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Original Article

The Effects of Combined Training on Functionality, Balance, and Gait Speed of the Elderly: A Systematic Review and Meta-analysis

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ABSTRACT

Background: Ensuring the safety and functional independence of older people is becoming increasingly important. Fall-prevention guidelines emphasize the use of highly challenging training modalities to reduce fall risk. Therefore, this systematic review and meta-analysis examined the effects of combined training (CT) on functionality, balance, and gait speed in older adults.

Methods: A systematic search was conducted in four electronic databases—PubMed, SCOPUS, Cochrane Central, and Web of Science—from inception to June 2, 2024. Standardized mean differences (SMDs), weighted mean differences (WMDs), and 95% confidence intervals (CIs) were calculated using fixed- or random-effects models, depending on heterogeneity.

Results: Twelve studies involving 570 participants met the inclusion criteria. Meta-analysis indicated that CT significantly improved functionality (SMD = 0.64; 95% CI: 0.34–0.93; p = 0.003), balance (SMD = 0.65; 95% CI: 0.39–0.90; p = 0.001), and gait speed (SMD = 1.18; 95% CI: 0.76–1.59; p = 0.001). Furthermore, CT was superior to traditional training (TT) in enhancing functionality (SMD = 0.50; 95% CI: 0.28–0.73; p = 0.001).

Conclusion: This meta-analysis demonstrates that combined training has a significant positive effect on functionality, balance, and gait speed in older adults. Compared with traditional training, CT yields greater improvements in functional performance. Therefore, CT is an effective and practical method for enhancing physical function and mobility in older people.

Introduction

The global population is aging rapidly, with life expectancy continuing to rise. In 2017, there were approximately 962 million people aged 60 years or older—more than double the 382 million recorded in 1980 [1]. By 2030, the number of older adults is projected to surpass that of children under 10 (1.41 billion vs. 1.35 billion). By 2050, the global elderly population is expected to double again, reaching an estimated 2.1 billion. [1].

Aging is frequently accompanied by declines in balance, physical performance, gait ability, and overall activity levels, all of which can impair functional independence [2] and substantially increase the risk of falls [3]. Falls are a major health concern among older

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adults, contributing significantly to morbidity and mortality. Globally, more than 11,000 people die annually as a result of falls [4]. Approximately two-thirds of fall-related accidents involve older adults, and nearly 40% of falls among individuals aged 60 years or older result in fatal outcomes [5]. Given these alarming statistics, enhancing the safety, physical function, and mobility of older people has become a critical public health priority.

Balance is a fundamental prerequisite for performing basic daily activities and is essential for both static and dynamic functional tasks [6]. Evidence indicates that balance impairments are among the major risk factors for falls in adults [7]. Consequently, balance rehabilitation has become a central focus for researchers and physiotherapists [8]. They are increasingly committed to understanding its underlying mechanisms and developing effective interventions to prevent falls [6]. In addition to balance deficits, reduced walking speed is commonly observed in older adults, often due to declines in muscular strength or flexibility. Numerous studies have demonstrated that slower gait speed is a strong predictor of fall risk in this population [9].

Exercise is a key intervention for improving physical function in older adults [10]. Its benefits in delaying physical dependence and enhancing overall physical performance are well-documented [11]. Traditional training (TT) programs—such as balance, strength, proprioception, whole-body vibration, and other single-modality exercises—typically involve one-dimensional routines that focus on only one type of training stimulus throughout the intervention period. These programs have been widely used to improve balance and have shown significant positive effects on gait, strength, and aerobic endurance; in some cases, they have even contributed to reducing fall incidence among adults [8,11-13]. More recently, studies have examined the effects of combining different types of exercises on motor performance and balance in the elderly [14,15]. In combined training (CT), two types of exercises are integrated and practiced simultaneously within a single training session.

Evidence synthesized from systematic reviews indicates that combined balance and strength training is an effective approach for enhancing postural balance in individuals recovering from stroke [16]. However, the present study investigates the effects of combined exercises specifically in healthy older adults. Numerous meta-analyses on single-modality (one-dimensional) interventions have examined variables such as balance, gait speed, and functional performance in older people, consistently reporting improvements in these outcomes [17,18].

In contrast, meta-analyses comparing single-modality and multi-dimensional training programs have shown mixed results. Several studies suggest that multi-dimensional interventions yield greater improvements in balance and gait speed than one-dimensional programs [19-21]. Labata-Lezaun et al. [22], for example, examined the impact of multicomponent training on physical performance in older adults and reported significant benefits. However, their work focused on broad multi component programs, whereas the present study investigates a more targeted form of combined (two-dimensional) training.

Additionally, other meta-analyses have explored combined training programs in older populations, particularly combinations of strength with balance or endurance exercises [22,23]. These studies, however, have primarily been conducted in frail older adults [23], whereas the current study focuses on healthy older individuals and examines a different combination of exercises.

Given the high prevalence and serious consequences of falls among older people, there is a clear need for a systematic review and meta-analysis to evaluate the effects of combined training (CT) on functional performance, balance, and gait speed in this population.

Method

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [24].

Search Strategy

Primary sources were retrieved from four electronic databases: PubMed, SCOPUS, Cochrane Central Register of Controlled Trials (CENTRAL), and Web of Science. The search covered all available years from database inception to June 2, 2024. Medical Subject Headings (MeSH) were initially used to develop the search terms, which were subsequently refined to ensure the inclusion of all relevant studies.

To increase the comprehensiveness of the search, Google Scholar was also screened, and the reference lists of all included articles were examined to identify any additional eligible studies.

The search strategy incorporated combinations of the following keyword groups: (1) Balance OR “Static balance” OR “Dynamic balance” OR “Postural instability” OR “Postural sway”; AND (2) Gait OR “Gait disorders” OR “Gait speed” OR walking; AND (3) elder OR old OR “older adult” OR senescent OR senile OR aged OR gray OR geriatric OR age OR aging OR elderly OR “oldest-old” OR “very old” OR “advancing age” AND (4) Function OR “Functional decline” OR “physical performance” OR “Functional limitations” OR “Mobility limitations”. The “AND” operator was used between the three keyword groups, while the “OR” operator was used within each keyword group.

Eligibility Criteria

The inclusion criteria were as follows: (1) Population: healthy elderly aged ≥60 years; (2) Intervention: combined training; (3) Comparator: combined training vs. a non-training control, or combined training vs. traditional training (4) Outcomes: balance, functionality, and gait speed; (5) Study Design: randomized or non-randomized controlled trials; (6) Publication Type: Peer-reviewed articles published in English.

The exclusion criteria were: 1) Studies involving older adults with underlying health conditions such as stroke, diabetes, or cardiovascular disease; 2) Conference proceedings, reports, editorials, letters, case studies, abstract-only publications, or systematic reviews and meta-analyses; 3) Studies lacking a clear defined methodology; 4) Studies focusing solely on kinematic walking parameters.

Two independent researchers (MD and AJ) conducted the literature search and independently screened all titles and abstracts according to the eligibility criteria. Any disagreements were resolved through discussion. Inter-rater reliability was assessed using Cohen's kappa (κ), where $\kappa \leq 0.40$ indicates poor agreement; 0.41–0.60, moderate agreement; 0.61–0.80, good agreement; and 0.81–1.00, excellent agreement [25]. The level of agreement between the reviewers was classified as good.

Data Extraction

Data from the included studies were independently extracted by two researchers (MD and AJ). Extracted information included: the first author's name; participant characteristics (sample size, age range, or mean age with standard deviation, and sex distribution); outcome measurement tools; and details of the training protocols (type of exercises, frequency, intensity, and duration). All extracted data were organized and summarized in Table 1.

Table 1: General Description of the Samples Included in the Individual Studies.

Source, year	Study design	Sample size	Sex	Age [years]	Groups	Participants characteristics	Intervention	Training characteristics= Frequency (time a week)/ Duration (week)	Outcomes measure
Abbasi et al (2011) [30]	NON-RCT, four arms	*60*	M	*EXP.1= 71.00±7.4 EXP.2= 70.00±8.2 EXP.3= 69.00±9.5 CON= 70.00±8.8*	*EXP.1= 15 EXP.2= 15 EXP.3= 15 CON= 15*	*Elderly*	*EXP.1= Whole Body Vibration* training *EXP.2= Aquatic Balance* training *EXP.3= Combined training CON= Everyday activities*	*3/8*	*- Timed Up and Go test - 5-Chair stand test*
Park et al, (2008) [38]	NON-RCT, two arms	50	F	*EXP= 68.3±3.6 CON= 68.4±3.4*	EXP= 25 CON= 25	Community-dwelling older adults	EXP= Combined training CON= Everyday activities	3/48	- Body sway -Velocity test
Wang et al, (2015) [31]	NON-RCT, two arms	29	F, M	*EXP= 70.29±4.57 CON= 70.50±5.57*	EXP= 12 CON= 17	Community-dwelling older adults	EXP= Combined training CON= Everyday activities	3/12	- Six-minute Walk test - Velocity test
Holviala et al (2012) [32]	NON-RCT, four arms	108	M	*EXP.1= 56.5±7.6 EXP.2= 55.5±8.7 EXP.3= 56.9±7.5 CON= 56.7±9.9*	*EXP.1= 30 EXP.2= 26 EXP.3= 31 CON= 21*	Elderly	*EXP.1= Strength* training *EXP.2= Endurance* training *EXP.3= Combined training CON= Everyday activities*	2/21	- 10-m walking test - Force platform
Islam et al, (2004) [33]	RCT, two arms	29	F, M	*EXP= 75.7±3.9 CON= 76.5±6.9*	EXP= 15 CON= 14	older adults	EXP= Combined training CON= Everyday activities	2/12	- One-leg Balance test - limits of stability test - Chair Sit-and-Reach test
Fahlman et al, (2007) [34]	RCT, three arms	109	F, M	*EXP.1= 75.8±1.0 EXP.2= 74.6±1.0 CON= 76.5±1.4*	*EXP.1= 37 EXP.2= 39 CON= 33*	older adults	*EXP.1= Resistance training EXP.2= Combined training CON= Everyday activities*	3/16	- Stair test - 6-Min Walk test - Time to and off the Floor test

Source, year	Study design	Sample size	Sex	Age [years]	Groups	Participants characteristics	Intervention	Training characteristics= Frequency (time a week)/ Duration (week)	Outcomes measure
Zouita et al, (2020) [35]	RCT, two arms	27	F	*EXP= 70.4±3.17* *CON= 72.0±3.5*	EXP= 12 CON= 15	older adults	EXP= Combined training CON= Everyday activities	3/8	- Sit to Stand Test - One-leg Balance test - Walk Across test
Im et al, (2019) [39]	RCT, two arms	25	F	*EXP= 71.57±3.22* *CON= 69.36±2.94*	EXP= 14 CON= 11	*Elderly*	EXP= Combined training CON= Everyday activities	3/12	- Force platform
Barzegari et al, (2019) [36]	RCT, two arms	40	M	*EXP.1= 60.80±1.67* *EXP.2= 61.40±1.95* *EXP.3= 60.9±1.96* *CON= 60.5±2.27*	*EXP.1= 10* *EXP.2= 10* *EXP.3= 10* *CON= 10*	*Elderly*	*EXP.1= Strength training* *EXP.2= balance training* *EXP.3= Combined training* *CON= Everyday activities*	3/8	- Get-up and go test - Sharpened Romberg test
Silva et al, (2018) [14]	RCT, three arms	33	F	*EXP.1= 65.69±5.72* *EXP.2= 66.36±4.38* *CON= 64.11±4.29*	*EXP.1= 13* *EXP.2= 11* *CON= 9*	*Elderly*	*EXP.1= Aerobic training* *EXP.2= Combined training* *CON= Everyday activities*	2/12	- 30-second chair-stand test - 6-minute-walk test - 8-foot up-and-go test
Ghaderian et al (2022) [40]	RCT, two arms	30	M	*EXP= 65.47±2.50* *CON= 65.80±2.34*	EXP= 15 CON= 15	*Elderly*	EXP= Combined training CON= Everyday activities	3/12	- Force platform
Samani et al, (2015) [37]	RCT, two arms	30	F	*EXP= 70.46±1.27* *CON= 71.4±1.36*	EXP= 15 CON= 15	*Elderly*	EXP= Combined training CON= Everyday activities	4/12	- Sharpened Romberg test - Berg balance test - Y Balance test

SD: standard deviation; M: male; F: female; EXP: experimental group; CON: control group; RCT: randomized control trial.

Table 2: Physiotherapy Evidence Database (PEDro) Scale Ratings

Study	Eligibility Criteria	Random Allocation	Concealed Allocation	Groups Similar At Baseline	Blind Subject	Blind Therapist	Blind Assessor	Follow-Up	Intention-to-Treat Analysis	Between-Group Comparisons	Point Measures and Variability	PEDro Score
Abbasi et al (2011) [30]	1	0	0	1	1	0	0	0	1	1	1	6.11
Park et al, (2008) [38]	1	0	0	1	1	0	0	0	1	1	1	6.11
Wang et al, (2015) [31]	1	0	0	1	1	0	0	0	1	1	1	6.11
Holviala et al, (2012) [32]	1	0	0	1	1	0	0	0	1	1	1	6.11
Islam et al, (2004) [33]	1	1	0	1	1	0	0	0	1	1	1	7.11
Fahlman et al,	1	1	1	1	1	0	0	0	1	1	1	8.11

Study	Eligibility Criteria	Random Allocation	Concealed Allocation	Groups Similar At Baseline	Blind Subject	Blind Therapist	Blind Assessor	Follow-Up	Intention-to-Treat Analysis	Between-Group Comparisons	Point Measures and Variability	PEDro Score
(2007) [34]												
Zouita et al, (2020) [35]	1	1	1	1	1	0	0	0	1	1	1	8.11
Im et al, (2019) [39]	1	1	0	1	1	0	0	0	1	1	1	7.11
Barzegari et al, (2019) [36]	1	1	0	1	1	0	0	0	1	1	1	7.11
Silva et al, (2018) [14]	1	1	1	1	1	0	0	0	1	1	1	8.11
Ghaderian et al (2022) [40]	1	1	1	1	1	0	0	0	1	1	1	8.11
Samani et al, (2015) [37]	1	1	1	1	1	0	0	0	1	1	1	8.11

Quality of Evidence

The methodological quality of the included studies was assessed using the Physiotherapy Evidence Database (PEDro) scale [26]. The PEDro scale consists of 11 items that assess internal validity and the adequacy of statistical reporting, with a total possible score of 0 to 11. Studies scoring 7-11 were classified as having high methodological quality, scores of 5-6 as fair, and scores of 4 or below as poor quality [21]. The detailed PEDro ratings for each included study are presented in Table 2.

Statistical Analyses

Heterogeneity across studies was assessed using the I^2 statistic, with the following thresholds: 0–30% representing negligible heterogeneity, 30–50% representing low heterogeneity, 50–75% representing moderate heterogeneity, and 75–100% representing high heterogeneity. Both random-effects and fixed-effect models were applied depending on the degree of heterogeneity. Specifically, a random-effects model was used when the I^2 value exceeded 50%, indicating substantial between-study variation [27].

For continuous outcomes, standardized mean differences (SMDs), weighted mean differences, and associated 95% confidence intervals (CIs) were calculated using the appropriate model (fixed or random effects). The level of statistical significance was set at $p \leq 0.05$. Effect size (ES) magnitudes were interpreted according to the following thresholds: <0.2 trivial, 0.2–0.6 small, 0.6–1.2 moderate, 1.2–2.0 large, 2.0–4.0 very large, and >4.0 nearly perfect [28].

Potential publication bias was evaluated using funnel plots and Egger's regression test, with Egger's test considered significant at $p < 0.1$. When publication bias was suspected, the trim-and-fill method was applied to estimate and adjust for the number of potentially missing studies [29].

All statistical analyses were performed using Comprehensive Meta-Analysis software, version 2.0 (Biostat Inc., Englewood, New Jersey).

Results

A total of 1,365 potentially eligible studies were retrieved from four electronic databases. Additionally, 10 records were identified through reference list screening using the ancestry method. Following the removal of 519 duplicate records, 856 titles and abstracts were screened, leading to the exclusion of 821 studies that did not meet the inclusion criteria.

The remaining 35 full-text articles were assessed for eligibility. Of these, 23 studies were excluded because they did not meet the prespecified inclusion criteria. Ultimately, 12 studies comprising 570 participants were included in this systematic review. The primary characteristics of the included studies, including sample size, participant demographics, intervention details, and outcome measures, are summarized in Table 1.

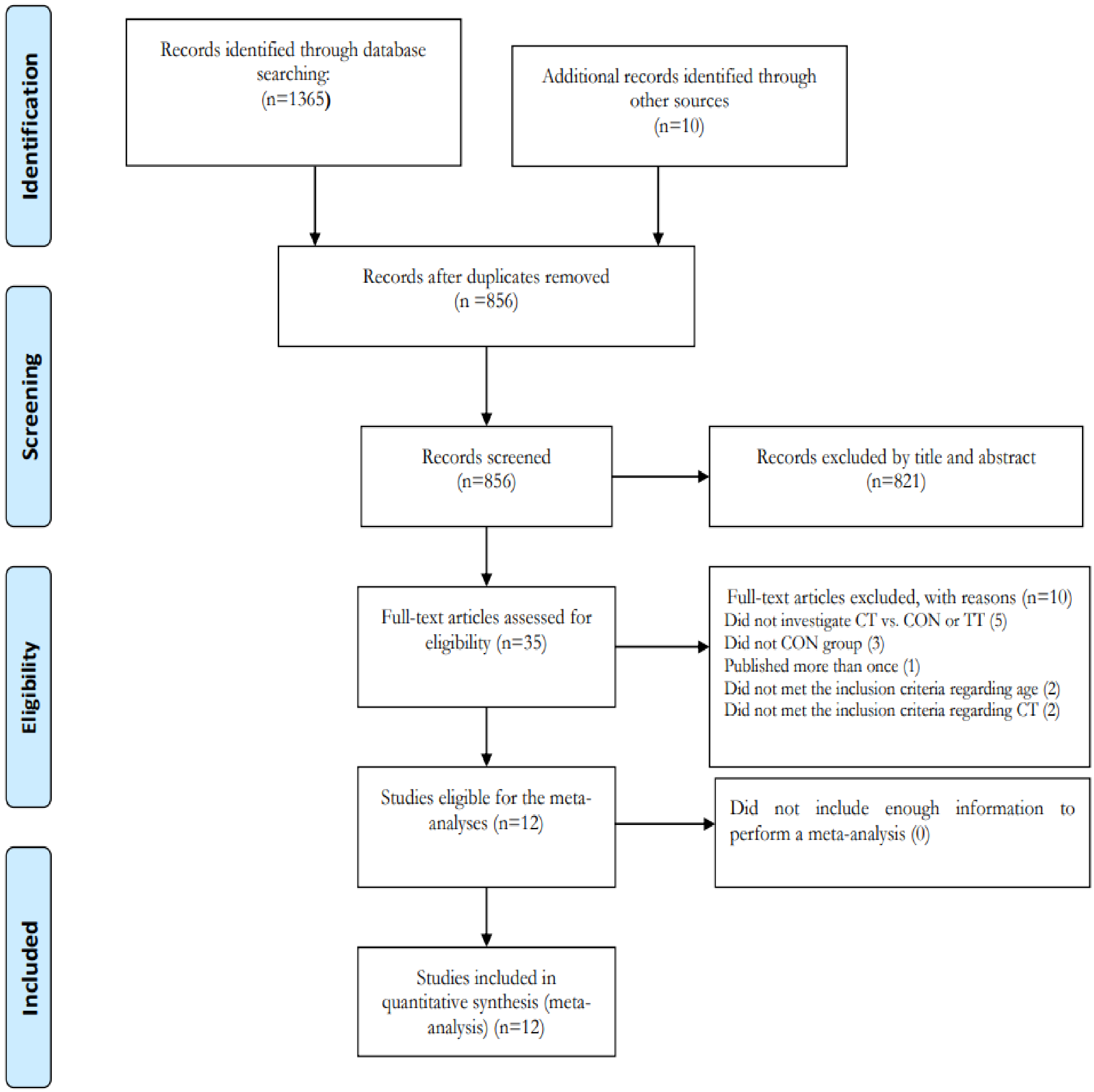


Figure 1: Flow Diagram of Systematic Literature Search. **CN, Control; TT, Traditional Training; CT**, Combined Training.

Quality of Evidence

Based on the Physiotherapy Evidence Database (PEDro) scale, among the 12 studies included in this review, eight studies were rated as high quality (scores ranging from 7 to 11). In comparison, four studies were rated as fair quality (scores of 5-6). Overall, the methodological quality of the included studies was considered adequate, supporting the reliability of the findings in this meta-analysis (see Table 2).

Population Characteristics

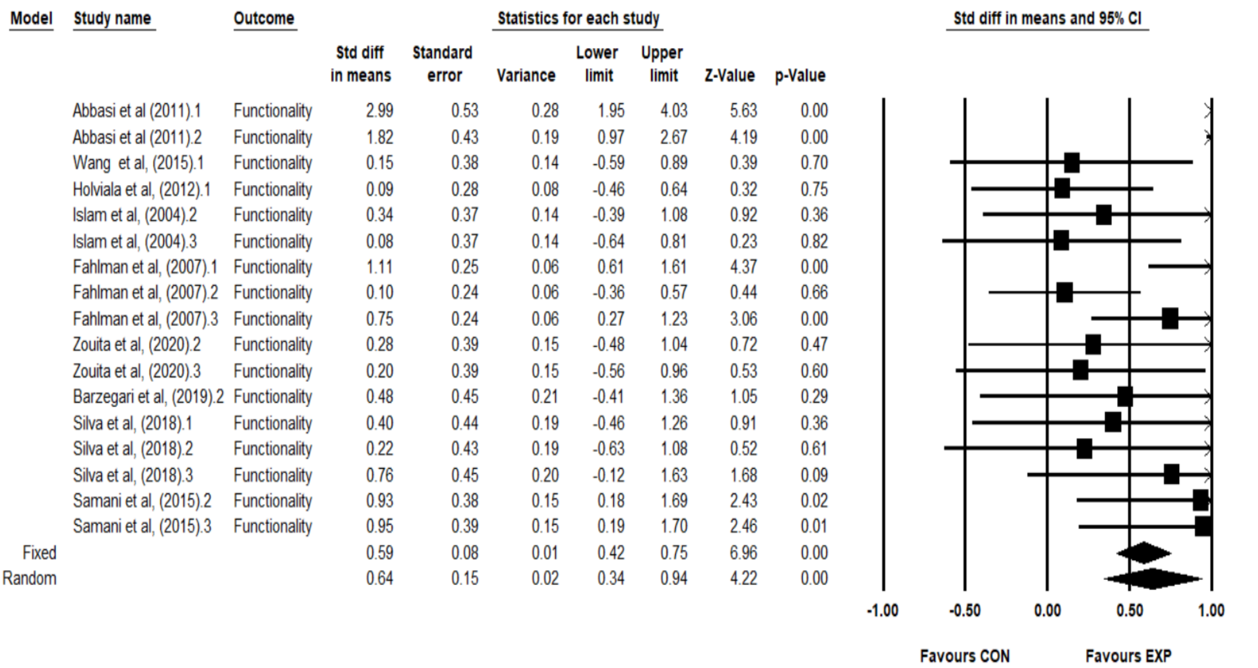
Across the 12 included studies, there were 17 intervention arms available for comparison of combined training (CT) versus control (CON) groups regarding functionality outcomes *[14,30-37]*. For balance outcomes, eight intervention arms were available for CT versus CON comparisons [32,33,35-40] . Regarding gait speed, three intervention arms were included for CT versus CON analysis [31,35,38]. Additionally, eight intervention arms were available for comparison of CT versus traditional training (TT) with respect to functionality [14,30,32,34,36].

Meta-Analysis

Combined Training versus the Control Group

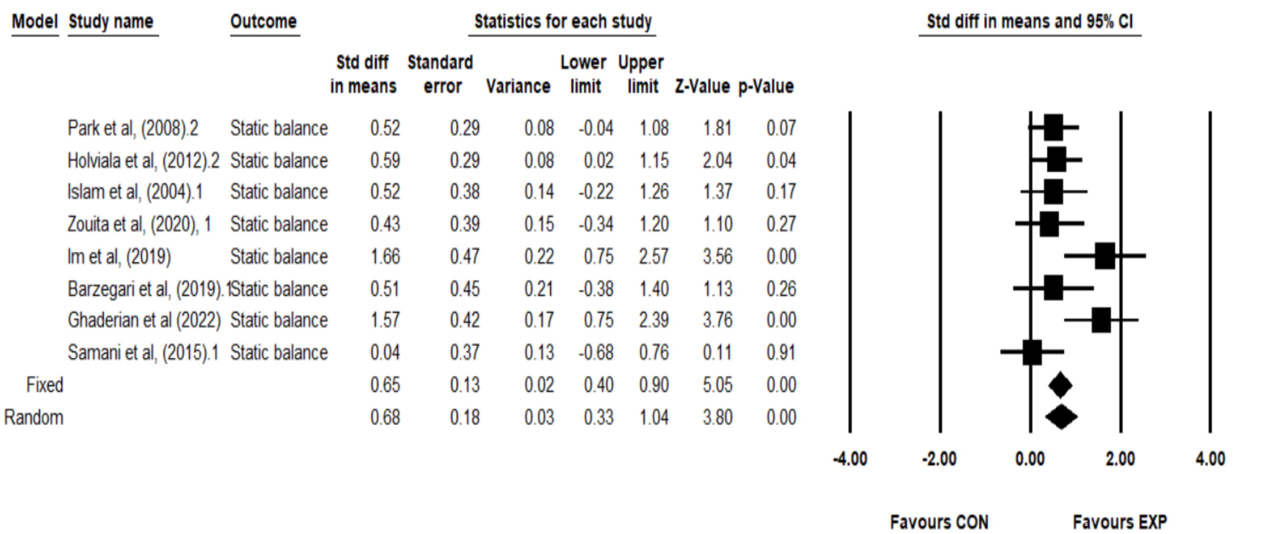
Functionality. Seventeen intervention arms were included to compare combined training (CT) versus control (CON) for functionality outcomes. The meta-analysis demonstrated that CT significantly improved functionality, with a standardized mean difference (SMD) of 0.64 (95% CI: 0.34–0.93, $p = 0.003$), indicating a moderate effect size. Significant heterogeneity was observed among the studies ($I^2 = 66.93\%$, $p = 0.001$) (see Figure 2).

Assessment of publication bias using both funnel plots and Egger's test revealed no significant bias ($p = 0.08$), suggesting that the results were robust and not substantially influenced by small-study effects.



Model	Study name	Outcome	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
	Abbasi et al (2011).1	Functionality	2.99	0.53	0.28	1.95	4.03	5.63	0.00
	Abbasi et al (2011).2	Functionality	1.82	0.43	0.19	0.97	2.67	4.19	0.00
	Wang et al, (2015).1	Functionality	0.15	0.38	0.14	-0.59	0.89	0.39	0.70
	Holviala et al, (2012).1	Functionality	0.09	0.28	0.08	-0.46	0.64	0.32	0.75
	Islam et al, (2004).2	Functionality	0.34	0.37	0.14	-0.39	1.08	0.92	0.36
	Islam et al, (2004).3	Functionality	0.08	0.37	0.14	-0.64	0.81	0.23	0.82
	Fahlman et al, (2007).1	Functionality	1.11	0.25	0.06	0.61	1.61	4.37	0.00
	Fahlman et al, (2007).2	Functionality	0.10	0.24	0.06	-0.36	0.57	0.44	0.66
	Fahlman et al, (2007).3	Functionality	0.75	0.24	0.06	0.27	1.23	3.06	0.00
	Zouita et al, (2020).2	Functionality	0.28	0.39	0.15	-0.48	1.04	0.72	0.47
	Zouita et al, (2020).3	Functionality	0.20	0.39	0.15	-0.56	0.96	0.53	0.60
	Barzegari et al, (2019).2	Functionality	0.48	0.45	0.21	-0.41	1.36	1.05	0.29
	Silva et al, (2018).1	Functionality	0.40	0.44	0.19	-0.46	1.26	0.91	0.36
	Silva et al, (2018).2	Functionality	0.22	0.43	0.19	-0.63	1.08	0.52	0.61
	Silva et al, (2018).3	Functionality	0.76	0.45	0.20	-0.12	1.63	1.68	0.09
	Samani et al, (2015).2	Functionality	0.93	0.38	0.15	0.18	1.69	2.43	0.02
	Samani et al, (2015).3	Functionality	0.95	0.39	0.15	0.19	1.70	2.46	0.01
Fixed			0.59	0.08	0.01	0.42	0.75	6.96	0.00
Random			0.64	0.15	0.02	0.34	0.94	4.22	0.00

Figure 2: Forest Plot of the Combined Training Versus Control Group Analysis on Functionality.



Model	Study name	Outcome	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
	Park et al, (2008).2	Static balance	0.52	0.29	0.08	-0.04	1.08	1.81	0.07
	Holviala et al, (2012).2	Static balance	0.59	0.29	0.08	0.02	1.15	2.04	0.04
	Islam et al, (2004).1	Static balance	0.52	0.38	0.14	-0.22	1.26	1.37	0.17
	Zouita et al, (2020), 1	Static balance	0.43	0.39	0.15	-0.34	1.20	1.10	0.27
	Im et al, (2019)	Static balance	1.66	0.47	0.22	0.75	2.57	3.56	0.00
	Barzegari et al, (2019).1	Static balance	0.51	0.45	0.21	-0.38	1.40	1.13	0.26
	Ghaderian et al (2022)	Static balance	1.57	0.42	0.17	0.75	2.39	3.76	0.00
	Samani et al, (2015).1	Static balance	0.04	0.37	0.13	-0.68	0.76	0.11	0.91
Fixed			0.65	0.13	0.02	0.40	0.90	5.05	0.00
Random			0.68	0.18	0.03	0.33	1.04	3.80	0.00

Figure 3: Forest Plot of the Combined Training Versus Control Group Analysis on Balance.

Balance. Eight intervention arms were included to compare combined training (CT) versus control (CON) for balance outcomes. The meta-analysis indicated that CT significantly improved balance, with a standardized mean difference (SMD) of 0.65 (95% CI: 0.39–0.90, $p = 0.001$), representing a moderate effect size. There was no significant heterogeneity among the studies ($I^2 = 46.65\%$, $p = 0.06$) (see Figure 3).

Visual inspection of the funnel plot suggested potential asymmetry; however, Egger's test did not reveal significant publication bias ($p = 0.21$), supporting the reliability of the pooled estimate.

Gait Speed. Three intervention arms were included to compare combined training (CT) versus control (CON) for gait speed. The meta-analysis demonstrated that CT significantly improved gait speed, with a standardized mean difference (SMD) of 1.18 (95% CI: 0.76–1.59, $p = 0.001$), representing a large effect size. There was no significant heterogeneity among the studies ($I^2 = 12.65\%$, $p = 0.30$) (see Figure 4).

Visual inspection of the funnel plot indicated potential asymmetry; however, Egger's test did not reveal significant publication bias ($p = 0.60$), suggesting the robustness of the pooled result.

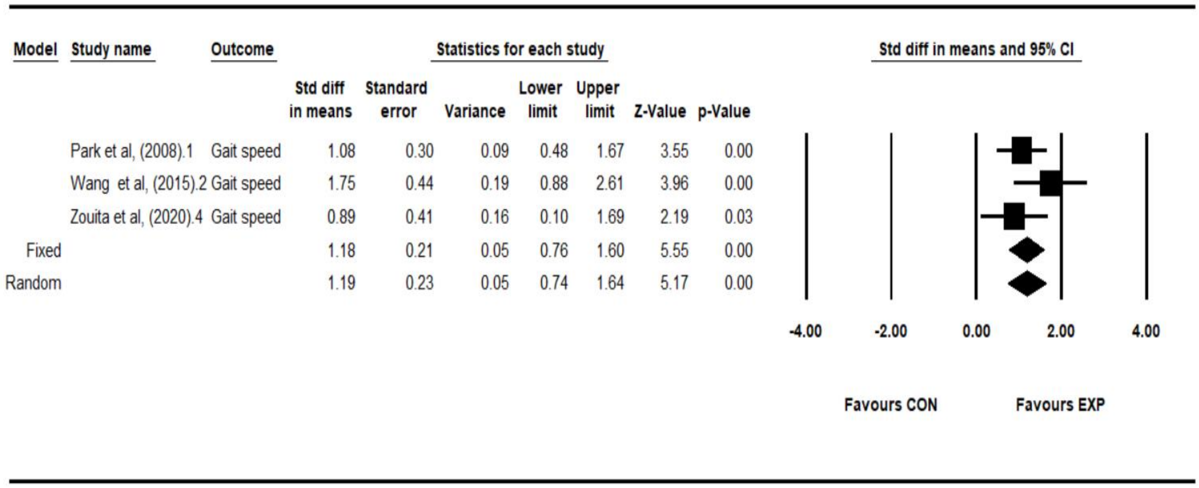


Figure 4: Forest Plot of the Combined Training Versus Control Group Analysis on Gait Speed.

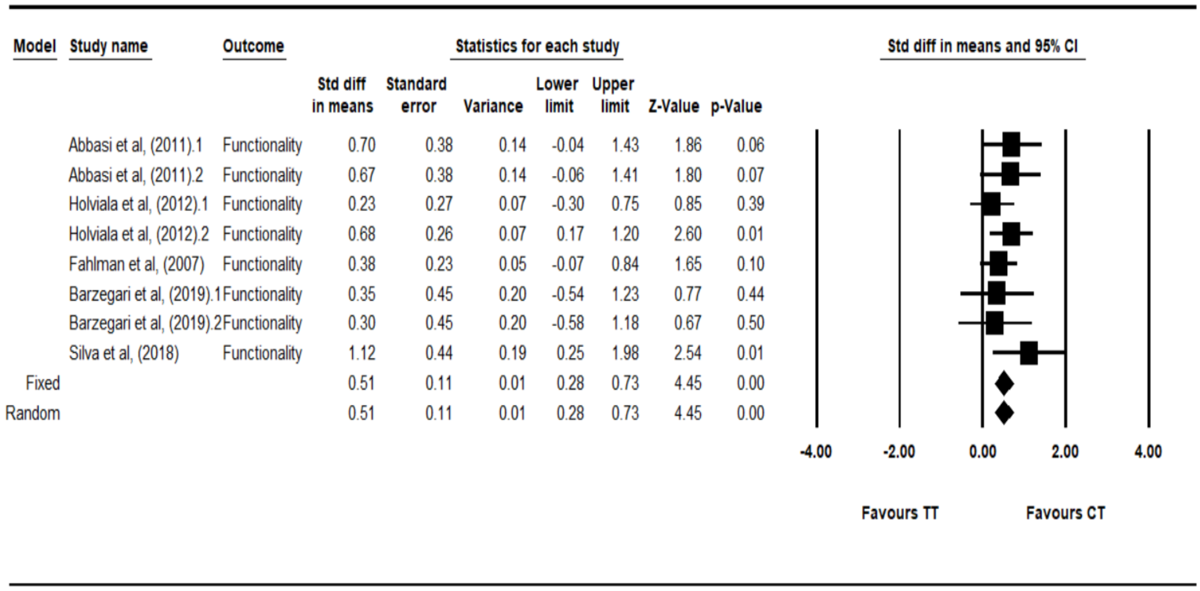


Figure 5: Forest Plot of the Combined Training Versus Traditional Training Analysis on Functionality.

Combined Training versus Traditional Training

Functionality. Eight intervention arms were included in the comparison of combined training (CT) versus traditional training (TT) for functionality. The meta-analysis demonstrated a significant improvement in functionality favoring CT, with a standardized mean difference (SMD) of 0.50 (95% CI: 0.28–0.73, $p = 0.001$). There was negligible heterogeneity among the studies ($I^2 = 0.00\%$, $p = 0.71$). Both visual inspection of the funnel plots and Egger's test indicated no evidence of significant publication bias ($p = 0.62$) (see Figure 5).

Discussion

This systematic review and meta-analysis aimed to evaluate the effects of combined training (CT) on functionality, balance, and gait speed in older adults. To the best of the authors' knowledge, no prior systematic review has specifically addressed this topic. In the present analysis, CT was initially compared with a passive control group and subsequently with traditional training (TT). The results consistently demonstrated that CT has a positive impact on functionality, balance, and gait speed in older people. Importantly, when compared to TT, CT showed a significantly greater effect on functionality, highlighting its potential superiority as a multidimensional exercise approach for older adults.

The studies included in this systematic review varied in their definitions of outcomes, necessitating categorization of results into three distinct domains: functionality, balance, and gait speed. Despite these differences, consistent units of measurement across the studies allowed for separate meta-analyses for each outcome. Overall, the included studies demonstrated high methodological quality, supporting the reliability of the present meta-analysis. Publication bias was assessed using Egger's test, which indicated no significant bias. However, notable methodological limitations and heterogeneity were observed across the 12 studies. These included variations in assessment tools and methods, type, volume, and intensity of exercises, supervision by therapists or trainers, study sample characteristics, session duration, nature of exercises, and total training duration. While categorizing variables helped address heterogeneity in assessment tools, other differences contributed to variability in the results. Future studies should consider these factors to draw more precise conclusions about the effects of combined training on functional performance, balance, and gait speed in older adults.

The results of the meta-analysis demonstrated that combined training (CT) has a positive effect on functionality, balance, and gait speed in older adults, compared with both passive control groups and traditional training (TT). Aging is associated with a decline in physical function, including balance, flexibility, and muscle strength [41,42]. Regular physical activity and structured exercise are effective strategies for preventing, delaying, or mitigating age-related functional decline, with well-documented benefits for the quality of life of older adults [43]. Exercise contributes to maintaining and enhancing cardiovascular health, counteracting the loss of muscle mass and strength, promoting bone density, improving balance, and increasing flexibility [8,44]. Therefore, implementing CT programs that target multiple aspects of physical function simultaneously can be particularly advantageous for older people. These findings indicate that short-term interventions combining strength, endurance, balance, resistance, and aerobic exercises can improve joint mobility and muscle strength and endurance, ultimately enhancing functionality, balance, and gait speed among older adults.

Based on the theory of systemic function, the control of the body's position in space arises from a complex interaction between the nervous system and the musculoskeletal system [45]. Effective postural control, balance maintenance, and movement coordination rely on sensory input to detect body position as well as the musculoskeletal system's ability to generate and regulate force [46]. Musculoskeletal factors that influence balance include joint range of motion, muscle strength and endurance, and the biomechanical relationships among body segments. Weakness or impairment in any of these components can result in balance disturbances [47]. In this context, balance exercises—particularly those performed on a balance board—are effective for retraining proprioception [17]. Strength exercises, which reinforce ligaments, stabilize joints, and stimulate proprioceptive feedback, also play a crucial role in maintaining postural stability [48]. Because combined training (CT) incorporates multiple dimensions of physical function, including strength and balance components, it has been shown to effectively improve balance in older people.

Other interventions, such as general strength and endurance programs, were often implemented alongside force plate training programs. Enhancements in muscle strength and endurance likely contributed to older adults' improved ability to perform functional tasks and maintain postural stability [49]. However, the optimal combination of exercises to maximize overall locomotor function, as well as the interactions among multiple biological systems, remains unclear. Given the multifactorial nature of falls, programs that target multiple risk factors simultaneously are likely to be more effective at reducing fall risk [50]. Lowering the risk of falls in older adults not only helps to reduce healthcare costs but, more importantly, enables them to maintain an active, independent, and enjoyable lifestyle [51]. Therefore, exercise interventions that incorporate multiple components appear to play a crucial role in achieving these outcomes. To enhance overall fitness in older adults, it is recommended that they participate in well-rounded exercise programs that combine aerobic, resistance, and flexibility training.

In the present study, not all factors contributing to the locomotor system—such as hormonal, visual, somatosensory, vestibular, and neurological components—were assessed. Nevertheless, it is well established that these factors naturally decline with age. The optimal combination of exercises to enhance overall locomotor function and the interactions among these multiple biological systems remain unclear [52]. However, strength training, as well as combined strength and endurance training, has been shown to positively influence postural control and balance in older adults, thereby contributing to improvements in standing balance [32].

Reduced muscle strength is commonly associated with aging and is a major contributor to falls. Consequently, improvements in muscle strength may help further reduce fall risk [53]. However, the current intervention appears to have a limited impact on overall functional fitness, as other functional fitness variables did not demonstrate significant improvement [54]. This finding is not unexpected, given the targeted nature of most training programs. The intervention primarily focused on systems responsible for balance—namely, the visual, vestibular, somatosensory, and musculoskeletal systems—and was effective in significantly enhancing balance [11]. Nevertheless, to improve overall fitness in older adults, it is recommended to engage in comprehensive exercise programs that incorporate aerobic, resistance, and flexibility training.

All-related mortality rates have steadily declined in developed countries, largely due to improvements in acute hospital care for older adults [55]. Nevertheless, primary prevention of falls among apparently healthy older individuals has become increasingly important [56]. The present study, conducted in this population, demonstrates that the exercise program effectively targets intrinsic risk factors, which are responsible for approximately half of all falls in older adults. The remaining falls are largely influenced by extrinsic factors, such as poor lighting or slippery surfaces, which can be mitigated through environmental modifications [52]. Considering the multifactorial nature of falls, interventions that address multiple risk factors simultaneously are likely to have a greater impact on fall prevention [51]. Reducing fall risk not only decreases healthcare costs but also enables older adults to maintain a more active and fulfilling lifestyle [57]. Thus, this combined training program may play a pivotal role in promoting both safety and quality of life in older people.

Although the findings of the present meta-analysis are significant, several limitations must be acknowledged. First, the lack of allocation concealment in some included studies increases the risk of selection bias. Second, publication bias was observed in certain analyses; however, the trim-and-fill correction method indicated that the overall results were not substantially affected. Third, the use of a random-effects model in the presence of heterogeneity gave relatively greater weight to smaller studies, and funnel plot asymmetry may have skewed results toward them. Additionally, this review primarily focused on functionality, balance, and gait speed, leaving other important outcomes such as muscle strength, overall performance, and quality of life unexplored. Future meta-analyses should consider these variables to provide a more comprehensive assessment of the effects of combined training (CT) in older adults. In conclusion, despite these limitations, the present meta-analysis offers valuable evidence supporting the benefits of CT on key aspects of physical function in older people, while highlighting areas for further research.

Conclusion

The results of this meta-analysis demonstrate that combined training (CT) improves functional performance, balance, and gait speed in older adults. Furthermore, compared with traditional training (TT), CT had a significantly greater impact on the functional performance of older adults. These findings suggest that CT is a viable and effective method for enhancing physical function and mobility in the elderly population.

Authors' Contributions

Conceptualization: All authors; Methodology: Mahboobeh Dehnavi and Amirali Jafarnejadgero; Investigation: Mahboobeh Dehnavi; Writing – Original Draft: All authors; Writing – Review & Editing: All authors; Funding Acquisition: Mahboobeh Dehnavi; Resources: All authors; Supervision: Amirali Jafarnejadgero, Farhad Tabatabai Ghomsheh, Ali Fattahi.

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