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The Effect of Balance-Based Interventions on Cognitive Functions of the Healthy and MCI Elderly: A Systematic Review and Meta-analysis

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Abstract

Background: Aging is an inseparable part of life, accompanied by mild to severe cognitive disorders. This study aimed to investigate the influence of balance-based interventions on cognitive function in older adults, encompassing both healthy individuals and those with mild cognitive impairment (MCI).

Methods: A systematic review was conducted by searching multiple databases up to April 2023, and the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) checklist was followed for reporting. Sixteen studies, comprising 1148 participants aged 43 to 89 years, were analyzed. Balance exercises were administered 1 to 3 times per week, lasting 30 to 60 minutes per session. Methodological quality was assessed using the Downs and Black checklist. A meta-analysis was conducted for executive functions (Stroop Test) and complex attention (Trail-Making Test, TMT A&B), while other outcomes underwent qualitative analysis.

Results: Qualitative analysis revealed positive effects on specific executive functions and complex attention aspects. However, the meta-analysis did not show significant differences in scores between balance training and control groups, which included healthy adults receiving nonbalance interventions or no intervention.

Conclusion: Limited research and methodological constraints hinder conclusive findings on balance-based interventions for older adults' cognitive functions. Yet, these interventions show the potential to enhance executive function and complex attention, emphasizing the need for further research in disability and rehabilitation.

Keywords: Aging; Elderly, Balance, Equilibrium, Cognition, Executive function

Conflicts of Interest: *None declared*
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Introduction

Aging is a process in which one's functional abilities gradually deteriorate over time, resulting in impairment, dependency, sickness, and mortality (1). The number of elderly people around the world is growing rapidly. The number of elderly older than 60 years will increase by 56% in the next 15 years, and the number of "older people" (>80 years) will triple by 2050 (2). In the following years, non-communicable diseases such as hypertension, heart disease, type 2 diabetes, osteoporosis, osteoarthritis, loss of sensory, and falls will be highly prevalent in the elderly population

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↑What is "already known" in this topic:
Balance-based interventions demonstrate promise in enhancing executive function and complex attention in older adults, which may be beneficial for rehabilitation programs aimed at cognitive improvement.

→What this article adds:
Balance-based interventions should be used as potential components of comprehensive rehabilitation strategies for those with cognitive challenges, including those with mild cognitive impairment. The integration of balance-based interventions within rehabilitation programs, with a focus on optimizing their effectiveness in addressing cognitive decline and psychological health concerns in older adults is essential. Practitioners in the field of disability and rehabilitation should consider the potential benefits of balance training for specific aspects of cognitive function and its role in improving overall well-being among their older adults.

(3). Meanwhile, cognitive impairments are one of the significant causes of disability and dependency among older people around the world (4). The prevalence of cognitive impairments and incidence in community-dwelling adults >50 years ranges between 5.1% and 41% (5). The decline in cognitive and physical function can result in functional dependence and decreased ability to perform activities of daily living (ADL), which negatively influences the quality of life of older people and their caregivers (6, 7). As a result, exploring new strategies and modes of physical activity that promote the physical and cognitive functions of aging is essential.

It is now clear that some cognitive decline related to age and dementia can be diminished (8, 9) or delayed (10) through performing physical activities as an effective nonpharmacological therapy and maintaining an active lifestyle in aging. Balance exercises are commonly used as a mode of exercise to improve cognitive functions (11). Balance is the ability to maintain the body's center of mass over its base of support (12). Complex integration and coordination of sensorimotor control systems, perceptual processes, and cognitive influences are needed to achieve and maintain balance (13). It begins with sensory inputs, including proprioception, vestibular signals, and visual cues (14), which are fundamental for maintaining postural stability during exercises. These sensory inputs undergo integration within specialized brain regions such as the cerebellum and parietal cortex, enabling the brain to construct an accurate representation of body position and movement in space (15). In response, the brain generates precise motor commands, orchestrating muscle activity and coordination to sustain balance (14). Notably, this process demands continual cognitive engagement, calling upon attention, working memory, and executive functions to monitor and adapt to changing conditions during balance tasks (16). Over time, the repetitive nature of balance training fosters neuroplasticity, strengthening neural connections and promoting the formation of new synapses, potentially enhancing overall brain health and cognitive function (17). Recent evidence has demonstrated that exercise interventions can have helpful changes in the brain structure of the elderly depending on the dose of exercises (18). Exercise may improve specific cognitive functions in old age by increasing brain-derived neurotrophic factor (19), which can improve hippocampal atrophy and memory functions (20).

Previous systematic reviews and meta-analyses have provided evidence demonstrating the benefits of performing different exercise modes on the cognitive functions of older people with various cognitive statuses (21, 22). Many of these previous studies have illustrated the effect of other modes of exercise such as yoga (23), resistance exercises (24), dance (25), aerobic exercises (26), tai chi (27), and pilates (28) on cognition and mental health of the elders; however, to the best of our knowledge, no systematic review has yet been conducted to state the effect of balance exercises on cognitive functions of older people. Therefore, the main aim of this systematic review based on the PICO of this study (comparing the effectiveness of different types of balance-based interventions on cognitive functions of the healthy and MCI elderly) was to examine the effect of balance-based interventions on cognition functions in older adults who are healthy or have mild cognitive impairment (MCI).

Methods

Search Strategy

An extensive electronic literature search was conducted in 4 prominent databases, Web of Science, PubMed, Scopus, and ProQuest, to find the potential scientific documents published from inception until April 2023. First, a search strategy for PubMed was established, which was then modified for other databases (Appendix 1). The keyword variation between databases arises from the need to tailor the search strategy to accommodate each database's functionalities and indexing structures. This approach aims to maximize the efficiency of retrieving relevant articles from each source. By adapting our keyword selection to the specific database characteristics, we enhance our ability to explore the literature while maintaining precision comprehensively. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) checklist was utilized to report our findings. Four authors performed the search procedure, and the titles and abstracts were separately assessed for eligibility by 2 authors (M.A. and P.P.). The papers' full texts were acquired after the duplicates were removed using Endnote X7 software. Two authors (M.A. and P.P.) started the paper selection procedure based on the qualifying criteria. Any disagreements about the selection procedure were resolved through discussion between the 2 authors, with the third author (A.D.) involved if necessary (Figure 1).

Study Types

Clinical trials—including paired samples, parallel or crossover designs, un-blinded or blinded—were included in this review.

According to published articles, the following criteria were met for inclusion: (i) studies written in any language; (ii) older, healthy population; (iii) studies using balance training to measure cognitive functions and including at least 1 group that received balance training exclusively; and (iv) population older than 60 years old.

Studies in which participants had neurological disorders such as Parkinson's, Dementia, or other particular disorders and who were hospitalized were excluded.

Assessment of Methodological Quality

The methodological quality of the included articles was independently assessed by 2 authors (M.A and P.P.) using the modified Downs and Black checklist (29). The checklist comprised sections on reporting, external validity, bias, confounding, and power. We reduced this checklist (Table 1) to 23 elements, as excluded items (Q8, Q12, Q13, and Q19) were unsuitable for scoring in the included papers. Each question was scored with "unable to determine" (score 0), "no" (score 0), or "yes" (score 1) as the responses.

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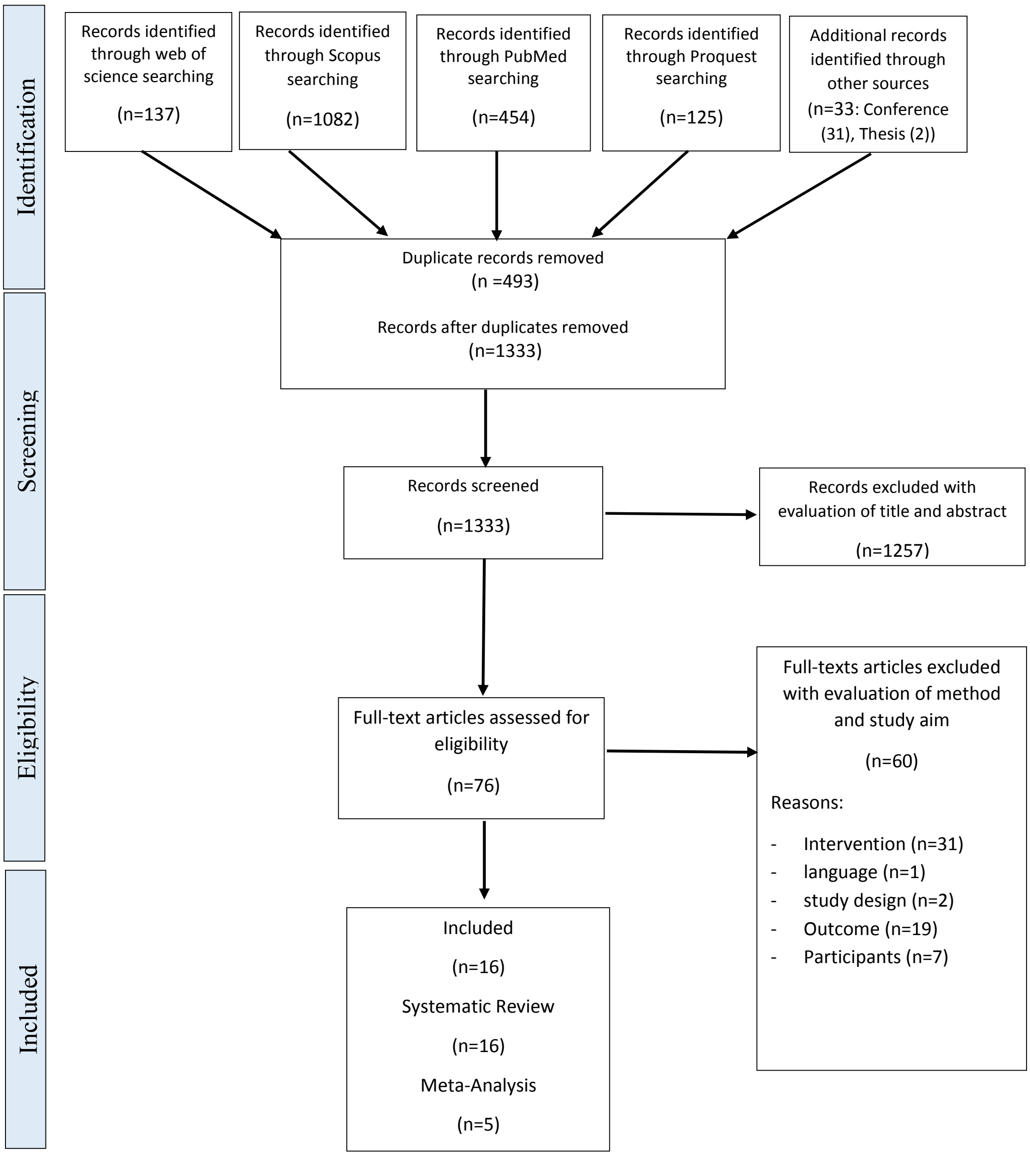

Figure 1. PRISMA flow chart of the study selection process

Data Extraction

Two authors extracted the data. The following information was extracted from the studies listed in Table 2: first author's name, publication year, trial design, sample size, population recruited (age, sex, living condition), inclusion and exclusion criteria, intervention administered, outcomes measured, and quality status. The respective authors were contacted for further information to compensate for the missing data.

Outcome Measures

The following outcome measures were considered for the present review based on the literature. Executive function and the related components (eg, inhibition, working memory, and problem-solving) were assessed using the following tests: Psytest psychological pest system, the Trail-Making Test (TMT A&B), the Stroop test, Tower of London software, Flanker task, Go no Go test, Digit Memory Test (DMT), N-back test, Digit Span test Backward (DSB), Catch game, and Executive Control task. Global cognition was assessed using the Montreal Cognitive Assessment (MoCA) test and Addenbrooke's cognitive examination. Complex attention and the related components (eg, speed processing, reaction time, selective, divided, and set-shifting attention) were examined by the advanced reaction time test, clinical reaction time test, simple reaction time test, choice reaction time test, TMT (A&B), Symbol Digit Modalities test (SDMT), Digit Symbol Substitution test (DSST), Digit Span test (DST), Visual Attention test (VAT), and Visual Search task. Other cognitive functions (eg, Memory and Spatial cognition) were evaluated using the Auditory Verbal Paired-associate Learning task, Orienting and Perspective test (OPT), Delayed Matching to Sample (DMS), German Intelligence Structure test (Figure orientation subscale), and German Wiled Intelligence test (Mirror images subscale).

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Table 1. Modified Downs and Black Quality Index results and total score.

Quality item		(45)	(43)	(44)	(33)	(34)	(36)	(37)	(38)	(39)	(30)	(40)	(41)	(42)	(31)	(35)	(32)
hypothesis/aim	Q1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Main outcomes in meth/Intro	Q2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Inclusion/exclusion criteria	Q3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Description of interventions	Q4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
distributions of principal confounders	Q5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Main findings	Q6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Random variability	Q7	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
Lost to follow-up	Q9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Actual probability values	Q10	0	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1
Representative of the entire population	Q11	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
Blind study subjects	Q14	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0
Blind those measuring	Q15	0	0	1	1	0	1	1	1	1	0	0	0	0	0	0	1
data dredging	Q16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
different lengths of follow-up	Q17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Statistical tests appropriated	Q18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Outcome measures used accurate	Q20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
different intervention groups	Q21	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Same period of time	Q22	1	1	1	0	0	1	0	1	0	1	1	1	1	1	0	0
Random allocation	Q23	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
concealed intervention from both patients and health care	Q24	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
adequate adjustment for confounding	Q25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Losses of patients to follow-up	Q26	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Estimate of Statistical power	Q27	1	1	1	0	0	1	0	1	1	0	0	1	1	0	0	0
Total 23 possible		15	7	18	14	15	19	17	19	17	16	17	17	17	16	15	16

1: Yes; 0: No; 0: unable to determine

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Table 2. Characteristics of the Studies on the effect of balance-based intervention on cognitive functions in elderly

Author (year)	Study design	Participants	Intervention for Intervention group	Intervention for Control group	Follow-up	Outcome measure (tool)	Main findings	Quality status
(45)	Quasi-experimental Pre-post design	-Total N=30 age=73 (±5) -IG1=11 -IG2=12 -CG=7	IG1: Aerobic exercise IG2: Balance and coordination	CG: Reading while sitting	3 Single sessions, 30 min	-Attention (Go no Go test (RTs and mean SD of RT for for the Go-no Go test), Stroop test (the no-interference (meaning) phase of the Stroop test)), -Executive Function (Performance indices for the Go no Go test and the Stroop test, and mean accuracy for the Catch Game)	No significant differences in executive function scores among the interventions. However, Single sessions of aerobic or balance exercises improved attention test scores compared to the control condition. (P<0.05)	Poor
(43)	Two-arm single-blind RCT	-Total N=70 age= 58–91 -IG1=28 -IG2=27	IG1: Sitting calisthenic balance (SCB) IG2: Resistance training (RT)	-	3 months Twice per week 40-50 min	-Global cognitive function (MoCA), -short-term memory (Digit Span and Delayed Matching to Sample), -set shifting (Trial Making Test Part B), -speed of processing simple visual stimuli (Simple Reaction Time), -decision making (Choice Reaction Time), -visual attention (Visual Attention Test (VAT)), and -neurotrophin level were examined.	The RT program led to enhanced global cognitive functioning (MoCA, P= 0.02), while the SCB program improved set-shifting, short-term visual memory, and processing speed of simple visual stimuli (SRT reaction time, P= 0.02; TMT B, P= 0.03; CRT errors, P= 0.04; VAT errors, P= 0.02). However there was no significant changes in the levels of neurotrophic factors.	Good
(44)	Single-blind Clinical Trials	-Total N=58 age -IG=29 -CG=29	IG: Receiving cognitive–physical dual-task training	CG: Receiving functional balance training	6 weeks 12 sessions	-Executive function (the Trail-Making Test (TMT-B))	The IG showed a greater improvement in the TMT-B (P < 0.001) compared to the CG.	Good
(33)	Quasi-experimental	-Total N=13, age=60-75 70.6±4.5	IG: Balance training including dynamic and static balance exercises	-	10 weeks 20 sessions 30 min	-Problem-solving (Tower of London software) - Working memory (N-back software) -Simple, Diagnostic, and Selective Reaction time (Advanced reaction time software)	The results found meaningful improvements in problem-solving (P=0.003) and working memory (P<0.001) after balance training compared with before training. However, no significant change was observed in the reaction time.	Poor
(34)	The pilot study was randomly assigned to groups	-Total N=28, age=≥65 -IG=14, age=70.7 ± 3.7 -CG=14, age=71.6 ± 4.7	IG: Multidirectional perturbations while walking on a treadmill	CG: Walking on the treadmill but without experiencing perturbations	1 week 2 days 34 min	-Information processing speed (SDMT) - Selective attention (TMT).	participants in the IG showed acute changes in SDMT (P < 0.001) but TMT did not show any significant modifications in both groups	Poor

IG: Intervention Group, CG: Control Group, RCT: Randomized clinical trial

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Table 2. Continued

Author (year)	Study design	Participants	Intervention for Intervention group	Intervention for Control group	Follow-up	Outcome measure (tool)	Main findings	Quality status
(39)	RCT	-Total N=40, -IG=19, age=43.9±14.92 -CG=21, age=46.6±15.18	IG: Balance training on varying surfaces	CG: Relaxation training	12 weeks Twice a week 50 min	-Memory auditory verbal paired-associate learning task) -Executive functions (Stroop Test) - Spatial cognition (Wilde Intelligence Test, IST-2000R, Orienting and Perspective Taking Test)	The results showed balance training improves cognitive functions, in particular memory (P= 0.043) and spatial cognition (P= 0.027).	Good
(40)	RCT	-Total N=27, age=65- over 65 -IG=15, -CG=14 age=mean age79.2±7.3	IG: Cognitive-motor training includes an interactive video game-based physical exercise.	CG: Conventional balance training, static and dynamic exercises.	8-10 weeks 3 per week 30 min	-EFs (working memory, inhibition (go-no-go), (selective) attention, and switching). (Four tests from Psytest Psychological Test system)	EFs improved both within the exergame (working memory (P=0.021), divided attention visual (P=0.040), divided attention auditory (P=0.009), inhibition(P=0.008), set shifting (P=0.002)) and within the balance group (set shifting (P=0.042))	Good
(41)	Open-label Pilot RCT	-Total N=22 (MCI), age=78.2 ± 8.7 -IG=12 -CG=10	IG: The sensor-based balance training program including -ankle point-to-point reaching tasks and -virtual obstacle crossing tasks	CG: No training	4weeks Twice a week 45 min	-Global cognition(MOCA) -Trail Making A and B tests	No intervention effects were obtained for cognitive performances (P= 0.132–0.738)	Good

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Table 2. Continued

Author (year)	Study design	Participants	Intervention for Intervention group	Intervention for Control group	Follow-up	Outcome measure (tool)	Main findings	Quality status
(42)	RCT	-Total N= 33 age 74.9 ± 6.9 -IG=19 -CG=14	Cognitive-motor video game dancing (DANCE)	Balance and stretching training (BALANCE)	8-week three sessions of 30 min per week	- Executive functions- general cognitive ability- information processing speed= - Shifting (the Trail Making Test B) - inhibition (Stroop Word-Color Interference task) - working memory (Executive Control task) - general cognitive ability (MoCA) - information processing speed (the Trail Making Test A)	The results showed that both interventions significantly reduced left and right hemispheric PFC oxygenation during the acceleration of walking P<0.05 while DANCE showed a larger reduction at the end of the 30-s walking task compared to BALANCE in the left PFC P=0.035 These exercise training-induced modulations in PFC oxygenation correlated with improved executive functions (P<0.05).	Good
(31)	RCT	-Total N=80 (MCI) age= 67.07 ±4.3 -IG=40 age=68±4.4 -CG=40 age=65.9±6.2	IG: CogniPlus together with balance training	CG: Only balance training	10 weeks 20 sessions twice per week 30 min	-Cognitive functions (Addenbrooke's cognitive)	After training, there were significant differences between these two groups recorded in the assessment of several cognitive functions by the Addenbrooke's cognitive examination in favor of the experimental group (P<0.05-0.0001)	Fair

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Table 2. Continued

Author (year)	Study design	Participants	Intervention for Intervention group	Inter-vention for Control group	Follow-up	Outcome measure (tool)	Main findings	Quality status
(32)	A 12-month RCT	-Total N=36 age= 62-89 -IG1= ,13 age=67.69±2.78 -IG2= 14, 69.50±4.74 -CG=9 age=69.56±3.40	IG: Coordination training (such as balance, eye-hand coordination, leg–arm coordination as well as spatial orientation and reaction to moving objects/ persons).	CG: Stretching and relaxation	12 months Three times a week 45-60 min	-Executive control (Flanker task) -perceptual speed (Visual search task)	Coordination training Increased caudate and globus pallidus volume. P=0.008 Pearson product-moment correlations within the coordination group showed that there was no direct association of changes in basal ganglia volume (neither caudate nor globus pallidus volume) with changes in Flanker task accuracy or reaction time in the Visual Search task P=0.014	Fair
(35)	12-month longitudinal study Randomly assigned	-Total N=44 Age=62-79 -IG1= 17 age = 68.47 -IG2=16 age=71.13 -CG=11 age=69.27	IG1: Cardiovascular training IG2: Coordination training (such as balance, eye-hand coordination, leg–arm coordination as well as spatial orientation and reaction to moving objects/ persons).	CG: Relaxation and stretching	12 months three times a week 1 hour	-Perceptual speed (Visual Search Task) -Executive Control (Flanker Task)	Cardiovascular and coordination training groups showed significant improvements in performance accuracy in the Flanker Task ((P= 0.013 and P= 0.024, respectively)) compared to the control group. Coordination training specifically led to significant improvements in the Visual Search Task (P= 0.008) while cardiovascular training showed a marginally significant improvement in this Task (P= 0.08)	Poor

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Statistical Analysis

For the quantitative analysis (meta-analysis), the Stata software 11.0 (Stata-Crop) was used. The mean and standard deviation of outcomes were extracted and analyzed. Where possible, the effect size across the studies was calculated by standardized mean difference (SMD; Cohen's d) and 95% confidence intervals using a random-effects model. The SMD of 0.2, 0.5, 0.8, and >0.8 corresponded to small, medium, large, and significant changes. The results for every comparison were represented in forest plots. The heterogeneity among the studies was calculated using I-square (I^2). Also, I^2 values of <25%, 25%–50%, and 50%–100% were chosen as low, medium, and high, respectively.

Results

Study Identification

A total of 1826 records were identified from preliminary searches according to the predetermined search strategy. Two authors (M.A., P.P.) disregarded irrelevant records based on the abstract or the title. The authors also examined the studies available in other languages rather than English, and their abstracts were in English. Still, none of the non-English language articles met the inclusion criteria for our study. A total of 76 potential studies were further evaluated for their eligibility, and 16 studies ultimately met the inclusion criteria. However, 5 studies lacked the original data. We emailed the original authors; 3 provided the entire text, but 2 did not respond. Finally, 16 studies involving 1148 participants were included in the review. The detailed screening flow used to find eligible studies is presented in Table 1.

Quality Status

The quality status of the studies had a scientific rigor of 16 (medium or fair) (30-32) out of 23 and ranged from 14 (low or poor) (33-35) to 19 (high or good) (36-42). All studies failed in items that evaluated adjustment for confounding in the analyses and distributions of principal confounders in each group of subjects.

Characteristics of Included Studies

The analysis of the articles showed the effect of balance training programs on global cognition (n = 5 (31, 36, 41-43), executive function and the related components (n = 12; eg, inhibition, problem-solving, working memory (32, 33, 35-40, 42), complex attention and its components (n = 12;eg, reaction time, speed processing, and type of attention (30, 32-38, 41, 42), and other cognitive functions such as memory and spatial cognition (n = 3) (33, 39, 43). The characteristics of each of the included studies are summarized in Table 2. Across 16 studies, the total sample size was 1148 older adults (age range, 43-89 years). Fourteen studies explored the effect of balance on cognition in healthy older adults, and 2 studies with older adults with MCI (31, 41). Participants were recruited from the community (n = 964) (30, 32, 34-39, 42-45), retirement homes (n = 42) (33, 40), and clinical outpatients (n = 102) (31, 41).

Balance exercises target 2 primary aspects of postural control—static and dynamic postural control. Static postural control or balance is the capacity to hold a support base with little movement. In contrast, dynamic postural control or balance is the ability of a person to anticipate postural changes while moving and to respond appropriately to changes in balance (46). The frequency of balance training sessions varied from 1 to 3 weekly and 30 to 60 minutes per session. One study did not mention the exact time of the balance intervention (2 hours per week, both balance training and health education) (36). The duration of the intervention was evaluated immediately (34). Short-term (<3 months) (31, 33, 37, 38, 40-42) and (≥ 3 months) (30, 39), long-term effects were also evaluated(≥ 12 months) (32, 35, 36). Only 1 study did not have any control group (33), 5 studies did not specify experimental and control groups (37, 38, 40, 42), and 5 studies had 3 groups regarding intervention programs (30, 32, 35, 37).

Of these 16 studies, in 3 studies (30, 41) the experimental group received balance exercises while the control group received no intervention; in 1 study, the control group received health education (36), in 1 study the control group received relaxation training (39), in 2 studies control groups received relaxation and stretching exercises (32, 35), and in 1 study, walking on the treadmill was the intervention for the control group (34). Four studies (30, 31, 40) compared balance exercises with dual-task training (ie, CogniPlus program, Exergame program), 2 studies (37) compared these exercises with resistance exercises, 1 study (42) compared the exercises with dance, and 2 of them compared them with aerobic exercises (38).

Three studies (30, 33) had warm-ups before intervention. Six studies had a cognitive screening for inclusion criteria as a general cognitive profile, such as the Mini-Mental State Examination (MMSE) (30, 31, 33, 35, 37, 40), Pfeiffer short portable mental status questionnaire (36), Clock drawing test (37), The German "Mehrfachwahl-Wortschatztest" (MWT-B)(39), MOCA (41), digit-symbol substitution (32), identical picture tests (32), figural analogies, letter series (32), paired associate test (32), naming the animals (32), and vocabulary test (32). Because of the limited number of studies for each parameter, a meta-analysis was conducted for executive function evaluated by the Stroop test (36, 37, 39, 42) and complex attention evaluated by TMT (A&B) (36, 37, 41, 42). Qualitative analysis was conducted for other outcome measures.

Findings of Studies

Global Cognition

Five studies (31, 36, 41, 42) assessed the effect of balance training on global cognitive function through the MoCA, Addenbrooke's cognitive examination in the old healthy population (36, 42), and those with MCI (31, 41). Meta-analysis was not used because of the various tools employed in the studies above. The results of 1 study revealed that balance training could significantly increase global cognitive function among MCI participants; the experimental group demonstrated a significant improvement in Addenbrooke's cognitive examination scores compared to the control group, with statistical significance ranging from $P < 0.05$ to $P < 0.0001$ (31).

Other research, however, that used the MoCA test to compare experimental groups receiving balance therapies

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to control groups receiving health education, no intervention, resistance training, and dance did not find any significant differences (36, 41, 42).

Executive Function

Executive function and its related components were assessed using the Stroop test (eg, inhibition; 5/16 studies), Psytest psychological test system (1/16 studies), executive control task (eg, working memory; 1/16 studies), digit memory test, and digit span test backward (eg, working memory; 2/16 studies), N-back test (eg, working memory; 1/16 studies), Go no Go task (eg, inhibition; 2/16 studies), Flanker task (eg, inhibition, 3/16 studies), catch a game (1/16 studies), TMT-B (eg, set-shifting; 2/16 studies), and Tower of London test (eg, problem-solving; 1/16 studies).

The meta-analysis conducted on the Stroop test (36, 37, 39, 42) showed no significant differences between the balance training and the control groups (n = 644, SMD = 0.11, 95% CI, –0.33 to 0.54, I-squared = 67.1% (Figure 2). The results of the qualitative analysis revealed that balance training could have a significant impact on executive function through the Psytest psychological test system (in each component: working memory; *P* = 0.021, inhibition; *P* = 0.008; set-shifting; *P* = 0.002), and TMT-B test (set-shifting; *P* = 0.04). In addition, significant improvements were observed in working memory, as measured by the Digit memory test (*P* = 0.004) (37) and the N-back test (*P* < 0.001) (33). However, no significant differences in executive control task (42), Go no Go (45), Stroop test (45), catch game (45), TMT-B (44), and digit span test backward (43) were reported. Moreover, there was a significant difference between groups before and after balance training in the response inhibition for the Flanker task (32, 35, 38). Problem-solving was also assessed through the Tower of London test in 1 study (33), which reported a significant increase in problem-solving after balance training (*P* = 0.003).

Complex Attention

Complex attention was evaluated as processing speed through SDMT (34), DSST (37), simple reaction time (43), and visual search task (32, 35, 38), reaction time through advanced reaction time test (33), clinical reaction time test (38), simple reaction time test, and choice reaction time test (30), and auditory and visual attention, including selective, sustained, divided and set-shifting through the TMT (A&B) test (34, 36, 37, 41, 42), digit span test (43), Go no Go (45), Stroop test (45), and visual attention test (43). The results of the meta-analysis of the TMT (A&B) test revealed that the balance training groups were not significantly different from the control groups who received health education, resistance training, dance, and no intervention (36, 37, 41, 42). Figure 3 demonstrates the following values: TMT: n = 626, SMD = 0.11, 95% CI, –0.67 to 0.88, I-squared = 94.4%.

Figure 4 shows the following values: TMT: n = 626, SMD = 0.09, 95% CI, –0.12 to 0.29, P = 0.000, I-squared = 29.7%.

According to the qualitative analysis, the processing speed showed significant improvements in SDMT (*P* < 0.001) (34), medium effect in DSST between groups (*P* = 0.024), significant improvement in simple reaction time (*P* = 0.020) (43), and visual search task (*P* = 0.050) (32, 35, 38) after balance training. Moreover, no significant difference was found in the advanced reaction time test (33). In contrast, significant differences were shown in the clinical reaction time test (*P* < 0.001) (38), simple reaction time test, and choice reaction time test (*P* < 0.05) (30) after balance interventions. Dunsky et al study indicated a significant improvement in attentional levels after a single session of balance intervention, as measured by the Go-No-Go and Stroop tests (45) (*P* = 0.05). Furthermore, significant differences were found in the digit span test for auditory and visual attention tests for visually sustained attention (43).

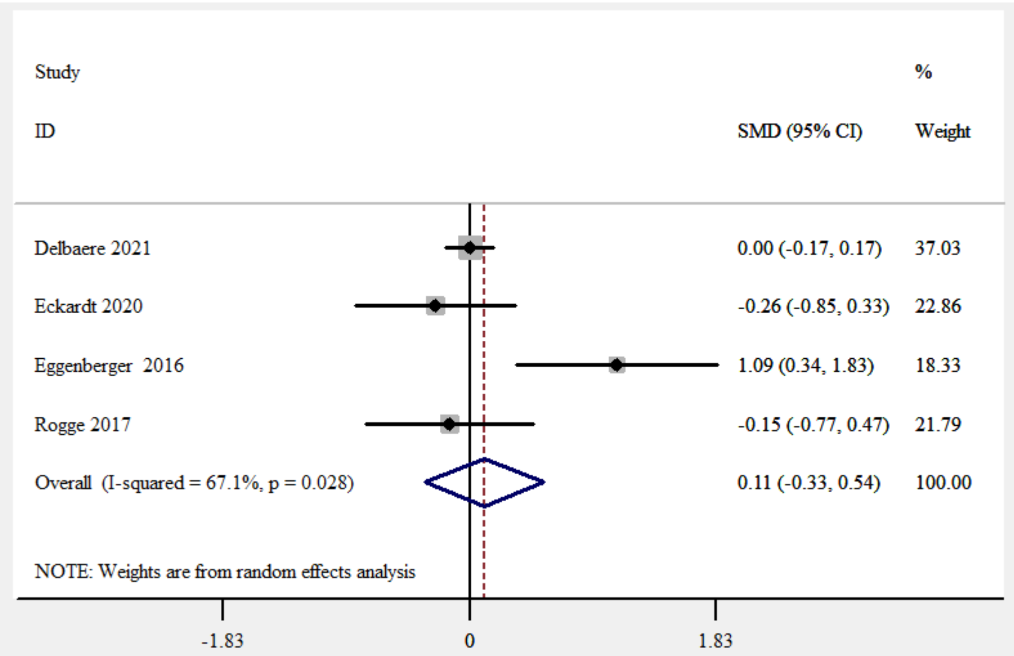

Figure 2. The results of Meta-analysis in Stroop test

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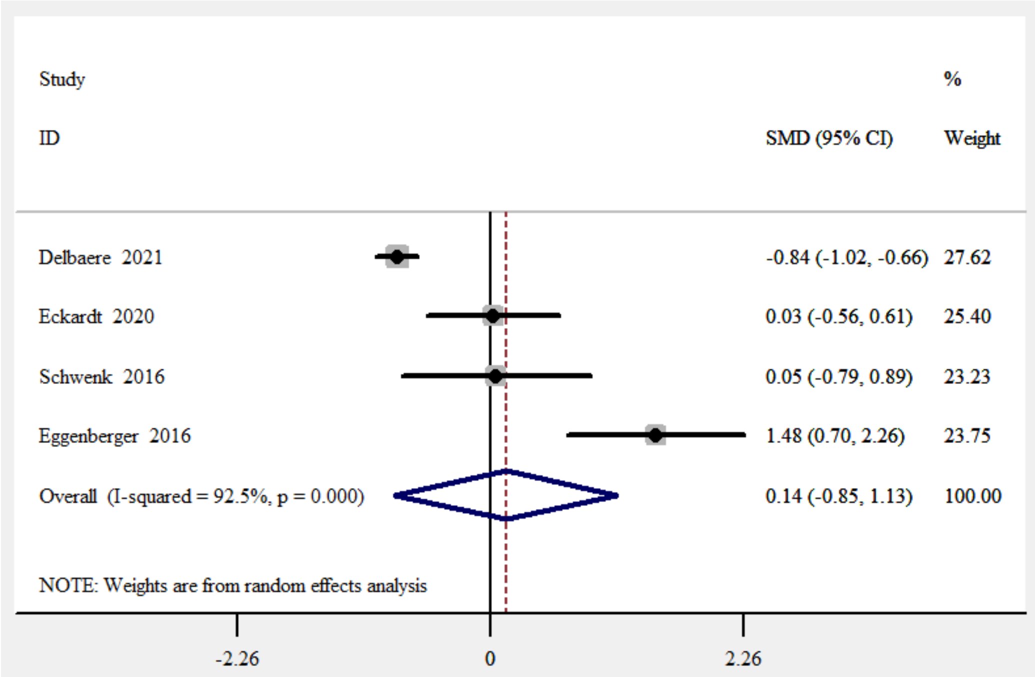

Figure 3. The results of Meta-analysis in TMT-A

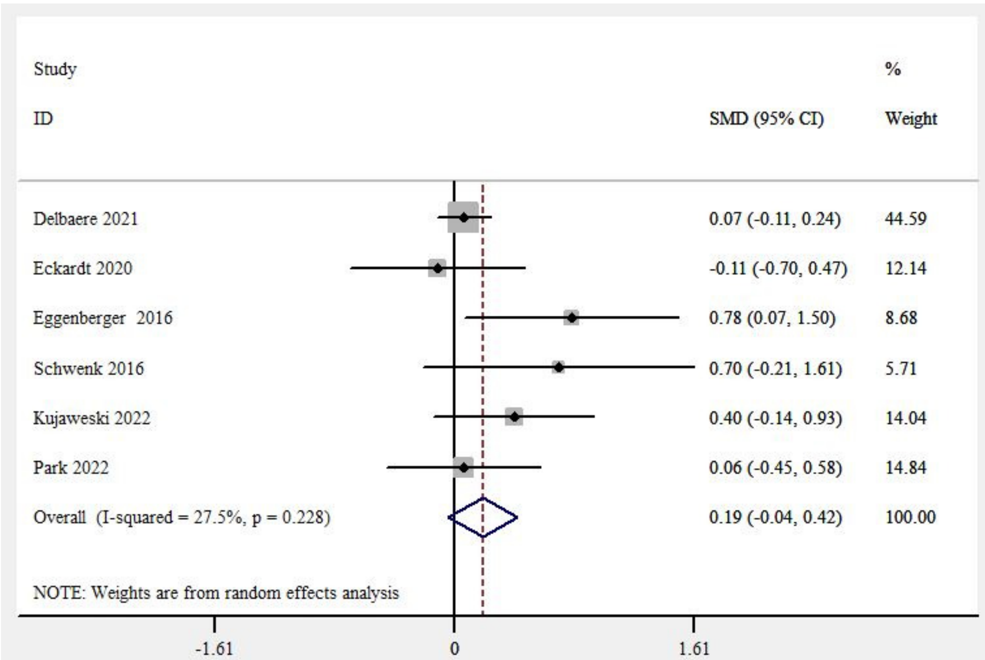

Figure 4. The results of Meta-analysis in TMT-B

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Other Cognitive Functions

Two studies evaluated short-term memory using the auditory verbal paired-associate learning task (39) and delayed matching to sample (DMS) (43). The results showed that balance training can significantly affect short-term memory (auditory verbal paired-associate learning task; *P* = 0.043 and DMS; *P* = 0.03). Additionally, spatial cognition assessed through the orienting and perspective-taking test (OPT), German intelligence structure test (Figure orientation subscale), and German wilder intelligence test (mirror images subscale) were used (39). The analysis of spatial scores yielded a significant group effect after balance training (*P* = 0.027).

Discussion

This systematic review and meta-analysis aimed to show the effect of balance-based interventions on the performance of cognitive domains, including global cognitive function, working memory, complex attention, response inhibition, problem-solving, and spatial memory among older adults and people with MCI. Balance, or postural control, denotes the intricate coordination and regulation of one's body position in space to ensure both stability (preventing falls) and orientation (aligning with the surrounding environment) (47). It arises from the intricate interplay among diverse bodily systems, including musculoskeletal and neural elements, collectively forming what we refer to as the "postural control system." Musculoskeletal factors include joint flexibility, muscle properties, and biomechanical relationships among various body segments. On the other hand, the neural components encompass motor processes (pertaining to muscle coordination), sensory processes (involving the visual, vestibular, and somatosensory systems), and higher-level cognitive processes (48).

Cognitive functions are pivotal in postural control, impacting adaptive and anticipatory balance dimensions. Adaptive postural control involves making real-time sensory and motor systems adjustments in response to shifting environmental and task demands. In contrast, anticipatory control entails pretuning these systems based on prior experiences and learned responses. These cognitive functions contribute to the fine-tuning of posture and stability. Moreover, attention, motivation, and intent represent additional cognitive processes that influence postural control. As a result, balance or postural control emerges as a dynamic and multifaceted process shaped by the intricate interaction of various bodily systems and cognitive functions, enabling individuals to navigate their physical surroundings while ensuring stability and orientation effectively (49).

Recent evidence has indicated that balance exercises can positively impact the cognitive functions of the elderly. These exercises, designed to enhance postural control and stability, offer additional cognitive benefits beyond their primary aim.

After mentioning 4 to 6 studies, the results give a conclusion like "Collectively, these investigations suggest Breast Cancer survivors (BCSs) heavily rely on visual feedback to maintain upright posture, which may be because of the loss of proprioception commonly displayed after cancer treatment. Clinicians should rely on tests that challenge balance without visual feedback or with challenging proprioceptive conditions when assessing balance. Furthermore, clinicians should use caution using the single leg stance test because there are mixed results when comparing with those who never had breast cancer and normative values."

Future work should continue to identify which factors contribute to slow gait speed and explore whether exercise improves these factors and, consequently, gait function in BCSs.

This review provides important information for BCSs and clinicians. BCSs should report any noticeable changes in their gait or balance to clinicians because early detection may prevent long-term impairment. Clinicians should also assess gait and balance at the clinic both during and following treatment. Assessing balance with a force plate will better detect changes in stability, but the functional reach test can also be quickly administered to detect balance impairments. To assess gait speed, clinicians should assess usual and fast gait speed over 10 m or use TUG because a shorter distance appears to be able to detect changes in gait. Assessing and tracking their gait and balance can help identify BCSs needing rehabilitation to improve their mobility. Improving gait and balance may reduce fall risk and prevent fall-related injuries such as hip fractures. (39) Future research is also needed to help clinicians identify the type, intensity, and frequency of exercises that may improve gait and balance and reduce fall risk tailored for BCSs."

Following a thorough review of the literature, 7 studies were included in the meta-analysis (36, 37, 39, 41, 42). The meta-analysis results indicated that balance training could not improve some components of executive functions (eg, inhibition) and complex attention. However, the descriptive analysis of 6 of 16 publications (32, 33, 35, 38) found significant improvements in various domains of cognitive functions such as set-shifting, response inhibition, working memory, speed processing, reaction time, problem-solving, short-term memory, global cognition, and spatial cognition after participating in balance-based interventions.

Summary of Evidence and Reporting Therapeutic Balance Interventions

Conflicting results have been reported according to the current overall results of studies. The balance-based interventions did not demonstrate a significant difference in global cognition performance as assessed by the MoCA test (36, 41, 42). Delbaere et al (2021) highlighted several crucial factors that should be considered to ensure the study findings' robustness and accuracy. These factors encompass the need for meticulous control of participant masking, careful consideration of potential errors stemming from subsequent multiple testing, and the recognition of the influence of participants' educational levels on the observed outcomes (36). In addition, limited training duration, the protocol of intervention with more and less cognitive demands, the relatively small sample size employed in the study, and the absence of any exercise or intervention in the control group collectively contributed to the impact on the observed results (41). Eggenberger et al (2016) indicated although age cannot affect the results of balance interventions on some cognitive functions, intervention design and the general ability (eg, physical or mental) of participants can affect the results (42). However, Hagovska et al (2016) revealed that dynamic balance training among MCI adults could positively enhance the subscores of Addenbrooke's cognitive examination including—attention, memory, and language ability (31). Based on the quality status, the studies utilizing the MoCA test were deemed to have a "good" status, but the study with the Addenbrooke cognitive outcome measure had a "poor" status. Despite the limited number of studies available and the utilization of diverse outcome measures, it can tentatively be inferred that balance-based interventions do not yield significant improvements in global cognition performance among older healthy and MCI adults.

The effect of balance training on executive function and its components (eg, working memory, inhibition, and problem-solving) was evaluated more than other cognitive functions. (32, 33, 35-40, 44, 45) Our meta-analysis results revealed that significant differences were not seen through

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the Stroop test (36, 37, 39, 42). It is important to mention that heterogeneity within the studies was included in our analysis. Heterogeneity, as quantified by the I^2 statistic, emphasizes that the diversity in our meta-analysis's results reflects differences in the effectiveness of balance training on cognitive functions and variations in study designs, participant characteristics, and intervention types. The lack of uniformity in cognitive outcomes highlights the complexity of this field, where the effects of balance exercises may be contingent upon specific factors. However, qualitative results indicated that balance-based intervention can be effective in improving executive function and its components (32, 33, 35, 38, 40). Moreover, among the studies that evaluated response inhibition using tests such as the Flanker test and Go no Go test, the majority demonstrated statistically significant improvements (32, 35, 38, 40). However, there was 1 particular study (45) that utilized the Go no Go test and reported no significant differences in executive function scores across the interventions. The studies that did not demonstrate significant improvements in executive functions have identified some factors that should be considered—including control of participants' blindness, individual differences in education and skill acquisition, participants' MMSE score, intervention requirements (complexity and simplicity), limited duration of the training or inadequate intensity, single-session intervention, and small sample size (36, 37, 39, 42, 45). The assessment of complex attention—including such measures as speed processing, reaction time, visual search, and attention—did not yield consistent results. Quantitative findings from some studies (36, 37, 41, 42) did not indicate significant improvements in the TMT (A&B) test. However, some qualitative results indicated significant improvement (30, 32, 34, 35, 38). The studies that used the same outcome measures showed the same results; thus, perhaps the sensitivity of the outcome measures can affect the results; however, further studies should be conducted to illustrate the findings accurately.

Furthermore, a diverse set of cognitive outcome measures—including the MoCA, TMT A&B, Stroop test, and Flanker test—were employed to assess the impact of balance-based interventions on cognitive functions. The MoCA test, known for its high sensitivity to change, exhibited superior performance in capturing cognitive abilities compared to the Mini-Mental State Examination (MMSE) (50). However, despite the strong validity and reliability of the MoCA, the included studies in this systematic review did not show significant differences between pre- and postevaluations. While TMT-A was predominantly utilized to evaluate processing speed across most studies in this review, a detailed analysis reveals that TMT-A primarily taps into visuoperceptual abilities. Moreover, contrary to most studies employing TMT-B to assess set-shifting abilities, it initially reflects working memory (34, 51). Thus, it is crucial to carefully select appropriate and objective outcome measures (eg, functional magnetic resonance imaging, event-related potentials, and functional near-infrared spectroscopy for future investigations in this field.

Different Types of Balance-Based Intervention

Several reviews demonstrated engaging in various types of exercises could improve cognitive functions in older healthy and MCI adults (24, 25, 52). According to the World Health Organization guidelines, doing regular physical exercises is recommended to achieve optimal health outcomes (53). The balance-based interventions consisted of dynamic and static balance exercises, including perturbations, instability-free weight resistance, sensor-based balance, and coordination training. Therefore, the protocol of balance interventions should be considered because those can affect positively the results (34, 38, 39, 54). In addition, the intensity and time of exercise are important to discriminate between the results of studies (33, 40, 54). Additionally, the limited duration of the intervention may have been a significant factor in the observed results, and it has been suggested that longer duration can be more effective for improving cognitive functions (37, 41).

Among the included research, Schwenk et al . examined the impact of sensor-based balancing training for 4 weeks, twice a week, on cognitive functions (MoCA and TMT). This study had the least follow-up, and the findings revealed no intervention effects on cognitive performances.

The limited duration of the follow-up assessment may not adequately reflect the durability or long-term sustainability of the intervention effect on cognitive functions (41). In addition, some studies highlighted that the requirements and demands of the intervention could hugely affect the participants' performance and the improvement of their cognitive functions; thus, they suggested combining balance-based interventions with cognitive demands (eg, dual task, dance, and Cogniplus with physical exercises) would be more effective to improve cognitive functions among seniors (31, 42).

Limitations

The present review has some limitations. First, the interventions' duration, frequency, and intensity varied across the included studies, making it challenging to establish the optimal duration required for achieving significant cognitive benefits. Second, the types of balance interventions and their respective durations varied. Third, given the scarcity of studies investigating the effect of balance exercises on cognition, a diverse range of balance exercise types was considered in this review to ensure inclusivity. Fourth, this paper did not address potential confounding factors, such as differences in baseline cognitive status, participants' educational levels, physical health, or socioeconomic factors that may have influenced the results. Fifth, the subgroup analysis was not applicable due to the small number of studies. Also, the limitation of not consulting with information professionals during the search process is recognized. Last, expert guidance from health sciences librarians or information professionals can be valuble in constrcting more robust search strategies.

Conclusion

Although the existing body of literature is insufficient to establish definitive conclusions regarding the potential benefits of balance-based interventions on cognitive functions in the elderly, it is noteworthy that such interventions hold

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promise as a viable therapeutic strategy for enhancing cognitive functions in healthy older adults and individuals with MCI. These interventions have demonstrated the potential to improve specific cognitive domains—including executive function, complex attention, global cognition, spatial cognition, and memory.

Authors' Contributions

Conceptualization: Pashmdarfard M, Azhdar M, Parchini P, Daryabor A, Data collection: Azhdar M, Parchini P, Methodology: Pashmdarfard M, Dayabor A, Writing – original draft: Azhdar M, Parchini P, review & editing: Pashmdarfard M, Daryabor A, Azhdar M.

Ethical Considerations

The ethics committee of Shahid Beheshti University of Medical Sciences approved this study with the ethics code of IR.SBMU.RETECH.REC.1403.057.

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Conflict of Interests

The authors declare that they have no competing interests.

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Appendix 1.

Web of Science

((((((((TS=(aging)) OR TS=(Elder*))) OR TS=(older)) OR TS=(ageing)) OR TS=(senior)) AND TS=("balance training")) OR TS=("equilibrium training")) AND TS=(cognitive*))

Scopus

(TITLE-ABS-KEY (elder*) OR TITLE-ABS-KEY (aging) OR TITLE-ABS-KEY (senior) OR TITLE-ABS-KEY (ageing) OR (older)) AND (TITLE-ABS-KEY (balance training) OR TITLE-ABS-KEY (equilibrium training)) AND (TITLE-ABS-KEY (cognitive*))

Pubmed

(((((((((((aging[Title/Abstract]) OR (senior[Title/Abstract])) OR (elder*[Title/Abstract])) OR (older[Title/Abstract])) OR (ageing[Title/Abstract])) AND ("balance training"[Title/Abstract])) OR ("equilibrium training"[Title/Abstract])) OR ("motor control"[Title/Abstract])) OR ("control postural"[Title/Abstract])) OR ("multi task"[Title/Abstract])) OR ("dual task"[Title/Abstract])) AND (cognitive*[Title/Abstract])) Filters: Clinical Trial, Randomized Controlled Trial

Proquest

ab((elder* OR aging OR older OR ageing OR senior)) AND ab((balance training OR equilibrium training)) AND ab((cognitive*))

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