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Effectiveness of combined physical exercise and cognitive training in older adults with cognitive impairment: A systematic review and meta-analysis

Dwi NK. Wati[1,2], Heng Y. Lin[1] and Jing J. Wang[1*]

[1]Departement of Nursing, College of Medicine, National Cheng Kung University, Tainan, Taiwan; [2]Community Health Nursing Department, Faculty of Nursing, Universitas Indonesia, Depok, Indonesia

*Corresponding author: ns127@mail.ncku.edu.tw

Abstract

Falls among cognitively impaired older adults are a global concern. The aim of this study was to assess the efficacy of combining physical exercise and cognitive training to improve balance among older adults. A systematic search of databases, including Embase, Medline-OVID, CINAHL-EBSCOhost, and Central-Cochrane Library, was conducted from March 9 to April 6, 2023. The search used keywords based on the PICO question, where the population was older adults with cognitive impairment. Compared to a single therapy, the intervention involved a combination of muscle strengthening and cognitive therapy, with the outcome of falls or balance. Inclusion criteria were randomized controlled trials (RCTs) in any setting. Studies with participants under 60 years old and lacking baseline clinical assessments were excluded. EndNote 20 was used as a reference manager tool, and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 flow diagram was used to map out the number of identified records. Two investigators worked independently, and the Jadad scale was used for critical appraisal. The PROSPERO registration number is CRD42023454876. A fixed-effects meta-analysis was performed using an inverse-variance method. Four articles met the inclusion criteria, three of which were included in the meta-analysis. Studies were from Europe, New Zealand, and the Philippines, with a total sample of 255 participants and mean ages of 65.9–87.5 years. The studies used combined physical and cognitive training in one group. Results showed a significant moderate effect size (effect size (ES): 2.29; standardized mean difference (SMD): 0.41; $p<0.05$; heterogeneity (I^2): 0%) indicating no heterogeneity. In conclusion, the combined intervention displayed the potential to improve balance for cognitively impaired older adults.

Keywords: Cognitive impairment, cognitive training, fall, older adults, physical exercise

Introduction

The incidence of falls among older adults is high and increases with age. Globally, 28% to 35% of older adults experience a fall within a year. In the United States, approximately 29% of adults aged 65 and above have experienced falls in the past year, while in Australia, falls account for 17% of older adults' visits to the emergency department, with over 50% of nursing home residents experiencing falls annually [1-4]. Unfortunately, some of these falls lead to hospitalization, the need for advanced medical care, and even death among older adults [5]. Of all fall incidents, 40–60% result in injuries, with 30–50% minor injuries, 5–6% major non-fracture injuries, and 5% leading to fractures, with hip fractures being the most common [6].

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The definition of a fall event can vary among studies, but it generally refers to an unintentional incident where an older person rests on the ground or at a lower level, regardless of whether the event is witnessed [7]. Balance is the ability to control body posture in a normal position [8]. Among older adults, balance disorders can have multifactorial causes, primarily attributed to physiological changes in the musculoskeletal system, central nervous system, and sensory systems, which all contribute to an increased risk of falling [8-14]. Cognitive decline is considered part of the normal aging process, whereas cognitive impairment can range from mild to severe with different symptoms and characteristics [15]. Older adults with cognitive impairment often exhibit balance deficits, reduced mobility, and slower gait [16-18], making them more susceptible to falls compared to individuals with intact cognitive abilities [12,19-21]. Fall prevention activities for older adults are well-established and typically encompass five primary types of training, including physical exercise, cognitive training, artificial intelligence-based equipment training, pharmacologic treatments, and fall prevention education [10]. Simulated physical exercises have shown significant improvements in balance and reductions in falls among older adults [22-25]. As part of cognitive training, cognitive behavioral therapy (CBT) and memory exercises have also demonstrated significant reductions in fall risk [26,27]. To enhance intervention outcomes, some studies employed multifactorial interventions involving two or more components tailored to each individual's fall risk and multiple interventions incorporating two or more components without customization [28]. However, there is limited-quality evidence indicating that multifactorial and multiple interventions may reduce the risk of falls [27]. Therefore, combining muscle strengthening and cognitive training may offer a more substantial opportunity to improve balance and reduce the risk of falling.

This review underscores the importance of fall prevention among older adults with cognitive impairment, focusing on addressing balance as the pivotal risk factor for falls. It emphasizes the need for evidence on the impact of combining muscle strengthening and cognitive therapy to prevent falls in older adults with cognitive impairment. The aim of this study was to evaluate the effectiveness of combined intervention compared to single treatments across various care settings.

Methods

Study protocol

The review protocol was registered on the International Prospective Register of Systematic Reviews (PROSPERO) database with the registration number CRD42023454876 (https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=454876). The protocol followed the Transparent Reporting of Systematic Reviews and Meta-Analyses (PRISMA) diagram 2020 and included the PRISMA checklist for reporting the review [29].

Search strategy

A systematic literature search was conducted in various electronic databases, including OVID Medline, Embase, CINAHL EBSCOhost, and CENTRAL COCHRANE Library, from March to April 2023, without publication year or language restrictions. Any articles published until April 2023 were screened. The search strategy employed controlled vocabularies (Emtree, Mesh, and CINAHL synonyms) with search terms such as "older adult AND cognitive impairment" AND "muscle strengthening AND cognitive therapy" AND "fall OR balance," applying randomized controlled trial (RCT) filters. Synonymous terms like "muscle strengthening," "exercise," "physical training," and "physical exercise" were used interchangeably, as were "cognitive therapy," "cognitive training," and "cognitive exercise." These terms were used to screen retrieved articles, and a detailed search strategy is available in the **Underlying Data**. The study also considered relevant systematic reviews and performed a citation-based hand search.

Study selection

Selected studies for inclusion in this review were carefully managed using EndNote 20 (Clarivate, Philadelphia, USA). Duplicate articles were eliminated, as automated deduplication was only partially successful. To ensure accuracy, any remaining duplicates were manually identified. Two independent reviewers, DN and ST, assessed the full-text articles to determine their eligibility.

Eligibility criteria

To be included in this review, studies had to meet specific criteria: participants were older adults over 60 years old with cognitive impairment regardless of setting, interventions included both muscle strengthening and cognitive therapy, there was a comparison group using a single therapy, and outcome measures included falls or balance. Articles without a clinical assessment at baseline were excluded, with priority given to the muscle-strengthening group when selecting comparisons, and data from various healthcare settings were considered.

Data abstraction

Two independent reviewers, DN and ST, independently extracted data from each study, recording details including study location, sample size, age distribution, baseline measurements, intervention protocols, outcomes, results, intervention definitions, and relevant statistical values.

Quality assessment

Study quality was assessed using the Jadad scale, comprising seven items. The first five items indicated good quality, adding one point each to the score, while the remaining two items represented poor quality, deducting one point per item if their criteria were met. The Jadad scale allowed scores between zero to five, with a score of three or higher indicating that an article was of good quality. Consistent scoring by all raters was ensured, irrespective of background and disagreements between reviewers were resolved through discussion and mutual agreement [30].

Statistical analysis

Our meta-analysis assessed the combined impact of muscle strengthening and cognitive therapy on balance, deriving a pooled effect size (ES) from studies that reported balance outcomes. Our analysis encompassed the physical training control group, employing the standard mean difference (SMD) for studies with different measurement scales to facilitate robust research and cross-study comparisons [31,32].

Results

Included studies

A total of 2,120 articles were identified from electronic databases and registers, and another five articles were found through other citations. After removing duplicates and excluding abstracts, non-RCTs, and protocol studies, eleven studies underwent a full-text review from the databases and registers. The PRISMA 2020 flow diagram is depicted in **Figure 1**. In the end, four articles were included in the final analysis. Across these four studies, there were 255 participants with a mean age ranging from 65.9 to 87.5 years old. Two studies were conducted in Europe (the Republic of Slovakia and France) [33, 34], one was conducted in New Zealand [35], and one was conducted in the Philippines [36], representing the Asian region. Most participants were female, and the cognitive status at baseline was measured using the Mini-Mental State Exam (MMSE) and Montreal Cognitive Assessment (MoCA). Only one study reported both fall incidents and balance as outcomes [36], while the other studies focused solely on balance. Three studies used the Timed Up and Go (TUG) test [34-36].

Binns *et al.* [35] was the only study that reported no significant difference between groups at the baseline of a seven-week intervention consisting of one hour of exercise twice a week. Included studies separated the group into two groups: intervention and control groups, as shown by Binns *et al.* [35] and Hagovska *et al.* [33]. In addition, other studies separated the groups into four groups, including physical training, cognitive training, physical-cognitive training, and control groups [34,36].

Quality assessment

The Jadad Scale ratings for the included studies are presented in **Table 1**. All four studies were classified as randomized, and their randomization methods were clearly explained. They specified inclusion criteria and participant selection and diligently randomized and assigned participants to intervention and control groups, although none achieved double-blinding. However, the facilitators were blinded, and participants were free to choose their participation. Q6 and Q7 did not affect the total score, as all studies adequately described their randomization sequences.

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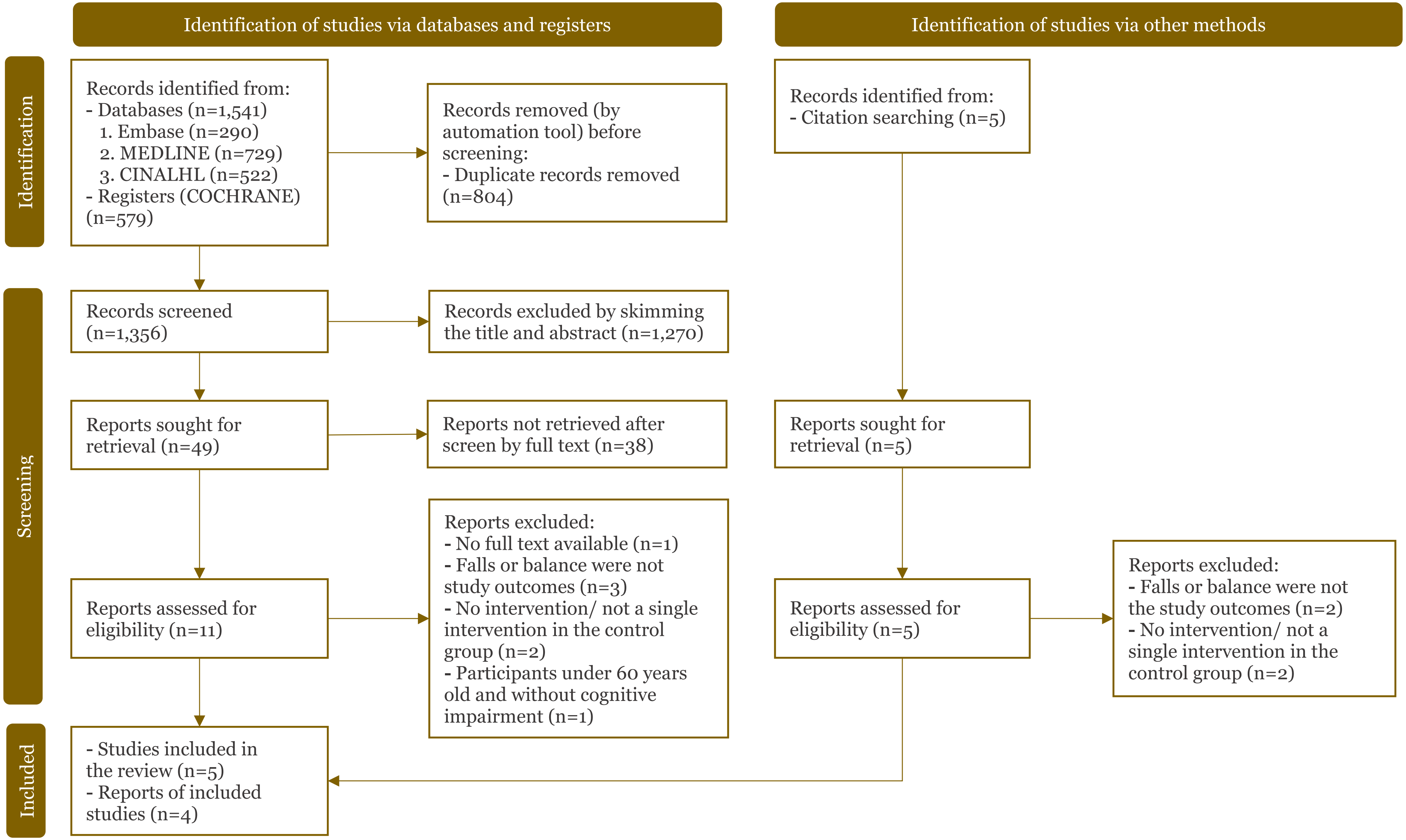

Figure 1. PRISMA 2020 flow diagram.

Table 1. Quality assessment using the Jadad scale

Author, year	The Jadad scale							Quality assessment
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	
Binns E, 2020 [35]	1	1	0	0	1	0	0	3 (Good)
Donnezan C, 2018 [34]	1	1	0	0	1	0	0	3 (Good)
Hagovska M, 2016 [33]	1	1	0	1	1	0	0	4 (Good)
Lipardo D, 2020 [36]	1	1	0	0	1	0	0	3 (Good)

Combined intervention

The combination of physical and cognitive training in each study involved different types of exercises. Two studies used aerobic exercise [34,35], while the other two used balance exercise [33,36]. One study employed a combined intervention called CogEx, which included aerobic exercise, strengthening, balance exercise, and cognitive stimulation therapy (CST) [35]. More specifically, balance training included flexibility, strength, and endurance training. The CST cognitive training included reality orientation, reminiscing, socializing, and active stimulation. Furthermore, cognitive training in the four studies had the same goals: to strengthen memory and orientation. Hagovska *et al.* [33] implemented a training battery called CogniPlus, specially developed for patients with MCI, using a computer program to analyze. The authors faced challenges in implementing muscle strengthening and cognitive therapy, particularly in maintaining fidelity to the research assistant who guided the intervention [35] (**Table 2**).

Each of the studies had a different intervention time. Lipardo *et al.* had the most frequent intervention, with more than 36 sessions during twelve weeks and follow-up until 36 weeks with 60–90 minutes per session [36]. Hagovska *et al.* combined interventions with different frequencies for each type of exercise, namely balance and cognitive exercises. The balance exercise was performed daily for ten weeks, with each session lasting 30 minutes [33]. In contrast, cognitive therapy using battery exercises was conducted twice a week for ten weeks. Binns *et al.* reported insignificant results after the intervention, where the exercise frequency was fourteen sessions over seven weeks, each lasting one hour [35]. Another study by Donnezan *et al.*, which also had a one-hour intervention duration, involved only one weekly session but extended over twelve weeks. However, they observed significant results in each group [34] (**Table 2**).

Fall, balance, and cognitive assessment

In the studies' baseline assessment, participants' cognitive status was measured using the Montreal Cognitive Assessment (MoCA) by Binns *et al.* [35] and Lipardo *et al.* [36], while the Mini-Mental State Exam (MMSE) was used in studies by Donnezan *et al.* [34] and Hagovska *et al.* [33]. The MoCA is widely used to detect mild cognitive impairment. The studies using the MoCA reported lower scores than the two studies that used the MMSE to measure cognitive levels. The average MoCA scores ranged from sixteen [35] to twelve [36], while the average MMSE scores ranged from 28/30 [34] to 25/30 [33] (**Table 2**).

Falls as outcomes were only identified in one study [36]. The Timed Up and Go (TUG) test is a trusted instrument for measuring balance among older adults, as it was applied in three of the four included studies [33, 34, 36]. Only one study used a different instrument to measure balance: Brief BESTest [35]. Other measurements related to muscle strength, flexibility, and fear of falling included the Tinneti performance-oriented mobility, Multi-Directional Reach (MDR) test, and Fall Efficacy Scale (FES) [33]. Further studies by Lipardo *et al.* [36] have used the 10-meter walk test, the 30-second chair stand test, and the TUG test (**Table 2**).

Meta-analysis

A meta-analysis was conducted based on three included studies, with Lipardo *et al.* [36] excluded due to reporting only median values, reflecting a non-normal data distribution. The pooled data from these three studies revealed a significant positive association between the combination of muscle strengthening and cognitive therapy and balance (ES: 2.29; SMD (95%CI): 0.41 (0.66–0.76); $p<0.05$; heterogeneity/I^2: 0%) (**Figure 2**).

Table 2. Characteristics of included articles

Author, year	Country, setting	Participants	Intervention	Duration	Outcomes of interest	Study results
Binns *et al.*, 2020 [35]	New Zealand, resident aged care	IG (n=13) Age: mean (range)=87.5 (81–95) Female=9/13 MoCA: mean±SD=16±4.2 Balance: mean±SD=2.4±1.6 CG (n=10) Age: mean (range)=83.6 (71–95) Female=8/10 MoCA: mean±SD=18.0±5.6 Balance: mean±SD=2.4±1.4	IG: CogEx (aerobic exercise, strengthening, balance exercise) plus CST CG: CST (reality orientation, reminiscing, socializing, and actively stimulating)	One hour twice a week for seven weeks (14 sessions)	1. Cognition: MoCA, ADAS-Cog11 2. Balance: Brief BESTest 3. Functional mobility: SPPB	No difference between groups at baseline or after seven weeks
Donnezan *et al.*, 2018 [34]	France, specialist clinic	G1 (n=14) Age; mean±SD=77.1±1.44 MMSE: mean±SD=28.2±1.46 TUG: mean±SD=9.96±1.75 G2 (n=14) Age: mean±SD=76.3±1.5 MMSE: mean±SD=27.3±0.42 TUG: mean±SD=10.24±2.68 G3 (n=20) Age: mean±SD=75.2±1.3 MMSE: mean±SD=28.1±1.36 TUG: mean±SD=12.79±2.17 G4 (n=14) Age: mean±SD=79.2±4 MMSE: mean±SD=27.3±0.5 TUG: mean±SD=11.65±2.04	G1. PT: Aerobic training on a bike G2. CT: Working memory, mental flexibility, inhibition, reasoning, and updating using commercialized gaming software G3. Combined simultaneous PACT: Combination of CT and PT G4. CG: Usual lifestyle	One-hour session per week over 12 weeks.	Executive measures 1. The flexibility part of the Stroop Color Word test 2. DSF 3. DSB Motor measures 1. TUG test 2. Single-task walking (normal environment & electronic walkway) 3. WSC 4. Dual-task walking condition	- The PT group improved in two measures (cognitive and motor) - The CT group improved only in one cognitive measure - The PACT group improved in eight measures, including both cognitive and motor
Hagovska *et al.*2016 [33]	Republic of Slovakia, outpatient psychiatric clinic	IG (n=40) Age: mean±SD=68±4.4 Female=18/40 MMSE: mean±SD=25.97±2.57 TUG: mean±SD=10.02±2.82 FES: mean±SD=18.67±15.6 CG (n=38) Age: mean±SD=65.9±6.2 Female: 21/38 MMSE: mean±SD=26.02±1.47 TUG: mean±SD=9.09±2.12 FES: mean±SD=15.40±8.63	IG: Combined cognitive training battery (attention, working memory, long-term memory, executive functions, visuomotor coordination, spatial processing) and balance training (walk over obstacles, walk with direction, walk with load, walk up and down the stairs) CG: Standard intervention	30 minutes, 10 weeks (total 20 sessions)	Assessment of the fear of falling, balance, and mobility: 1. FES 2. Tinetti performance-oriented mobility assessment 3. TUG 4. Multi-directional reach test	All measures improved significantly when compared within groups

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Author, year	Country, setting	Participants	Intervention	Duration	Outcomes of interest	Study results
Lipardo *et al.*, 2020 [36]	The Philippines, community-dwelling older person	PACT (n=23) Age (median): 67 Female: 16/23 MoCA: mean±SD=17.5±4.7 TUG: mean±SD=10.7±2.8 PT (n=23) Age (median): 73 Female=22/23 MoCA: mean±SD=17.0±4.1 TUG: mean±SD=10.6±3.0 CT (n=23) Age (median): 68 MoCA: mean±SD=20.4±4.9 TUG: mean±SD=9.1±3.0 WG (n=23) Age (median): 68 MoCA: mean±SD=18.3±4.1 TUG: mean±SD=10.6±4.0	PACT: Combination of physical and cognitive training PT: Balance, strength, endurance, and flexibility CT: Paper-based cognitive exercise on executive function, memory, attention, and orientation training WG: Usual activity	Three times per week over 12 weeks with 60-90 minutes per session	1. Fall incidence 2. PPA-short form 3. TUG test 4. The 10-meter walk test 5. The 30-second chair stand test	- No significant difference in fall incidence among the groups at 12 weeks (p=0.152) and 36 weeks (p=0.954) - The combined physical and cognitive training group had a statistically significant reduction in overall fall risk from baseline to 12 weeks (p=0,009) and from baseline to 36 weeks (p=0.001)

ADAS-Cog11: Alzheimer's disease assessment scale-cognitive; Brief BESTest: brief balance evaluation systems test; CG: control group; CogEx: cognitive exercise; CST: cognitive stimulation therapy; CT: cognitive training; DSB: digit span backward test; DSF: digit span forward test; IG: intervention group; MoCA: Montreal cognitive assessment; PACT: physical and cognitive training; PPA: physiological profile assessment; PT: physical training; QOL-AD: quality of life-Alzheimer's disease; RAC: residential aged care; SPPB: short physical performance battery; TUG: the timed up and go test; WG: waitlist group

The absence of heterogeneity among the included studies, indicated by the I^2 value and the low *p*-value, suggests that the observed effect size is not likely due to chance alone. This implies that the combined interventions had a meaningful impact. The SMD of 0.41 represents a moderate effect size, and the studies included in the analysis consistently demonstrate similar results without significant heterogeneity.

Figure 2. Meta-analysis of the included studies.

Discussion

This review confirmed that combining physical and cognitive exercises effectively improves balance in older adults with cognitive impairment, aligning with previous findings [37,40] that identified poor balance and cognitive impairment as key predictors for falls. The combination of these two interventions precisely addressed the two primary risk factors associated with falls, as underscored by previous studies [22,23,37]. Physical exercise effectively addressed issues related to balance, muscle strength, flexibility, and endurance in older adults. Cognitive decline in older adults was occasionally considered a normal part of aging. However, cognitive impairment occurred due to pathological conditions stemming from central nervous system damage. Cognitive impairment in older adults often leads to mobility issues and reduced daily activity abilities [16], highlighting the potential for combining these interventions to address this population's fall risk associated with gait and balance disorders. The combination of these two interventions was not included in the multiple/multi-component or multifactorial interventions in fall prevention programs, as can be clearly understood from the provided definition [27]. Multi-component and multifactorial interventions had not been able to provide clear evidence about their effectiveness in reducing the incidence of falls or other related measurements [27]. Dual exercise, namely physical and cognitive, appeared more rational and sustainable for older people in communities and hospitals, especially residents in institutions or nursing homes.

Physical exercise interventions aimed at preventing falls encompass various activities. The findings of this review suggested that such activities as balance exercises and cognitive training focused on memory and orientation. Cognitive training, whether technology-based or traditional card-based methods, could enhance memory among older adults [33,36]. The training began with orienting participants regarding the activity's time, place, and purpose, then introducing participants to the group members before the main activity. Furthermore, interventions should have consisted of more than 14 sessions (twice a week), each lasting at least 60 minutes to achieve significant results. A higher training frequency has been linked to more noticeable improvements [38]. While some older adults may have viewed physical exercise as unnecessary or potentially harmful, others recognized its benefits [39]. According to older adults, several factors should be considered to encourage their participation in exercise. These factors include: first, explaining the benefits of the planned physical exercises; second, improving the exercise environment and financial accessibility; and third, considering the exercise's intensity, volume, and duration [11,39].

Implementing physical and cognitive training in healthcare requires trained staff and adherence to institutional regulations. The authors encountered difficulties maintaining fidelity to the research assistant who guided the intervention [35]. To ensure the safety and effectiveness of exercise or cognitive training interventions, qualified trainers or instructors should offer proper guidance and supervision [40,41]. Establishing a team of trained staff capable of facilitating the program before implementation was vital. Research on fall prevention programs in older adults with cognitive impairment faced challenges in using the number of falls as an outcome due to difficulties in monitoring and recording these events. Instead, balance status was commonly employed as a research outcome in this area because self-reporting of falls is subjective and often underreported, potentially leading to inaccurate fall rate representations [42, 43]. Balance served as a vital indicator for predicting falls in older individuals, as identified in prior research [14,44]. The TUG test, a simple and easily accessible assessment, was frequently used for fall prediction [8,37]. Additionally, the Balance Berg Scale (BBS), with its 14 assessment items, demonstrated an 89% sensitivity in predicting falls among older adults [8]. Relying on a single assessment tool to gauge fall risk was limited due to the variations in older adult service settings [45,46]. Utilizing multiple assessment tools that accurately measure outcomes in fall prevention among older adults with cognitive impairment can significantly enhance the effectiveness of fall prevention programs [47].

Assessing the cognitive status of older adults at baseline provided valuable insights into their health conditions and self-awareness, contributing to a broader understanding of general risk factors. However, there was a lack of a clear definition for criteria related to cognitive impairment. Various instruments, such as MMSE and MoCA, were used in the included studies to identify participants with mild cognitive impairment (MCI) or cognitive impairment without dementia. Determining the status of older adults with MCI remained a complex challenge, necessitating a more comprehensive, multidisciplinary approach to establish objective outcomes and fall assessments for this group [48].

This study employed rigorous methods, including independent double-screening of initial results, considering previous systematic reviews in the field, and examining reference lists of eligible papers. These approaches provide high confidence that all relevant studies were included. The quality assessment of the included studies reached a consensus among the two independent reviewers. However, the review also has several limitations. The small number of participants in each study means that the resulting conclusions still need to be proven in a larger population. That also means not all the studies can be included in the meta-analysis because they had different statistical analyses. Although the four studies implemented a combination of both interventions, the diversity of activities, duration, and other techniques makes it difficult to generalize and recommend the best combination of interventions.

Conclusion

Engaging in physical exercise and cognitive training offers significant benefits in maintaining the well-being of older adults with cognitive impairment, particularly in preventing falls. The pooled effect estimates indicate the effectiveness of combining these interventions. The duration of the intervention and the presence of qualified facilitators play a crucial role in achieving positive outcomes. Future research should focus on obtaining data from randomized controlled trials with more significant participant numbers to investigate this research topic further.

Ethics approval

Not required.

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Competing interests

All the authors declare that there are no conflicts of interest.

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Underlying data

Derived data supporting the findings of this study are available at the following link https://doi.org/10.6084/m9.figshare.26927068.

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