volunteer subjects (mean age, 80y)	BBS $r=-.72$, gait speed $r=-.55$, Barthel Index $r=-.51$
Expanded Timed Up-and-Go (ETUG) test[90]	Yes	1. Intrarater reliability 2. Interrater reliability 3. Test-retest reliability	1 and 3. 28 home-dwelling people (mean age, 80y) with impaired mobility 2. 3 raters	1. ICC=.91 2. ICC range=.86 to.96 3. ICC range=.54 to .85	Yes	Concurrent validity	Compared with the TUG[88] test score	28 home-dwellingpeople (mean age, 80y) with impaired mobility	Corrected Pearson=.85
TURN180[91]	No	NA	NA	NA	Yes	Concurrent validity	Correlated with gait speed, fall history, perceived steadiness, and fear of falling	142 people admitted to an acute geriatric ward (mean age, 81y)	Spearman r with fall history=.35, gait speed=.71, perceived steadiness=.35

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Supplemental Table S2 *(continued)*

Measure	Reliability Tested	Reliability Type	Reliability Sample Size	Reliability Score	Validity Tested	Validity Type	Validity Method	Validity Sample Size	Validity Score
Unified Balance Scale[92]	Yes	Internal consistency	217 people with a neurological diagnosis (mean age, 59.5y)	Cronbach α=.98	No	NA	NA	NA	NA
Unilateral Forefoot Balance Test[93]	Yes	Test-retest reliability	28 women (age, 58 to 69y)	ICC=.96	Yes	Concurrent validity	Compared with Single-leg Stance Test[81] with eyes closed	142 women (mean age, 61.6y)	r=.63
Timed Up-and-Go Assessment of Biomechanical Strategies (TUG-ABS)[94]	Yes	1. Intrarater reliability 2. Interrater reliability	22 people with stroke (mean age, 54.7y), 4 raters	κ coefficient range=0.36 to 1.0	Yes	1. Content validity 2. Criterion-related validity	1. Ranking by experts 2. Compared with Sit-to-Stand task	13 people with stroke (mean age, 63.4y)	1. Final set of items reached κ>.72 2. κ ranges from 0.29 to 1.0
Posture and Posture Ability Scale (PPAS)[95]	Yes	1. Interrater reliability 2. Internal consistency	30 adults with cerebral palsy (age, 19 to 22y)	1. κ coefficient ranges from .85 to .99 2. Cronbach α ranges from .96 to .97	Yes	Construct validity	Compared with Gross Motor Function Classification System	30 adults with cerebral palsy (age, 19 to 22y)	Significant differences between known groups represented by gross motor function levels (P< .02)
High Level Mobility Assessment Tool (HiMAT)[96,97]	Yes	Internal consistency	103 people with traumatic brain injury (median age, 27y)	Cronbach α=.99	No	NA	NA	NA	NA
Cross Step Moving on Four Spots Test (CSFT)[98]	Yes	Test-retest reliability	533 older adults (age, 65 to 94y)	ICC=.833 in men, ICC=.825 in women	No	NA	NA	NA	NA

NOTE. See supplemental appendix S2 for full list of references.
Abbreviations: ICC, intraclass correlation coefficient; NA, not applicable/available; NCAA, National Collegiate Athletic Association; NS, not significant.

Supplemental Appendix S2. Full Reference List for all Sources Used in Scoping Review (Including Full References for Included Studies)

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