

Original Research

Validity and Reliability of Dynamic and Functional Balance Tests in People Aged 19-54: A Systematic Review

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Evaluating an impairment in an individual's capacity to maintain, achieve, or restore balance suggests a deficiency in postural control. For effective identification of individuals at risk for falls, balance assessment should exhibit reliability, validity, and ease of use. This systematic review concentrated on dynamic and functional balance assessment methods and their validity in healthy adults aged 19-54. The objective was to clarify the tools that health professionals can utilize to assess balance in this healthy population.

Methods

A systematic literature search conducted in August 2019 yielded nine articles meeting predefined selection criteria. Inclusion criteria required studies featuring healthy adult participants aged 19-54, published in English, and focusing on dynamic and functional balance testing. Exclusion criteria excluded studies involving participants with chronic diseases or musculoskeletal disorders, systematic reviews, professional athletes, and those lacking specific participant age information. The quality of the studies was evaluated using a modified PEDro scale.

Results

This review analyzed ten distinct postural balance tests. The Star Excursion Balance Test and Y-Balance Test exhibited moderate to high reliability, establishing them as dependable measures of dynamic balance. The Nintendo Wii Balance Board, Clever Balance Board, and Posturomed device also displayed excellent reliability for assessing dynamic postural balance. Comparing one-arm and two-arm functional reach tests, the one-arm reach test emerged as a more suitable option for evaluating dynamic balance among young adults. Moreover, an investigation comparing three dynamic balance tests (one-leg jump landing, Posturomed device, and stimulated forward fall) revealed a low correlation among these tests, indicating a measurement of different balance constructs.

Discussion

In conclusion, the Y-Balance Test stands out as the most practical dynamic balance assessment for clinical use, characterized by a standardized protocol, good repeatability, affordability, and ease of application. The Nintendo Wii Balance Board also presents itself as a cost-effective and reliable tool for dynamic balance evaluation in clinical settings. It is crucial to recognize that these tests appraise discrete postural skills, preventing direct comparisons between test outcomes. This review equips healthcare professionals with valuable insights into optimal balance assessment methods for the healthy, 19 to 54 aged population.

Levels of evidence

Level 3

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INTRODUCTION

One definition of postural balance is the ability to achieve a state of equilibrium by keeping the body's center of gravity (COG) over the base of support (BOS).¹ Postural balance can be categorized into static and dynamic balance. Static balance involves maintaining balance while standing or sitting, with the BOS remaining stationary and only the COG moving. Dynamic balance, on the other hand, is the ability to maintain balance while moving from one point to another, such as during walking. In dynamic balance, both the BOS and COG are in motion, and the COG never stays within the BOS during periods of single-limb support.^{2,3}

Balance comprises both postural and equilibrium components. Postural control involves managing gravitational forces to maintain posture, while equilibrium control involves managing acceleration forces to maintain overall stability.³ The control of balance is achieved through a continuous feedback system that processes somatosensory (proprioception), vestibular, and visual inputs and elicits neuromuscular responses.¹ Disturbances in these systems can make maintaining balance more challenging.³

Current standardized clinical balance assessment tools are designed to screen for balance problems and predict the risk of falls, particularly in elderly individuals.⁴ Common dynamic or functional balance tests, such as the Berg Balance Scale, Get Up and Go test (with or without timing), Functional Reach test, Tinetti Balance and Mobility scale, and the Dynamic Gait Index, are widely used to differentiate fallers from non-fallers and assess fall risk among older adults who are more prone to balance issues and increased risk of falling. These tests are also applicable to post-stroke patients, individuals with certain neurological conditions such as Parkinson's disease or multiple sclerosis, and those with vestibular disorders, all of whom have an elevated risk of falling.^{3,5}

Most of the current standardized balance tests are primarily applicable to the elderly population or individuals with specific disabilities. While there is abundant scientific literature on these balance assessment tools, to best of the authors' knowledge, only a few studies have focused on balance testing in healthy adults between 18 to 64. Moreover, encouraging the inclusion of middle-aged in balance testing recommendations can assist in identifying the pattern of balance decline. The Star Excursion Balance Test (SEBT) appears to be one of the most extensively investigated clinical balance assessment tools in this age group.^{6,7} The SEBT is a functional and cost-effective measurement tool for assessing postural control, and it is sensitive to age-related changes in balance.⁶ The test involves reaching in eight directions: anterior, medial, lateral, posterior, anteromedial, anterolateral, posteromedial, and posterolateral. The individual stands on a single leg and reaches as far as possible in each direction, lightly touching the floor tape with the free-floating leg.⁸ However, due to the time-consuming nature of performing the SEBT with several directions and trials, researchers have developed modified versions of the test that include only three out of the eight directions.^{6,7} As a result, a clinically applicable version called the Y-Bal-

ance Test (YBT) was developed. The YBT focuses on three reach directions: anterior, posterolateral, and posteromedial. Unlike the SEBT where the measurement is executed in floor level, in the YBT, the subject needs to push a reach indicator block as far as possible using the foot. The YBT follows a standardized protocol and takes less time to complete than the SEBT. Additionally, the YBT has shown good to excellent intra-rater (0.85-0.91) and inter-rater reliability (0.99-1.00).^{7,9}

This systematic review concentrated on dynamic and functional balance assessment methods and their validity in healthy adults aged 19-54. The objective was to clarify the tools that health professionals can utilize to assess balance in this healthy population.

METHODS

LITERATURE SEARCH

Searches were conducted using PubMed, Scopus, Cochrane Library, and Medline databases from 2009 to July 2019 using search terms related to dynamic balance, testing, assessment, and evaluation. Full search strategies are provided in Appendix 1.

SELECTION CRITERIA AND PROCESS

The included studies had to meet the following criteria: 1) participants were healthy adults aged 19 to 64 years old, 2) the study was published in English, and 3) the study focused on dynamic and functional balance testing methods.

The primary exclusion criteria were: 4) participants had chronic diseases that could affect balance, and 5) the article was a systematic review.

Additional exclusion criteria included: To further narrow down the selection of articles to the desired target group, an additional exclusion criterion was implemented. 6) studies involving participants with musculoskeletal diseases, that affect postural balance 7) studies focused on athletes (either amateur or professional level), and 8) the articles had to mention the exact ages of the participants ([Figure 1](#)).

Initially, the titles of all the studies identified through the database search were screened. After excluding studies that did not meet the criteria, the abstracts were analyzed by two reviewers (ST and KL). If any important information (e.g., exact age of participants) was not found in the abstract, the full text was reviewed by reviewers (ST and KL). Finally, when only a few potential studies remained, the full texts were read to make a final decision on eligibility. For detailed information about the study selection, refer to [Figure 1](#), the Prisma flowchart.

ASSESSMENT OF THE METHODOLOGICAL QUALITY

The methodological quality of the studies was assessed using the Physiotherapy Evidence Database (PEDro) scale. The PEDro scale consists of eleven items and is primarily designed for rating the methodological quality of randomized controlled trials (RCTs). However, there is evidence suggesting the need to revise the PEDro scale to better suit

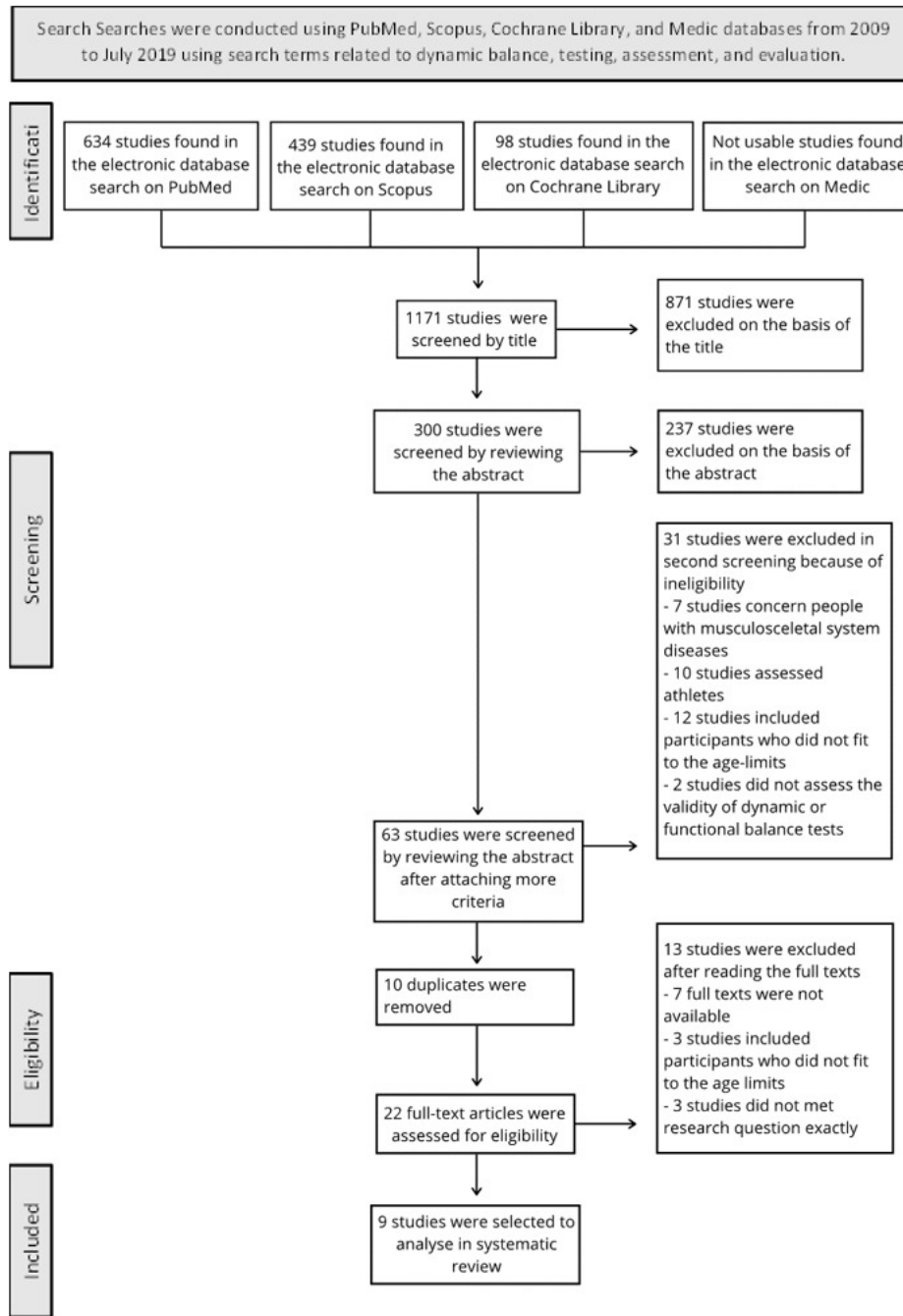


Figure 1. Prisma flowchart of article selection

the purpose of use for in studies based of methodological aspects. Items such as randomization, concealed allocation, and blinding have discriminative validity and may not be applicable in certain study designs.¹⁰

In controlled training studies, blinding is often not feasible, so for this review, the items related to blinding of subjects, therapists, and assessors were excluded from the PEDro scale. As a result, the total PEDro score was adjusted to 7 points instead of 10, and a modified rating system was used: 6 to 7 points indicated “excellent quality,” 5 points indicated “good quality,” 4 points indicated “moderate quality,” and 0 to 3 points indicated “poor quality.”¹⁰ The studies were independently rated on this modified PEDro scale by two reviewers (ST and KL).

RESULTS

STUDY CHARACTERISTICS

The systematic literature search identified a total of 1,171 studies. After screening the titles, 300 studies remained for further evaluation through abstracts. The screening process was repeated twice, resulting in 64 studies that met criteria 1-5. To further narrow down the selection of articles to the desired target group, an additional exclusion criterion was implemented and (criteria 6-8) were then applied, and duplicates were excluded, leaving 22 studies for full-text analysis. After independent screening by two researchers, a total of nine articles (total of 319 participants) were se-

Table 1. Quality assessment of the selected studies using the modified PEDro scale

Study	1	2	3	4	5	6	7	Score
Kage et al.	1	0	1	1	0	0	1	4
Šarabon et al.	1	0	1	1	0	1	1	5
Bouillon et al.	1	0	1	1	0	1	1	5
Coughlan et al.	1	1	1	1	0	0	1	5
Teyhen et al.	0	0	1	1	0	0	1	3
Schmidt et al.	1	0	1	1	0	0	1	4
Bonnechère et al.	0	0	1	1	0	0	1	3
Mengarelli et al.	0	0	1	1	0	0	1	3
Ringhof et al.	0	0	1	1	0	1	1	4

Note: * Score – 1 (presents the criterion); 0 (does not present the criterion). ** Items of evaluation – 1: randomized allocation; 2: concealed allocation; 3: similarity between groups; 4: dimension of results; 5: analysis through treatment intention; 6: intergroup statistical comparison; 7: accuracy and variability measurements.

lected for inclusion in this research. Please refer to [Figure 1](#) for a detailed overview of the screening process

Among the selected studies, three were rated as having “good” methodological quality,^{6,7,11} three as having “moderate” quality,¹²⁻¹⁴ and three received a score of 3 on the modified PEDro scale, indicating “poor” quality,¹⁵⁻¹⁷ Most participants in the included studies were young adults, ranging in age from 19 to 39 years,^{7,11-17} only one study included middle-aged adults aged 40-54 years,⁶ and no studies healthy adults aged 55 to 64. Two studies exclusively included women,^{6,14} one study included only men,⁷ while five studies included both men and women,^{11-13,16,17} and one study did not specify the sex of the participants.¹⁵

TESTS INCLUDED

The studies included in this systematic review investigated a total of ten different postural balance tests. Three studies focused on the Star Excursion Balance Test (SEBT) or the Y-Balance Test, which is a modification of the SEBT.^{6,7,17} The Functional Reach Test (performed with one arm or two arms) was used in two studies.^{12,15} One study utilized the Nintendo Wii Balance Board (NBB),¹⁵ while another study did not involve any specific devices.¹² The NBB was also employed in a study by Bonnechère et al.,¹⁶ along with a force plate (FP). The Posturomed device was used in two studies,^{13,14} and the Clever Balance Board (CBB) was used in one study.¹¹ Other methods employed to investigate dynamic balance included one-leg jump landing and simulated forward falls.¹⁴ Detailed information on the results can be found in [Table 2](#).

Based on this systematic review, it is evident that among healthy adults aged 19-54 years, one of the most used dynamic balance tests in clinical settings are the functional tests like Star Excursion Balance Test (SEBT) and the Y-Balance Test (YBT). These tests were employed in three out of the nine studies included in this review: one study exclusively used the SEBT,⁶ one study focused on the YBT,¹⁷ and one study compared the two tests.⁷

Bouillon and Baker⁶ used the SEBT to investigate the effect of age on functional balance. Their hypothesis was that increasing age would lead to lower excursion scores, indicating poorer dynamic balance. Notably, the partici-

pants' ages spanned from adults (30.4 ± 6.73) to middle-aged (46.6 ± 3.95), ($p < 0.01$). The intraclass correlation coefficient (ICC) values for reaching distance ranged from 0.95-0.97 in the adult group and from 0.72-0.96 in the middle-aged group, indicating moderately high to high reliability in reaching distance between the two groups. Using the SEBT to investigate differences between the groups, the results showed that the adult group achieved greater reach distances in every direction compared to middle-aged group, indicating a decline in dynamic balance with increasing age.⁶

Coughlan et al.,⁷ compared results between the SEBT and the YBT and found a difference in anterior reach-direction distance between the two tests. The SEBT demonstrated significantly greater reach distances in the anterior direction for both the left ($p = 0.0002$) and right legs ($p = 0.003$) compared to the YBT. Bland-Altman analysis showed strong agreement between the left leg results ($5.08 [-4.69$ to $14.85]$), with a performance difference of 5.08% of limb length based on a 95% confidence interval. Distinct results were found also for the right leg ($4.59 [-7.41$ to $16.60]$), indicating the reach SEBT score higher than the YBT score. No significant differences were noted in the posteromedial and posterolateral directions. Paired sample correlations were all equivalence ($0.572-0.781$), indicating that both the SEBT and YBT are reliable tools for assessing dynamic balance.⁷

Teyhen et al.¹⁷ found a correlation between greater reach distance in the YBT and better performance in other physical activities. Their results demonstrated that better performance on the YBT was associated with better performance on the Functional Movement Screen (FMS) in-line lunge ($r = 0.40$, $p = 0.001$), shoulder/upper trunk mobility ($r = 0.29$, $p = 0.017$), greater gastrocnemius flexibility ($r = 0.38$, $p = 0.004$), and a reduced number of hops needed during a 6-meter hop test ($r = -0.35$, $p = 0.004$).¹⁷

Various balance boards were used in the included studies.^{11,13-16} The Nintendo Wii Balance Board (NBB) was utilized in two studies, both of which demonstrated its suitability for assessing dynamic balance.^{15,16} Mengarelli et al.¹⁵ found a high correlation between the NBB and an instrumented dynamic force platform (Bertec 4060H, 60x40 cm) in both the anterior-posterior and medial-lateral di-

Table 2. Overview of included articles.

Authors/ year	PEDro scale score	Objectives	Sample	Balance testing device or tool?	Implementation	Results	Type of research
Kage et al.2009 ¹²	4	To discern which functional reach test (a one-arm reach or a two-arm reach) correlates better with center of pressure excursion.	25 healthy young adults (14 males, 11 females, range 19-30 years)	One-Arm and Two-Arm Functional Reach test	In one-arm reach subjects reached as forward as they could with holding right arm horizontal and keeping left arm at the side of the body. In two-arm reach subjects reached forward with both arms horizontal. Subjects repeated both conditions and better results were accepted for analysis.	For the one-arm reach, the correlation between the reach distance and the center of pressure deflection was remarkably higher as compared to two-arm reach. The one-arm reach is more convenient to assess dynamic balance among young adults. The one-arm reach is more convenient to assess dynamic balance among young adults.	Comparative study
Šarabon et al.2009 ¹¹	5	To determine the intra- and inter-session reliability of a Clever Balance Board, an original dynamic balance diagnostic tool.	Group 2: 20 healthy young adults (8 men, 12 women, age range 23.4 ±1.8 years)	Clever Balance Board (CBB)	The participants performed a double-leg balance test on a CBB. Intention was to stand with both legs on the board in a semi-squat posture with arms on the hips and eyes open and maintain balance for 40 s. Test was repeated 2 days later by the same examiner.	A high retest correlation was found for all three balance indicators (percentage of active time, average angular velocity during active balancing and average frequency of changing the direction of movement). Within-individual variation was acceptable. Between the two sessions, no significant differences were found.	Cross-sectional study
Bouillon et al.2011 ⁶	5	To evaluate how age affects dynamic balance and excursion scores in Star Excursion Balance test.	29 adult aged women (age range 23-39 years) 24 middle-aged women (age range 40-54 years).	Star Excursion Balance test	Participants carried out 3 reaches in a randomized order. Directions were anteromedial, medial and posteromedial. There were 3 trials for each.	By using SEBT to investigate dynamic balance, moderate to high reliability was found between the adult and middle-aged groups across all directions.	Cross-sectional study
Coughlan et al. 2012 ⁷	5	To compare the anterior, posteromedial, and posterolateral directions between SEBT and YBT and figure out if any differences appear in a reach distance.	20 healthy active males (age 22.5 ± 3.05 years).	Star Excursion Balance Test SEBT and Y Balance Test YBT	Participants performed two test sessions at least 7 days apart. 3 trials were allowed in each test direction.	There was a difference in the anterior reach between SEBT and YBT. The Bland-Altman analysis demonstrated SEBT reach excursions to be greater than YTB values on average. Reach distance was further in SEBT on both legs. In the posteromedial and posterolateral directions there were no differences. Paired sample correlations were parallel between SEBT and YBT.	Comparative study

Authors/ year	PEDro scale score	Objectives	Sample	Balance testing device or tool?	Implementation	Results	Type of research
Teyhen et al. 2014 ¹⁷	3	To clarify the association between specific balance, flexibility, strength, power, and endurance measures. Y-Balance test and functional movement screen (FMS) were used in a comparison.	64 healthy, active, duty service members. (53 men and 11 women, age 25.2 ± 3.8 years).	Balance measurement: Y-Balance Test YBT	There were 7 testing positions and subjects performed the tests in a counterbalanced order. Balance measurements: Assessed using Y-Balance Test. 6 trials were allowed to achieve 3 successful trials. Of these 3 trials the maximum and average reaching distance of each direction were recorded.	Better performance on the YBT related better performance on FMS and upper trunk mobility tests, greater flexibility of gastrocnemius muscle and reduced hops in a 6-m hop test.	Single cohort-Correlational study
Schmidt et al. 2015 ¹³	4	To use the Posturomed device to analyze intra- and inter-day reliability of dynamic balance responses after perturbations that were unexpected.	30 healthy young adults (15 men and 15 women, age range 24.3 ± 3.2 years).	The Posturomed device	Participants were standing on the Posturomed with their dominant leg. Anterior-posterior and medial-lateral perturbations were caused. 12 trials in both directions were gathered in a randomized order. Each participant performed the testing procedure twice per day and repeated it another day.	For both perturbation directions and analyzed intervals were found good absolute	Repeatability study
Bonnechère et al. 2016 ¹⁶	3	To verify the usability of Nintendo Wii Balance Board (NBB) assessing dynamic balance responses after perturbations that were unexpected.	35 healthy adults (21 men and 14 women, age 25 ± 3 years).	Nintendo Wii Balance Board NBB and a gold standard force plate FP	Subjects played two serious games that were specially developed. Displacements of center of pressure were concurrent registered with NBB and FP. FP was embedded within the laboratory floor and NBB layed on the top of it.	Results showed an excellent correlation between Nintendo Wii Balance Board and force plate for each parameter for the two games.	Comparative study
Mengarelli et al. 2018 ¹⁵	3	To establish if the Nintendo Wii Balance Board NBB could be used as reliable device for dynamic balance measuring.	48 healthy young adults (age range 23.4 ± 2.1 years).	The Functional Reach Test by using Nintendo Wii Balance Board NBB	The participants accomplished the Functional Reach Test standing on NBB that was placed on a force plate FP. Data were simultaneously obtained from both devices.	FP and NBB-COP (center-of-pressure) displacements pointed a high correlation in both anterior-posterior and medial-lateral directions.	Comparative study
Ringhof et al. 2018 ¹⁴	4	To compare three common dynamic balance tests and investigate how these tests measure dynamic postural stability.	24 healthy young females (12 training swimming, 12 gymnastics, age 23.7 ± 1.0 years).	One-leg jump landing, Posturomed perturbation and stimulated forward fall.	The participants needed to regain balance as fast as possible in each of the tests. Footwear was standardized and subjects used the dominant leg. 3 valid trials were registered for each test.	Low correlation was found between the tests in all measurements of dynamic stability.	Comparative study

rections ($r > 0.990$). The root-mean-square error values for center of pressure displacements were 1.14 ± 0.88 mm and 0.55 ± 0.28 mm in the anterior-posterior and medial-lateral directions, respectively. Bonnechère et al.¹⁶ reported an excellent correlation ($r = 0.95$ and 0.96) between the NBB and a gold standard force plate (AMTI model OR6-6, Watertown, MA), in two video games played by the participants during the examination.

Šarabon et al.¹¹ investigated the inter-session reliability of the Clever Balance Board (CBB), a diagnostic tool for assessing dynamic balance. They used ICC-values, where values below 0.5 indicate poor reliability, between 0.5 and 0.75 moderate reliability, between 0.75 and 0.9 good reliability, and any value above 0.9 indicates excellent reliability. They found a high test-retest correlation (ICC = 0.77-0.90) and acceptable within-individual variation (CV = 8.4-13.9%). No significant differences were observed between the two test sessions for all three CBB scores ($t = 0.27-0.57$; $p > 0.5$). These results suggest that the Clever Balance Board could be a reliable tool for assessing dynamic balance among healthy, physically active individuals.¹¹ Another reliable electronic dynamic balance measuring system in healthy individuals is the Posturomed device (Haider Bioswing GmbH, Germany). Schmidt et al.¹³ demonstrated good relative and absolute reliability for the analyzed intervals and perturbation directions, with ICC values ranging between 0.71-0.97 for all intervals and intra- and inter-day comparisons. A mild learning effect was detected in the anterior-posterior direction when considering intra-day comparisons.¹³

Kage et al.¹² compared the one-arm and two-arm functional reach tests and found that the one-arm reach test was more appropriate for assessing dynamic balance among young adults than the two-arm reach test. Significant correlations were observed between all reach distances (finger-to-finger, heel-to-finger, and finger forward distance) and center of pressure excursion in the one-arm reach test ($r = 0.4-0.78$). In contrast, the two-arm reach distances showed no significant correlation with center of pressure excursion, except for the heel-to-finger distance ($r = 0.46$, $p < 0.05$).¹²

Mengarelli et al.¹⁵ also used the functional reach test to establish the validity of the NBB for assessing dynamic balance. The validity of the NBB was evaluated by comparing it to a laboratory-grade force plate. They found a high correlation between the force plate and NBB center of pressure displacements in both the anterior-posterior ($r = 0.998 \pm 0.004$) and medial-lateral ($r = 0.995 \pm 0.010$) directions.¹⁵

Ringhof and Stein¹⁴ compared three common dynamic balance tests: one-leg jump landing, Posturomed perturbations, and simulated forward falls. They hypothesized a low correlation between these tests. However, no significant correlations were found between the dynamic balance tests, with r -values ranging from -0.161 to 0.057 . There was also no significant correlation between static stability in single-leg stance, measured for comparison to dynamic stability, and the dynamic stability tests, with r -values ranging from -0.152 to 0.201 . These findings suggest that different balance tests do not measure the same construct, i.e., dynamic postural balance, but rather task-specific sensorimo-

tor skills. Therefore, the results of different tests cannot be directly compared to each other.¹⁴

DISCUSSION

This systematic review underscores the importance of selecting appropriate postural balance assessment methods based on the target population and emphasizes the critical evaluation of validity, reliability, and repeatability. The study provides evidence supporting the Star Excursion Balance Test (SEBT) and the Y-Balance Test (YBT) as valid and reliable tools for measuring functional balance in healthy adults aged 19-54 years. Both tests have been extensively studied, with moderate to high reliability reported for the SEBT and high interrater and intrarater reliability for the YBT.

The YBT, specifically designed to enhance repeatability and standardize testing procedures, exhibits promising reliability and validity.^{9,18} Studies suggest an association between better YBT performance and improved physical capacity, highlighting its potential as an equipment free,¹⁹ valid and reliable dynamic balance measurement tool.^{17,20} However, the comparison between SEBT and YBT is complex, as differences in setup and participants' postural control strategies influence assessment outcomes. The SEBT tends to yield higher results in anterior reach distance than the YBT especially with previously trained individuals,²¹ cautioning against direct comparisons⁷ between the two tests. Ultimately, both the YBT and SEBT are valuable tools for assessing dynamic balance, and the selection between them may be influenced by factors such as available equipment, specific research questions, or clinical preferences.

Additionally, the one-arm Functional Reach Test (FRT) challenges the prevailing use of the two-arm FRT, offering distinct benefits in evaluating dynamic balance. The one-arm FRT, originally developed by Duncan et al.²² shows a higher correlation between reach distance and center of pressure excursion, suggesting advantages in assessing dynamic balance.¹² Notably, the one-arm FRT is cost-effective, user-friendly, and demonstrates good intra-rater reliability.²³ The FRT has been established as a reliable measure for assessing limits of stability,²⁴ detecting age-related declines in performance,^{25,26} indicating physical frailty,²⁷ and predicting fall risk.²⁸ Further, no relationship has been reported between one-arm reach and trunk rotation.^{12,29}

Furthermore, the Nintendo Wii Balance Board (NBB) exhibits a strong correlation with Force Plate (FP) measurements,^{15,16} showcasing potential as an affordable and portable balance assessment tool. Despite variations in reliability reported in different age groups, the NBB shows promise in clinical settings for assessing static balance.³⁰⁻³² Notably, despite the absence of a calibration procedure, the NBB exhibited good agreement with the a force plate.¹⁶ The NBB is a relatively new device for balance assessment, characterized by its affordability (<\$100 USD) and portability, with a compact platform measuring 23 x 43 cm that captures vertical ground reaction forces when the user stands on it.^{30,33}

Bower et al.³⁴ conducted a study showing the NBB to be highly reliable for assessing static and dynamic balance in stroke patients. Zhong and Rau³² concluded that the NBB is a feasible tool for evaluating postural balance in a clinical setting, exhibiting good reliability and validity in older individuals. Conversely, Chang et al.³⁵ reported lower reliability in young adults (mean age 22.17 ± 1.35 years) but higher reliability in elderly individuals (mean age 67.32 ± 3.43 years) when measuring standing balance using three different tests: standing with eyes open, standing with eyes closed, and one-leg standing.³⁵ Clark et al.³⁶ highlighted the acceptable reliability and validity of the NBB in measuring static standing postural balance. Hence, the NBB could be introduced as a reliable method for assessing postural balance in clinical settings.

The Posturomed device demonstrates good reliability for assessing dynamic balance among healthy adults.³⁷ One major benefit is, that it is also employed as a training and therapy device for rehabilitation and sports injury prevention.³⁸ However, the challenge related to its usability is the high price of the device (> 1800 €).³⁹ While the Posturomed device may find utility in large clinics specializing in sports medicine, its everyday use in common clinics may be impractical.

The CBB's reliability, particularly highlighted in the included study,⁴⁰ positions it as a promising tool for evaluating dynamic balance in healthy, physically active adults. Its portability and moderate price further enhance its appeal, suggesting a potential role for widespread clinical use.^{40,41}

The one-leg jump landing test is widely utilized for assessing dynamic balance.⁴²⁻⁴⁴ The challenging nature of performing this measurement has highlighted significant variability in stability-based measurements of dynamic postural control.⁴⁵ Thus, based on this research and the existing literature, it appears that the one-leg jump landing test may not be a reliable tool for assessing dynamic balance in individuals other than athletes.

In conclusion, the SEBT, YBT, one-arm FRT, NBB, CBB, and Posturomed device offer valid and reliable options for assessing dynamic balance, as well as to investigate the fall risk among elderly of individuals, predict future falls, and screen for potential balance-related disorders,^{1,46,47} each with unique advantages and considerations. The choice of method should align with the specific goals, target population, and available resources in clinical settings.

CLINICAL IMPLICATIONS

When assessing postural control in a clinical setting, it is essential to utilize quantitative, norm-referenced tools that meet specific criteria. These tools should: 1) Consider both the functional capabilities and quality of movements, 2) Demonstrate sensitivity and selectivity for identifying abnormalities in postural control, 3) Possess reliability and validity, and 4) Be practical, meaning they should be easy to use and cost-effective.⁴⁷

This systematic review investigated the reliability and validity of various dynamic balance tests or testing devices. Based on the results of this research, the following tests have demonstrated both validity and reliability in assessing

dynamic balance: the Star Excursion Balance Test (SEBT), the Y-Balance Test (YBT), the One-Arm Functional Reach Test (FRT), the Clever Balance Board, the Posturomed device, and the Nintendo Wii Balance Board. SEBT, YBT, and FRT are all practical and cost-effective options, but YBT stands out due to its standardized protocol.⁹ Among the electronic balance boards, the Nintendo Wii Balance Board is the most practical tool, and thanks to its affordability and portability,³³ it holds potential for broader clinical utilization.

Regarding the demands mentioned earlier, specifically 1) considering both the functional capabilities and quality of movements, and 2) demonstrating sensitivity and selectivity for identifying abnormalities in postural control, the results of this systematic review were unable to inform a definitive stance. Further investigation is required to address these aspects.

LIMITATIONS

This systematic review has some limitations that should be acknowledged. Firstly, the number of studies included in this review was relatively small, comprising only nine studies. This limited sample size may restrict the comprehensiveness of the review. Additionally, the number of participants in the studies included was also small, ranging from 20 participants to 64 participants. Furthermore, most participants were young adults, with ages ranging from 19 to 30 years, making it challenging to directly apply the results to aging adult's individuals e.g., 50 to 54 years. The study by Bouillon and Baker,⁶ was the only one that included older participants, but it solely consisted of women, thereby lacking data on older men. This gender imbalance is a notable deficiency since gender can influence performance in balance tests.

The quality of the studies assessed using the modified PEDro scale ranged from "poor" to "good," indicating an overall weak quality. Blinding participants in controlled training studies is often impractical, and blinding therapists or investigators is uncommon. As a result, the PEDro scale may not be the most suitable tool for evaluating the quality of the examined studies. Alternatively, the CASP Appraisal Checklist or LEGEND Evidence Evaluation Tools might have been more suitable for assessing systematic review articles of this nature. Furthermore, some studies did not properly divide participants into groups or used arbitrary divisions based on different characteristics such as age. It is also important to note that the participants in these studies were healthy adults without any specific treatment or therapy, further affecting the applicability of the PEDro score in assessing study quality.

CONCLUSION

In conclusion, this systematic review highlights the limited availability of dynamic and functional balance tests specifically designed for healthy, aged 19 to 54 years old individuals compared to elderly individuals. Among the tests reviewed, the YBT emerges as the most suitable option for

functional balance assessment in clinical settings. Additionally, the Nintendo Wii Balance Board stands out as a low-cost and reliable tool for balance assessment, showing potential for clinical use. Other viable tests include the SEBT and the one-arm functional reach test.

It is important to note that each dynamic and functional balance test measures different postural skills, making it challenging to directly compare results between tests. Further research is warranted, particularly focused on middle-aged individuals who represent a potential at-risk population for future falls. By conducting more studies targeting this age group, a better understanding of their dynamic bal-

ance characteristics can be gained, contributing to the development of effective fall prevention strategies.

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CONFLICT OF INTEREST

The authors report no conflicts of interest

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SUPPLEMENTARY MATERIALS

Appendix 1

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