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Comparative Effectiveness of Balance Training on Dynamic Balance in Older Adults: A Systematic Review

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Abstract

Background: Impairment in dynamic balance is a major contributor to falls among older adults and represents a critical target for rehabilitation. Although various balance training approaches have been developed, their comparative effectiveness remains unclear.
Objective: To evaluate and compare the effectiveness of multicomponent, technology-based, and dual-task balance training in improving dynamic balance in older adults.
Methods: A systematic review was conducted in accordance with PRISMA guidelines. Four electronic databases (Scopus, PubMed, Google Scholar, and Semantic Scholar) were searched for randomized controlled trials published between 2018 and 2025. Studies involving participants aged ≥60 years and reporting dynamic balance outcomes were included. Methodological quality was assessed using the Physiotherapy Evidence Database (PEDro) scale. Due to heterogeneity in interventions and outcome measures, findings were synthesized narratively.
Results: Nine studies involving approximately 553 participants were included. All studies reported improvements in dynamic balance, with most demonstrating statistically significant effects ($p < 0.05$). Technology-based and dual-task interventions tended to produce greater improvements compared with multicomponent training; however, results were not consistent across all studies. Reported effect sizes ranged from moderate to large (Cohen's d up to 1.12; η^2 up to 0.395), while reporting of confidence intervals was inconsistent.
Conclusion: Balance training is effective in improving dynamic balance in older adults. Technology-based and dual-task approaches may provide additional benefits; however, these findings should be interpreted with caution due to methodological variability. Clinical implementation should consider individual patient characteristics.

Keywords
postural balance, exercise therapy, rehabilitation, accidental falls, aged

Introduction

The aging process is a progressive and multifactorial phenomenon characterized by declines in physiological, functional, and cognitive capacities, which collectively contribute to reduced independence and increased vulnerability to adverse health outcomes.[1] The global population aged ≥65 years is projected to increase substantially, reaching approximately 16% of the total population by 2050, thereby intensifying the burden on healthcare systems.[2] Among the most significant health concerns in this population are falls, which are associated with morbidity, mortality, and decreased quality of life.

Falls in older adults are typically the result of complex interactions between intrinsic and extrinsic factors. Among these, impairments in balance and muscle strength are consistently identified as primary contributors.[3] In addition, cognitive decline, altered gait patterns, and reduced functional performance further increase the risk of falls.[4] These factors highlight the importance of maintaining adequate balance function as a key component of fall prevention strategies in older adults.

Balance is defined as the ability to maintain the body's center of mass within its base of support through the integration of visual, vestibular, and somatosensory systems. It can be categorized into static balance, which refers to maintaining a stable posture without movement, and dynamic balance, which involves maintaining stability during movement or functional activities such as walking and turning. Age-related decline in dynamic balance is particularly critical, as it directly affects mobility and increases fall risk.[5] Consequently, improving dynamic balance has become a central focus in geriatric rehabilitation.

In physiotherapy practice, balance training is widely used to enhance postural control and functional independence.[6] Over time, rehabilitation approaches have evolved into several distinct modalities. Multicomponent balance training (MBT) aims to improve balance by simultaneously targeting multiple physiological systems, including strength, coordination, and proprioception. Technology-based balance training utilizes interactive systems and digital platforms to provide multisensory stimulation and real-time feedback, which may enhance engagement and motor learning.[7] Meanwhile, dual-task training (DTT) incorporates simultaneous cognitive and motor tasks, reflecting real-life functional demands and promoting cognitive–motor integration.[8]

A growing body of evidence suggests that these interventions are effective in improving balance and functional performance in older adults.[9,10] However, the existing literature remains heterogeneous in terms of study design, intervention protocols, duration, and outcome measures, which complicates direct comparison across studies.[6] Furthermore, most studies focus on a single intervention modality, limiting the ability to determine which approach offers the greatest benefit.

Recent research has highlighted the potential advantages of technology-based and cognitively demanding interventions, particularly in enhancing sensory integration and cognitive engagement.[11,12] Nevertheless, inconsistencies in methodological approaches and outcome reporting reduce the certainty of these findings. In addition, there remains a lack of comprehensive

synthesis directly comparing multicomponent, technology-based, and dual-task balance training using consistent methodological criteria.

Therefore, this systematic review aims to evaluate and compare the effectiveness of multicomponent, technology-based, and dual-task balance training in improving dynamic balance in older adults. By synthesizing current evidence, this study seeks to provide a clearer understanding of the relative benefits of these interventions and to inform evidence-based clinical decision-making in geriatric physiotherapy.

Methods

This study was conducted as a systematic review following the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) guidelines. The review protocol was not registered in PROSPERO; however, all methodological procedures, including the search strategy, eligibility criteria, study selection process, methodological quality assessment, and data extraction, were predefined to ensure transparency and reproducibility. The review focused on studies investigating the effectiveness of balance interventions in improving dynamic balance among older adults. The methodological framework was established to ensure that the identification, screening, selection, and evaluation of relevant studies were performed consistently according to the predefined criteria.

A comprehensive literature search was performed across four electronic databases: Scopus, PubMed, Google Scholar, and Semantic Scholar, covering publications from January 2018 to March 2025. The search strategy combined Medical Subject Headings (MeSH) and free text keywords related to population, intervention, and study design. The primary search string included: (“Aged”[MeSH] OR “older adults” OR elderly OR geriatric) AND (“Postural Balance”[MeSH] OR “balance training” OR “dual task” OR “multicomponent training” OR “technology based training”) AND (“Exercise Therapy”[MeSH] OR “Rehabilitation”[MeSH] OR exercise OR training) AND (“randomized controlled trial” OR RCT). The search was applied to titles and abstracts, and additional keywords were incorporated to maximize retrieval sensitivity and identify studies potentially relevant to the review objectives. The search process was supported by Publish or Perish to optimize results from Google Scholar. Records obtained from all databases were subsequently compiled for screening and duplicate removal.

Study selection was conducted independently by two reviewers using predefined inclusion and exclusion criteria. Duplicate records were removed prior to screening to avoid the repeated assessment of the same publication. Titles and abstracts were initially screened to identify studies that potentially met the eligibility criteria. Articles considered potentially relevant were subsequently subjected to full text assessment to determine their eligibility for inclusion. The screening process considered the relevance of the study population, balance intervention, and reported outcomes to the objectives of the review. Discrepancies between reviewers were resolved through discussion until consensus was achieved. The number of records identified, screened, excluded, assessed for eligibility, and ultimately included was documented throughout the selection process and is presented in the PRISMA flow diagram (Figure 1).

The inclusion criteria comprised: (1) randomized controlled trials or quasi experimental studies, (2) participants aged ≥60 years, (3) interventions involving balance training, (4) reporting outcomes related to dynamic balance, (5) articles published in English or Indonesian, and (6) studies with a Physiotherapy Evidence Database (PEDro) score >6, indicating good methodological quality. Studies were excluded if they were non interventional, including reviews, editorials, or case reports; involved participants aged <60 years; did not report dynamic balance outcomes; were not available in full text; or had a PEDro score <6. The eligibility criteria were applied consistently during the full text assessment to determine whether each study met the requirements for inclusion. The detailed inclusion and exclusion criteria are presented in Table 1.

The methodological quality of the studies that met the eligibility criteria was assessed using the PEDro scale. The assessment was used to determine whether the included studies fulfilled the predefined methodological quality requirement. Studies with a PEDro score >6 were considered eligible based on the methodological quality criterion established for this review. The characteristics of the eligible studies were subsequently reviewed and summarized based on the relevant information reported in each article, including participant characteristics, type of balance intervention, intervention frequency and duration, dynamic balance outcome measures, and the main findings. The extracted information was organized using the PICOS framework to facilitate a structured description and comparison of the included studies.

Table 1. Inclusion and Exclusion Criteria for Study Selection

Inclusion Criteria	Exclusion Criteria
Articles published between 2018 and 2025	Articles not available in full text
Randomized controlled trials (RCTs) or quasi-experimental studies	Non-interventional studies (reviews, meta-analyses, editorials, case reports)
Participants aged ≥60 years	Participants aged <60 years
Interventions involving balance training	Interventions not related to balance training
Reporting dynamic balance outcomes	Not reporting dynamic balance outcomes
Articles published in English or Indonesian	Articles published in languages other than English or Indonesian
PEDro scale score >6	PEDro scale score ≤6

Before presenting the study selection flow, it is important to note that the screening process followed a structured PRISMA framework. The flow of study selection can be summarized as follows: a total of 633 records were identified from database searches; after removal of 166 duplicates, 467 records were screened based on titles and abstracts. Of these, 47 were excluded, and 420 full-text articles were sought for retrieval. A total of 276 articles were excluded due to unavailability of full text. Subsequently, 144 full-text articles were assessed for eligibility, of which 135 were excluded due to not reporting dynamic balance outcomes, having a PEDro score <6, or lacking relevant outcomes. Ultimately, nine studies met all eligibility criteria and were included in the review. This process corresponds to the PRISMA flow diagram (Figure 1).

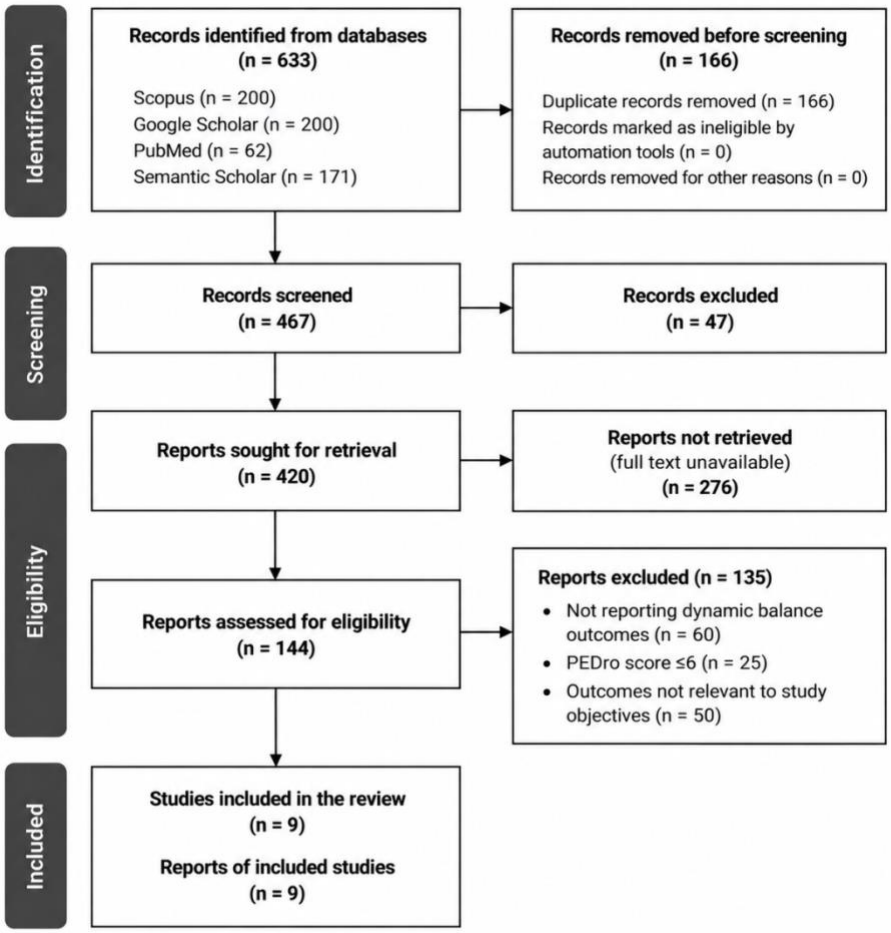

Figure 1. PRISMA 2020 Flow Diagram of the Study Selection Process for Balance Interventions in Older Adults

Data extraction was conducted using a standardized form to ensure consistency across studies. Extracted variables included author and year of publication, study design, sample size, participant characteristics, intervention type, duration and frequency of intervention, outcome measures, and main findings. All extracted data were managed using Mendeley reference management software.

Methodological quality of the included studies was assessed using the Physiotherapy Evidence Database (PEDro) scale, which is a validated tool for evaluating randomized controlled trials in physiotherapy research. The PEDro scale consists of 11 items assessing internal validity and statistical reporting, with scores ranging from 0 to 10 (excluding the first item related to external validity). Studies were categorized as poor (<4), fair (4–5), good (6–8), or excellent (9–10). Only studies with scores greater than 6 were included to ensure methodological rigor. However, it should be noted that the PEDro scale primarily evaluates methodological quality rather than specific domains of bias; therefore, a dedicated risk of bias tool, such as the Cochrane Risk of Bias tool, was not applied, which may limit comprehensive bias assessment.

Due to substantial heterogeneity in intervention types, outcome measures, and study protocols, a quantitative meta-analysis was not feasible. Therefore, data were synthesized narratively by grouping studies according to intervention categories: multicomponent balance training, technology-based balance training, and dual-task balance training. The synthesis focused on identifying patterns of effectiveness, consistency of findings, and reported effect sizes across studies.

Statistical results reported in the included studies, such as p-values, confidence intervals, and effect sizes (e.g., Cohen's d and η^2), were extracted and summarized descriptively. No additional statistical analyses were performed. A significance level of $\alpha = 0.05$ was adopted as reported in the original studies. As this study was based on previously published data, ethical approval was not required.

Results

The results are presented to summarize the characteristics of included studies, methodological quality, and the effects of different balance training interventions on dynamic balance outcomes in older adults. The synthesis is structured in accordance with the study objective, namely to compare multicomponent, technology-based, and dual-task balance training.

Following the study selection process described in the PRISMA flow (Figure 1), a total of nine randomized controlled trials were included in this review. These studies were conducted across multiple regions, including Europe, Asia, and South America, indicating a diverse representation of older adult populations. The included participants varied in characteristics, comprising community-dwelling older adults, institutionalized individuals, those at risk of falls, and individuals with a history of falls. To provide a structured overview of the methodological quality of the included studies, the PEDro scale scores are presented in Table 2. This table summarizes key methodological domains, including randomization, blinding, follow-up, and statistical reporting.

Table 2. Methodological Quality Assessment Using PEDro Scale

Study	Total Score
Espejo-Antúnez et al., 2020	6
Jiang et al., 2025	7
Rizzato et al., 2024	6
Fakhro et al., 2019	6
Guede-Rojas et al., 2023	6
Brüll et al., 2023	6
Park et al., 2022	7
Trombini-Souza et al., 2023	8
Choi & Lee, 2019	7

Overall, all included studies demonstrated good methodological quality, with PEDro scores ranging from 6 to 8. Random allocation and between-group comparisons were consistently reported across studies, while blinding of participants and therapists was generally not implemented. Follow-up completeness varied across studies, which may affect internal validity.

To further describe the characteristics of included studies and their findings, Table 3 presents a structured summary based on the PICOS framework, including study design, population, intervention type, duration, outcome measures, and key results.

Table 3. Characteristics and Main Findings of Included Studies (PICOS Framework)

Study	Population	Intervention	Duration	Outcome	Key Findings
Espejo-Antúnez et al., 2020	Institutionalized older adults	Multicomponent training	12 weeks	TUG, OLS	Significant improvement in TUG ($p < 0.05$)
Jiang et al., 2025	Community-dwelling older adults	Combined resistance + balance training	24 weeks	TUG, gait speed	Significant improvement ($p < 0.05$)
Rizzato et al., 2024	Community seniors	Unstable vs stable surface training	24 weeks	TUG, balance parameters	Greater improvement with unstable surfaces
Fakhro et al., 2019	Institutionalized older adults	Wii-based training	8 weeks	TUG, CoP	Significant improvement ($p < 0.05$)
Guede-Rojas et al., 2023	Community older adults	Exergames + therapy	8 weeks	8UG	Significant improvement ($p = 0.006$)
Brüll et al., 2023	Fall-risk older adults	Perturbation-based training	6 weeks	Balance tests	Significant improvement ($p < 0.001$)
Park et al., 2022	Older adults with fall history	Dual-task training	6 weeks	TUG, cognitive tests	Significant improvement ($p < 0.001$)
Trombini-Souza et al., 2023	Community older adults	Dual-task protocols	24 weeks	TUG, gait	Improvement in both groups
Choi & Lee, 2019	Older adults with MCI	Virtual kayaking	6 weeks	TUG, BBS	Significant improvement ($p < 0.001$)

Across the included studies, balance training interventions were categorized into three main groups: multicomponent balance training, technology-based balance training, and dual-task balance training. All studies reported improvements in dynamic balance outcomes following intervention.

In multicomponent balance training, consistent improvements in dynamic balance were observed across studies. These interventions typically combined strength, coordination, and proprioceptive exercises, resulting in significant improvements in functional balance measures such as the Timed Up and Go (TUG) test and other balance scales.

Technology-based balance training interventions also demonstrated significant improvements. These approaches included exergames, perturbation-based training, and virtual reality systems, which provided multisensory stimulation and real-time feedback. Most studies in this category reported statistically significant improvements in dynamic balance outcomes, with some reporting moderate to large effect sizes.

Dual-task balance training interventions showed improvements not only in balance performance but also in cognitive-related outcomes. These interventions involved simultaneous motor and cognitive tasks, and most studies reported significant improvements in dynamic balance measures. However, in some cases, no significant between-group differences were observed, indicating comparable effectiveness between intervention protocols.

Although most studies reported statistically significant improvements ($p < 0.05$), the reporting of confidence intervals and effect sizes was inconsistent across studies. Intervention duration ranged from 6 to 24 weeks, and variability in protocols, participant characteristics, and outcome measures was evident. These factors may influence the magnitude of reported effects and limit direct comparison across studies. Several potential confounding factors were identified, including differences in baseline characteristics, adherence rates, and measurement instruments. Dropout rates were reported in some studies, although not consistently across all included trials.

Discussion

This systematic review aimed to evaluate and compare the effectiveness of multicomponent, technology-based, and dual-task balance training in improving dynamic balance among older adults. Overall, the findings indicate that all three intervention approaches are beneficial, with technology-based and dual-task training demonstrating a tendency toward greater improvements. However, the magnitude and consistency of these effects varied across studies, reflecting underlying methodological and clinical heterogeneity.

The observed improvements in dynamic balance across all intervention types are consistent with current evidence highlighting the importance of targeted balance training in fall prevention strategies.[3,5] Multicomponent balance training, which integrates strength, coordination, and proprioceptive exercises, appears to improve postural stability through enhanced neuromuscular control and sensorimotor integration. This is supported by previous systematic reviews demonstrating that combined training modalities can effectively enhance functional balance and mobility in older adults.[5] The findings of the present review align

with these reports, as studies within this category consistently showed improvements in outcomes such as the Timed Up and Go test and other functional balance measures.

Technology-based balance training demonstrated promising results, particularly in studies utilizing exergames and perturbation-based systems. These interventions provide enriched multisensory input and real-time feedback, which are critical components of motor learning.[7,11] The integration of visual, auditory, and proprioceptive stimuli may enhance adaptive postural responses and improve dynamic stability. Moreover, interactive and engaging training environments may increase adherence and motivation, which are important determinants of rehabilitation outcomes. These findings are consistent with recent meta-analyses indicating that digital and interactive training approaches can significantly improve balance and reduce fall risk in older populations.[3]

Dual-task balance training also showed substantial benefits, particularly in improving both balance performance and cognitive function. This approach reflects real-life functional demands, where individuals are often required to perform concurrent cognitive and motor tasks.[8] The improvements observed in dual-task conditions may be explained by enhanced cognitive–motor integration and increased attentional resource allocation. Previous studies have reported that dual-task training can improve executive function and reduce dual-task cost, thereby contributing to better functional mobility and fall prevention.[13] The results of this review support these findings, as most included studies demonstrated significant improvements in both balance and cognitive-related outcomes.

Despite these positive findings, the comparative superiority of one intervention over another remains inconclusive. Although technology-based and dual-task interventions tended to show larger effect sizes, not all studies reported statistically significant between-group differences. This suggests that the effectiveness of balance training may depend not only on the type of intervention but also on factors such as training intensity, duration, and individual participant characteristics. Variability in intervention protocols, ranging from 6 to 24 weeks, as well as differences in outcome measures, further complicates direct comparison across studies.[6]

From a methodological perspective, the overall quality of included studies was considered good based on PEDro scores; however, several limitations should be acknowledged. The lack of blinding in most studies is a common challenge in exercise-based interventions and may introduce performance bias. In addition, incomplete follow-up and variability in adherence reporting may affect internal validity. Importantly, the absence of a formal risk of bias assessment tool, such as the Cochrane Risk of Bias tool, limits the ability to evaluate specific domains of bias comprehensively. This should be considered when interpreting the findings.

Another important limitation relates to the inconsistency in reporting statistical outcomes. Although most studies reported significant p-values, the reporting of confidence intervals and effect sizes was not uniform. This limits the ability to assess the precision and clinical relevance of the observed effects. Furthermore, differences in participant characteristics, such as baseline functional status, fall history, and cognitive function, may act as confounding factors influencing intervention outcomes.

From a clinical perspective, the findings of this review suggest that balance training should be tailored to individual needs. Technology-based and dual-task interventions may be particularly beneficial for older adults with higher functional capacity or those requiring more cognitively demanding training. Conversely, multicomponent training may be more appropriate for individuals with lower functional levels or in settings with limited access to advanced technology. These considerations are important for optimizing rehabilitation strategies in diverse clinical contexts.

Overall, while the consistency of positive findings across studies strengthens the evidence supporting balance training interventions, the presence of methodological heterogeneity and reporting limitations reduces the certainty of the conclusions. Therefore, the overall level of evidence can be considered moderate. Future research should aim to standardize intervention protocols, improve reporting of statistical outcomes, and incorporate comprehensive risk of bias assessments to enhance the robustness of evidence in this field.

Conclusion

This systematic review demonstrates that balance training interventions are effective in improving dynamic balance among older adults. All examined approaches—multicomponent, technology-based, and dual-task training—contribute to enhanced balance performance, although technology-based and dual-task interventions tend to yield greater improvements under certain conditions. However, the comparative effectiveness of these interventions remains inconclusive due to heterogeneity in study designs, intervention protocols, and outcome measures. Therefore, the selection of balance training strategies should be individualized, taking into account patient characteristics, functional capacity, and resource availability.

From a clinical perspective, technology-based and dual-task training may be particularly beneficial for individuals requiring higher levels of cognitive engagement and task complexity, whereas multicomponent training may be more feasible in resource-limited settings or for individuals with lower functional capacity. Future research should focus on standardizing intervention protocols, improving the consistency of outcome reporting—particularly effect sizes and confidence intervals—and incorporating comprehensive risk of bias assessments to strengthen the quality and comparability of evidence.

Author Contribution

Vanya Naura Qatrunnada: Conceptualization, methodology, literature search, study selection, data extraction, data analysis, investigation, writing of the original draft, and revision of the manuscript.
Muhamad Elfitra Salam: Supervision, methodology, validation, interpretation of findings, critical review of the manuscript, and final approval of the manuscript.

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Conflict of Interest Statement

The authors declare no conflict of interest.

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Ethics Statement

Ethical approval was not required as this study was based on previously published data.

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