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Review

Effect of combined physical and cognitive intervention on fear of falling in older adults: A systematic review and meta-analysis

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HIGHLIGHTS

- The combined physical and cognitive intervention had a small to moderate immediate effect on FOF among older adults compared with blank/placebo/usual control.
- The combined intervention can provide additional immediate benefits than the single cognitive intervention.
- The immediate effect of combined interventions is not preferable to the single physical intervention.
- No effect was found in a long-term retention effect of combined interventions on reducing FOF.

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ABSTRACT

Objective: Fear of falling (FOF) is common among older adults. Currently, physical exercise, cognitive intervention, and combined physical and cognitive intervention have been proven to be effective interventions. However, whether combined interventions can provide additional benefits than single interventions remains unclear. Thus, the systematic and meta-analysis was conducted to explore the immediate and retention effects of combined physical and cognitive interventions, in comparison with a single intervention.
Materials and methods: Randomized controlled trials of combined interventions on FOF in older adults were searched using Web of Science, PubMed, Cochrane Library, EMBASE, SCOPUS, CINAHL, and PsycINFO from inception to March 20, 2023. The risk of bias in included studies was evaluated using the Cochrane Collaboration Risk of Bias tool. Two independent researchers extracted the data using predetermined criteria.
Results: 31 studies were included in the systematic review and meta-analysis. For the immediate post-intervention effect, the combined intervention was more effective than the blank/placebo/conventional intervention and the single cognitive intervention, while no additional effect was observed compared with the single physical intervention. Moreover, no additional follow-up retention effects were found when comparing the combined intervention with the single intervention.
Conclusions: Combined interventions had positive immediate effects on FOF in older adults, compared with single cognitive intervention, while combined interventions had a similar effect as a single physical intervention. More well-designed studies are required to explore the additional benefits of combined interventions compared with a single intervention and to investigate the follow-up effects of combined interventions.

1. Introduction

Fear of falling (FOF) is defined as continuing concern about falling that causes individuals to avoid daily activities that they could be capable of performing(Tinetti & Powell, 1993). FOF is a common problem in older adults with a prevalence of 20–85%(Scheffer et al., 2008) and is associated with falls(Gambaro et al., 2022; Lavedan et al., 2018), poor quality of life(Scheffer et al., 2008), late-life depression (Gambaro et al., 2022; Yao et al., 2021), functional decline(Martin et al., 2005), balance impairment(Li et al., 2003), and mortality(Chang et al., 2017). FOF can be attributed to many factors(Dos et al., 2023; Park & Kim, 2022), such as age, female, comorbidity, worse self-rated health, physical performance, and cognitive ability. Thus, developing intervention strategies that target modifiable risk factors is vital to improving

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FOF in older adults.

Previous studies have already conducted different types of interventions to decrease FOF in older adults with exercise and cognitive intervention being the two most common interventions(Kruisbrink et al., 2021). Physical exercise can enhance muscle strength, walking ability, and balance performance(Salbach et al., 2005; Sherrington et al., 2008). A systematic review and meta-analysis of randomized controlled trials indicated exercise interventions had a small to moderate effect on improving FOF (standardized mean difference (SMD): 0.37, 95% CI 0.18–0.56)(Kumar et al., 2016). In addition, other studies have shown the benefits of cognitive interventions, including cognitive behavior therapy (CBT)(Liu et al., 2018) and cognitive training (CT)(Spano et al., 2022; Yoon et al., 2013), in reducing FOF in older adults.

The study has shown that risk factors for FOF are multidimensional (McAuley et al., 1997), interventions therefore that address factors in multiple domains are theoretically likely to reduce FOF in older adults to a greater extent(Vliek et al., 2008). On the other hand, due to the complexity of the combined physical and cognitive intervention, which can be difficult tasks for frail older adults, positive effects may not be observed compared with single interventions. Currently, a systematic review and meta-analysis has shown that physical combined with cognitive interventions can reduce FOF (Chua et al., 2019), but whether combined interventions can provide additional benefits than single interventions is controversial. Several studies indicated that combined interventions were preferable to single interventions(de Bruin et al., 2013; Liu et al., 2019), while other studies were not observed similar results(de Oliveira et al., 2021; Justina & Man, 2014; Turunen et al., 2022). Given the high cost and complexity of designing, analyzing, and implementing combined interventions(Vliek et al., 2008), evaluating and synthesizing the effects of combined interventions on reducing FOF is essential, when compared to single interventions. At present, however, no systematic review and meta-analysis has been conducted to explore the effect of combined interventions by contrast with single interventions.

Thus, the aims of this systematic review of randomized controlled trials are to investigate: (1) the immediate post-intervention and follow-up retention effects of combined physical and cognitive intervention, compared to a single intervention (physical or cognitive intervention), on fear of falling in older adults; (2) the effect size of combined interventions on reducing FOF, in comparison with conventional intervention, placebo control, blank control, or wait-list control.

2. Method

This systematic review and meta-analysis was registered on the PROSPERO (registration number: CRD42023425764) and followed the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines(Moher et al., 2009).

2.1. Search strategy

The PICO (Population, Intervention, Comparison, and Outcome) principle was performed to conduct the systematic search. Based on PICO principles, we retrieved in databases including Web of Science, PubMed, Cochrane Library, EMBASE, SCOPUS, CINAHL, and PsycINFO using the combination of MESH terms, free-text terms, and truncation retrieval from the inception to March 20, 2023. More detailed search strategy can be seen in Supplementary Material.

2.2. Inclusion criteria

2.2.1. Types of participants

Older adults aged 60 years or older, with no restrictions on location (e.g. community, hospitalization, or institution) were included in the analyses. Older adults with mild cognitive impairment (MCI) often have abnormalities in learning and memory functions, as well as executive functions (Guo et al., 2023). MCI is an intermediate condition between the normal cognitive state and dementia (Roberts & Knopman, 2013), and is not believed to affect the daily lives and communication abilities of older adults. Additionally, MCI is associated with FOF in older adults (Uemura et al., 2014). Therefore, participants with cognitive impairment were not excluded.

2.2.2. Types of interventions

The intervention must be the combination of cognitive intervention and physical training. Physical training can be any form of exercise, such as balance training, resistance training, aerobic training, strength training, Tai Chi and so on. Cognitive intervention includes cognitive therapy, cognitive behavioral therapy, and cognitive training, interventions that fit any of the above three formats, can be considered as cognitive intervention.

2.2.3. Types of comparators

The comparators can be any of the following types: single physical intervention, single cognitive intervention, conventional intervention(e.g. various forms of health education, such as lectures, brochures), placebo control, blank control or wait-list control.

2.2.4. Types of outcomes

Trials that measured FOF were included. Falls Efficacy Scale(Tinetti et al., 1990), Falls Efficacy Scale-International(Yardley et al., 2005), Activities-specific Balance Scale(Powell & Myers, 1995), and other scales that had been validated were considered accepted measurements.

2.2.5. Types of study design

Randomized controlled trails (RCTs) published in English were included.

2.3. Exclusion criteria

The exclusion criteria were the following: (1) review articles, protocol papers, conference abstracts, and case report; (2) data unavailable; (3) duplicate publications.

2.4. Data extraction

Two authors independently extracted data from studies that meet the inclusion criteria, and disagreements were resolved by the third author. The following information was extracted: the first author, year of publication, the country the study was conducted in, number of participants enrolled in the study, mean age, gender, type of the intervention, frequency of the intervention, duration of the intervention, follow-up period, and measurement scales.

2.5. Quality assessment

Two authors independently assessed the risk of bias of the included study according to the Cochrane Collaboration Risk of Bias tool (Cumpston et al., 2019), including selection bias(random sequence generation and allocation concealment), performance bias, detection bias, attrition bias, reporting bias and other bias. Each domain is classified as“low risk of bias”,“high risk of bias”, “unclear risk of bias”for each study by two authors. Disagreements were solved by the third author.

2.6. Statistical analysis

The comparisons of meta analysis include the combined intervention vs. conventional/placebo/blank/wait-list control, the combined intervention vs. single physical intervention, the combined intervention vs. single cognitive intervention. For meta-analysis, the outcome data are extracted in the form of means, standard deviations and the number of participants in each group. When the higher score represents the greater FOF, the mean is multiplied by −1 to ensure that score is in the same direction. We report continuous outcomes as mean difference (MD) or standardized mean difference (SMD) with 95% Confidence Intervals (CI), if the same scale or different scales are used, respectively. For SMD, 0.2 represents a small effect, 0.5 represents a medium effect, and 0.8 represents a large effect(COHEN, 1962).

Heterogeneity of trials are assessed with the chi-squared test and I^2 statistics. If $P \geq 0.1$ and $I^2 \leq 50\%$, we select the fixed effect model. If $P < 0.1$ and $I^2 > 50\%$, it indicates that there is high heterogeneity between studies(Higgins et al., 2003), the random effect model is used and we conduct a subgroup analysis to explore sources of heterogeneity. Sources of heterogeneity are mainly divided into methodological heterogeneity and clinical heterogeneity, including differences in study design, participants, interventions, exposures, and outcomes(Higgins & Thompson, 2002). Thus, a series of subgroup analyses are conducted according to FOF outcome measures, the place where older adults live (community-dwelling or not), length of the intervention (≤8 weeks,>8 weeks), type of cognitive intervention, the trial was registered or not, and the number of groups in the randomized controlled trial. Sensitivity analyses using the leave-one-out method are performed to confirm the consistency of the effect size. In addition, the study with low risk of bias in three domains (random sequence generation, allocation concealment, and missing participant outcome data) is categorized as having low overall risk of bias (Karam et al., 2023). In order to ensure the reliability of the results, we conduct sensitivity analyses of the trials with low overall risk of bias. The funnel plot and Egger's test(Egger et al., 1997) are used to evaluate publication bias. All analyses are performed using Review Manager 5.4.0 and Stata 17.0.

3. Results

3.1. Study selection

The flow diagram of study selection is shown in Fig. 1. A total of 2760 articles were retrieved from the seven databases. 117 articles remained after removal of duplicates and screening of titles and abstracts. After screening the full-text articles, 31 articles were included in systematic review and 27 were included in meta analysis. Four articles were not included in the Meta-analysis because two articles were not full data available(Kraiwong et al., 2021; Wetherell et al., 2018) and two articles with small sample sizes were reported in median/quartiles(Broscheid et al., 2020; Maria et al., 2021).

3.2. Study characteristics

The main characteristics of the 31 included studies are presented in Table 1. Among these articles, four articles were conducted in China (Huang et al., 2016, 2011; Justina & Man, 2014; Liu et al., 2019), three in Switzerland(de Bruin et al., 2020, 2013; Pichierri et al., 2012), three in Netherlands(Dorresteijn et al., 2016; Scheffers-Barnhoorn et al., 2019; Zijlstra et al., 2009), three in Brazil(de Oliveira et al., 2021; Gomes et al., 2018; Maria et al., 2021), three in Turkey(Uzunkulaoglu et al., 2020; Karagul & Kartaloglu, 2023; Akin et al., 2021), two in Germany(Broscheid et al., 2020; Freiberger et al., 2012), two in Australia(Callisaya et al., 2021; Schoene et al., 2015), two in USA (Wetherell et al., 2018; Plummer-D'Amato et al., 2012), two in Slovakia (Hagovska & Olekszyova, 2016; Mihalova et al., 2022), two in multiple countries (Barban et al., 2017; Reve & de Bruin, 2014), and the others were single studies conducted in different countries. The publication years of 31 eligible articles ranged from 2009 to 2023. Five articles were published in 2021(Akin et al., 2021; Callisaya et al., 2021; de Oliveira et al., 2021; Kraiwong et al., 2021; Maria et al., 2021), accounting for the highest proportion.

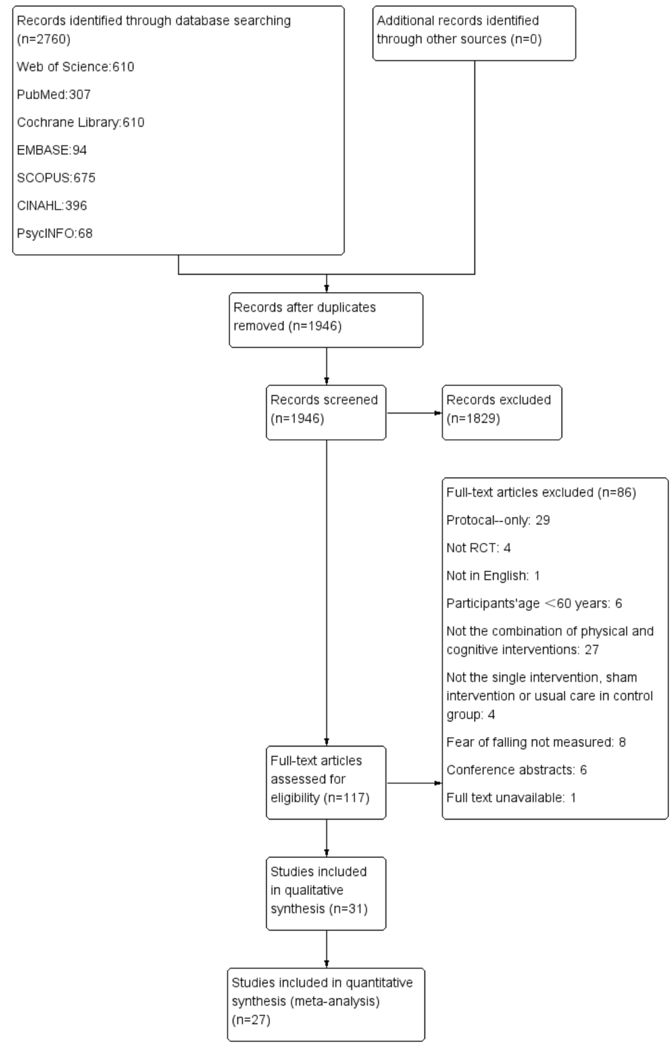

Fig. 1. PRISMA flow diagram of study selection.

3.2.1. Participants

A total of 3366 participants were included in this systematic review. Of the 28 articles that reported the percentage of females, 21 had greater than 50%. Among the 31 eligible articles, sample sizes varied from 13 to 540. The mean age of the participants ranged from 60 to 88 years, except for two studies, which did not report an exact mean age(Huang et al., 2011; Maria et al., 2021). Nine studies recruited participants with history of falls or FOF(Arnold et al., 2011; Barban et al., 2017; Dorresteijn et al., 2016; Freiberger et al., 2012; Justina & Man, 2014; Liu et al., 2019; Scheffers-Barnhoorn et al., 2019; Wetherell et al., 2018; Zijlstra et al., 2009), three studies with balance limited(Kraiwong et al., 2021; Mihalova et al., 2022; Uzunkulaoglu et al., 2020), three studies with cognitive impairment(Callisaya et al., 2021; Hagovska & Olekszyova, 2016; Yoon et al., 2013), two studies with lumbar spinal stenosis (Broscheid et al., 2020; Karagul & Kartaloglu, 2023), and one each with frailty/pre-frailty(Gomes et al., 2018) and hip osteoarthritis(Arnold et al., 2011).

3.2.2. Interventions

21 studies conducted combined interventions of physical exercise and cognitive training, nine studies adopted combined physical exercise and cognitive behavior intervention (CBI), and one was physical exercise, cognitive training plus CBI. The main components of cognitive training included memory training, attention training, and executive function training, while the CBI included cognitive restructuring, goal

Table 1
The characteristics of eligible studies ($n = 31$) included in a systematic review and meta-analysis.

The first author	Publication year	Country	Sample size (% female)	Mean age (SD)	Control group	Intervention group	duration of the intervention	frequency of the intervention	Follow-up time	Measurement tools
Karagul	2023	Turkey	43(49)	68.98 (3.05)	BT	BT + CT	4 weeks	3 times per week	—	ABC
Katri	2022	Finland	314(38)	74.45 (3.79)	AT + RT + BT	AT + RT + BT + CT	12 months	PT:2–3 times per week; CT:3–4 times per week	12 months	FES-I
Mihalova	2022	Slovakia	80(100)	75.5 (8.87)	PT	PT + pelvic floor muscle training + CT	12 weeks	2 times per week	—	FES
Javadpour	2022	Iran	69(71)	68.6 (3.3)	BT; blank control	BT + CT	6 weeks	3 sessions per week	—	ABC
De Oliveira	2021	Brazil	50(88)	68.3 (5.58)	ST	ST + CT	24 weeks	3 times per week	—	FES-I
Kraiwong	2021	Thailand	37(78)	71.22 (5.43)	HE	AT + RT + CT	8 weeks	3 sessions per week	12 months	FES-I-Thai
Callisaya	2021	Australia	93 (58.1)	72.8 (7)	HE	BT + ST +CT	6 months	120 min per week	—	ABC
Akin	2021	Turkey	50(38)	67.72 (7.33)	motor–motor DTT	motor-cognitive DTT	8 weeks	—	—	FES-I
Maria	2021	Brazil	16(88)	—	ST + BT	ST + BT + CT	6 weeks	3 times per week	—	FES-I-Brazil
Broscheid	2020	Germany	18(72)	71.5 (11.7)	PT	PT + CT	6 weeks	2 times per week	—	SFES-I
de Bruin	2020	Switzerland	17(59)	88.08 (6.1)	sham intervention	PT+ CT	8 weeks	3 times per week	4 weeks	FES-I
Uzunkulaogl	2020	Turkey	50(68)	72.95 (5.53)	BT	BT + CT	4 weeks	3 times per week	—	ABC
Scheffers-Barnhoorn	2019	Netherlands	77(79)	82.5 (7.6)	usual care	PT + CBT	discharge		3 months & 6 months	FES-I
Liu	2019	China	89(40)	60.47 (5.73)	HE + ST + BT	ST + BT + CBT	8 weeks	2 times per week	3 months &12 months	ABC
Wetherell	2018	USA	42(74)	77.9 (7.35)	HE	HE + CBT + ST + BT	8 weeks	once per week	—	SFES-I
Gomes	2018	Brazil	30(93)	84 (6.01)	HE	CT + PT	7 weeks	2 times per week	30 days	FES-I
Barban	2017	Italy, Greece, Spain & Serbia	481(65)	75.03 (8.14)	PT; CT; active control	PT + CT	3 months	2 times per week	3 months	FES-I
Huang	2016	China	75(48)	79.58 (6.6)	routine care; CBT	CBT+ PT	8 weeks	2 times per week	3 months	FES
Hagovska	2016	Slovakia	80(49)	66.95 (5.45)	BT	CT + BT	10 weeks	2 times per week	—	FES-I
Dorresteijn	2016	Netherlands	389(70)	78.31 (5.34)	usual care	CBT + PT	4 months	—	1 months & 8 months	FES-I
Schoene	2015	Australia	90(66)	81.52 (6.98)	brochure	cognitive-motor training	16 weeks	3 sessions per week		Icon-FES
Justina	2014	China	122(87)	74.51 (7.28)	Tai Chi	Tai Chi + CBT	8 weeks	—	2 months	CFES-I
Reve	2014	Switzerland&Germany	145(70)	81.52 (7.31)	ST + BT	ST + BT +CT	12 weeks	SB: 2 times per week CT: 3 times per week	—	FES-I
de Bruin	2013	Switzerland	13(62)	77.2 (7.74)	ST + BT	PT + CT	12 weeks	ST: 2 times per week CT: 3–5 times per week	—	FES-I
Yoon	2013	Korea	20(-)	74.39 (10.4)	PT	CT + PT	12 weeks	3 times per week	—	MFES
Pichierri	2012	Switzerland	22(—)	86.2 (4.6)	ST + BT	cognitive-motor exercise training	12 weeks	2 times per week	—	FES-I
Plummer-D'Amato	2012	USA	17(94)	76.64 (5.58)	BT	CT +BT	4 weeks	once per week	—	ABC

(continued on next page)

Table 1 (*continued*)

The first author	Publication year	Country	Sample size (% female)	Mean age (SD)	Control group	Intervention group	duration of the intervention	frequency of the intervention	Follow-up time	Measurement tools
Freiberger	2012	Germany	153(45)	76.23 (4.23)	blank control	ST + BT + CT + CBT	16 weeks	2 times per week	2 months, 8 months &20 months	ABC
Huang	2011	China	176(59)	—	blank control; CBT	CBT + Tai Chi	8 weeks	5 times a week	3 months	FES
Arnold	2011	Canada	54(—)	73.78 (6.2)	aquatic fitness class	BT + ST+ CBT	11 weeks	exercise: 2 times per week CBI: once per week	—	ABC
Zijlstra	2009	Netherlands	540(72)	77.9 (4.79)	usual care	CBT + stretching and flexing exercises + ST	2 months	once per week	6 months &12 months	MFES

Abbreviation:
Intervention type: AT: aerobic training; BT,balance training; CBT: cognitive behavior training; CT: cognitive training; HE: health education; PT: physical training; RT: resistance training; ST, strength training;
Scale: ABC, the Activities-specific Balance Confidence Scale; FES, the Falls Efficacy Scale; MFES,the Modified Falls Efficacy Scale; FES-I,the Falls Efficacy Scale International; CFES-I, the Chinese version of the Falls Efficacy Scale International; SFES-I, the short Falls Efficacy Scale–International;
—: No data available.

setting, and behavior change. For physical exercise, only 7 trials were the single exercise intervention, 4 trials were dual-task training, 2 studies did not provide a specific description of the intervention, and the remaining were combined physical interventions. Balance training accounted for the largest proportion of all exercise interventions, followed by strength training with 17 and 15 articles, respectively. In order to maximize the effectiveness of interventions, more targeted studies are needed in the future to explore which interventions contribute the most to reducing the fear of falling in older adults.

The duration of the intervention ranges from 4 to 52 weeks, except for one study, which regards the length of hospitalization as the duration of intervention. 13 studies conducted post-intervention follow-up ranged from 1 to 20 months to explore the retention effects of the intervention, with seven studies reporting short-term (≤6 months) effects only, two studies reporting long-term (>6 months) effects only, and four reporting both short-term and long-term effects.

3.2.3. Comparisons

Of 27 trials with two intervention arms, 16 trials adopted physical exercises in control group, eight trials were conventional intervention, and one each was the cognitive intervention, sham intervention, and blank control. The control group of three trials with three arms were blank control and physical intervention, conventional intervention and CBI, and blank control and CBI, respectively. One trial was a four-arm design with control groups of blank control, physical exercise, and cognitive training.

3.2.4. Outcomes

The 31 eligible studies had a wide variety of measurements. 15 studies adopted FES-I to assess FOF, and three of which used the Chinese version, the Brazilian version, and the Thai version of the FES-I, respectively. Eight studies adopted ABC scale, three studies adopted FES, two studies adopted the modified version of FES, two studies adopted the short version of the FES-I and the remaining one study used Icon-FES.

3.3. Risk of bias

The risk of bias of included studies is shown in Supplementary Material, Figs. S1 and S2. For the selection bias, 27 studies reported random sequence generation, and 25 studies reported allocation concealment. 22 studies were assessed at low risk of detection bias, 23 studies were judged as being low risk of attrition bias and 30 studies were judged as being low risk of reporting bias. However, only four studies had low risk of performance bias because blinding participants and researchers simultaneously was difficult.

3.4. Immediate post-intervention effects of combined interventions on FOF

3.4.1. Combined intervention vs. blank/placebo/conventional intervention

A total of nine trials, including 1201 participants, reported the effect of combined intervention on FOF compared with blank/placebo/conventional intervention. The results of meta-analysis are shown in Fig. 2, FOF was significantly improved in the combined intervention group (SMD = 0.37, 95% CI 0.14–0.60, *P* = 0.001). There was considerable heterogeneity among the included trials (χ^2 = 21.44, I^2 = 63%, *P* = 0.006).

3.4.2. Combined intervention vs. cognitive intervention

Four trials, consisting of 426 older adults, reported the effect of combined intervention group on FOF compared with single cognitive intervention group. As shown in Fig. 3, a fixed effects model was used because I^2 < 50% and *P* < 0.1. The results showed that the combined intervention was more effective in improving FOF in comparison with cognitive intervention (SMD = 0.20, 95% CI 0.01–0.39, *P* = 0.04).

3.4.3. Combined intervention vs. physical intervention

Seventeen trials, including 1456 older adults, compared the effect on FOF between the combined intervention and single physical intervention. The results are presented in Fig. 4. Compared with physical intervention, the pooled effect size indicated that there was no effect of the combined intervention on FOF (SMD = −0.09, 95% CI −0.27–0.08, *P* = 0.29) with significant heterogeneity (χ^2 = 39.07, I^2 = 56%, *P* = 0.002).

3.5. Short-term(≤6 months) and long-term(>6 months) retention effects of combined interventions on FOF

As shown in Fig. 5, in contrast with blank/placebo/conventional intervention, there was an edge effect (SMD = 0.28, 95% CI 0.00–0.57,

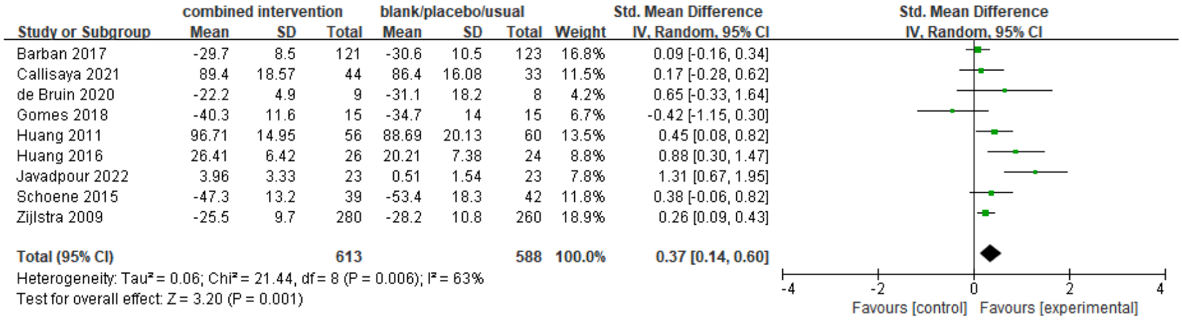

Fig. 2. Forest plot of the immediate effect of the combined intervention on FOF in older adults compared with the blank/placebo/conventional intervention.

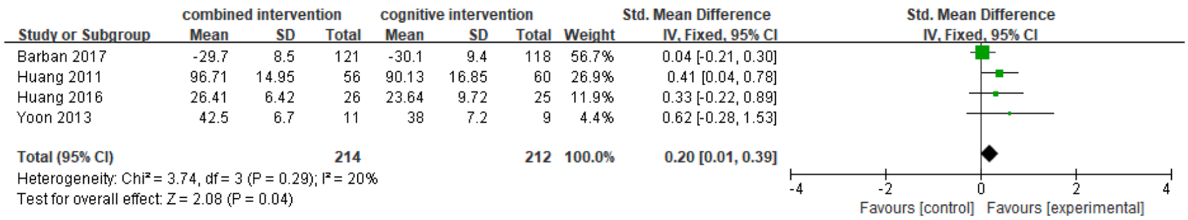

Fig. 3. Forest plot of the immediate effect of the combined intervention on FOF in older adults compared with the single cognitive intervention.

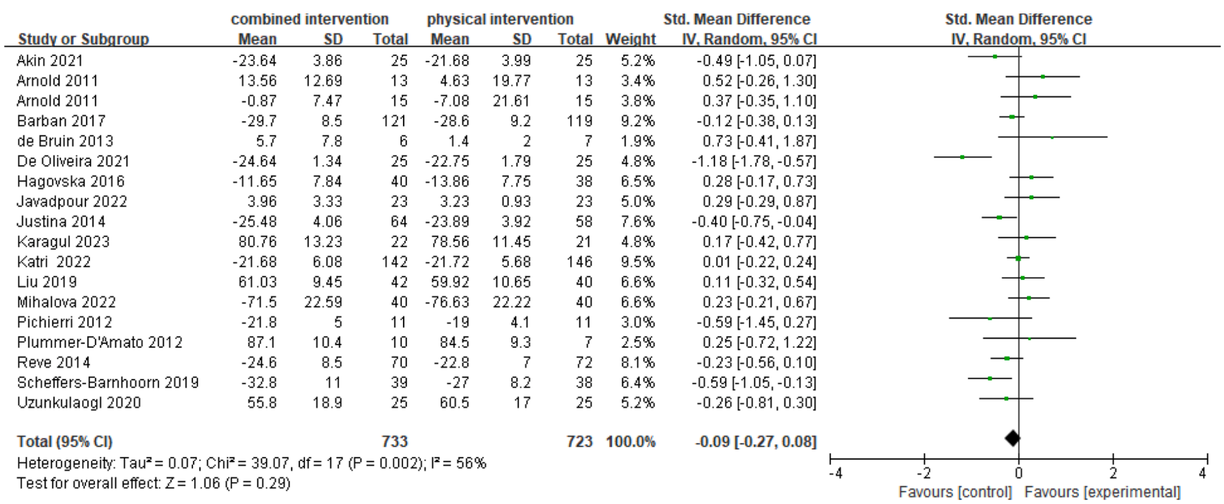

Fig. 4. Forest plot of the immediate effect of the combined intervention on FOF in older adults compared with the single physical intervention.

$P = 0.05$) of combined intervention on FOF in a short-term follow-up. However, no significant long-term retention effect (SMD = 0.08, 95% CI −0.18–0.34, $P = 0.53$) was observed between two groups. Figs. 6 and 7 showed the short-term and long-term retention effects of combined interventions on FOF, compared with single cognitive intervention, and single physical intervention, respectively. The results revealed that there were no differences between the combined intervention and single intervention group (SMD = 0.45, 95% CI −0.23–1.13, $P = 0.20$; SMD = −0.02, 95% CI −0.17–0.13, $P = 0.81$).

3.6. Subgroup analyses

Due to the high heterogeneity, subgroup analyses were conducted in the meta-analysis of combined intervention vs. blank/placebo/conventional intervention and combined intervention vs. single physical intervention. As shown in Supplementary Material, Fig. S3, the results suggested that the effect of combined intervention group on FOF did not differ by the FOF outcome measures ($\chi^2 = 4.24$, df = 4, $P = 0.37$), community-dwelling or not ($\chi^2 = 1.08$, df = 1, $P = 0.30$), type of cognitive intervention ($\chi^2 = 0.19$, df = 1, $P = 0.67$), the trial was registered or not ($\chi^2 = 0.03$, df = 1, $P = 0.86$), and the number of intervention arms ($\chi^2 = 2.02$, df = 1, $P = 0.16$). Length of intervention≤eight weeks (SMD = 0.63, 95% CI 0.26–1, $P = 0.0008$) significantly improved FOF compared to length of intervention>eight weeks (SMD = 0.12, 95% CI −0.09–0.34, $P = 0.27$). The effect of combined intervention varied by the FOF outcome measures, compared with physical intervention ($\chi^2 = 7.89$, df = 2, $P = 0.02$; please see Figure S4, in the supplementary material). Measured by FES-I scale, single physical interventions had a better improvement than combined interventions (SMD = −0.27, 95% CI −0.50–−0.04, $P = 0.02$). However, no significant difference was found (SMD = −0.06, 95% CI −0.23–0.12, $P = 0.53$; please see Fig. S5, in the supplementary material) when the changes of mean and SD were extracted to calculate SMD.

3.7. Sensitivity analyses

Sensitivity analyses, conducted in the meta-analyses of combined intervention vs. blank/placebo/usual control and combined

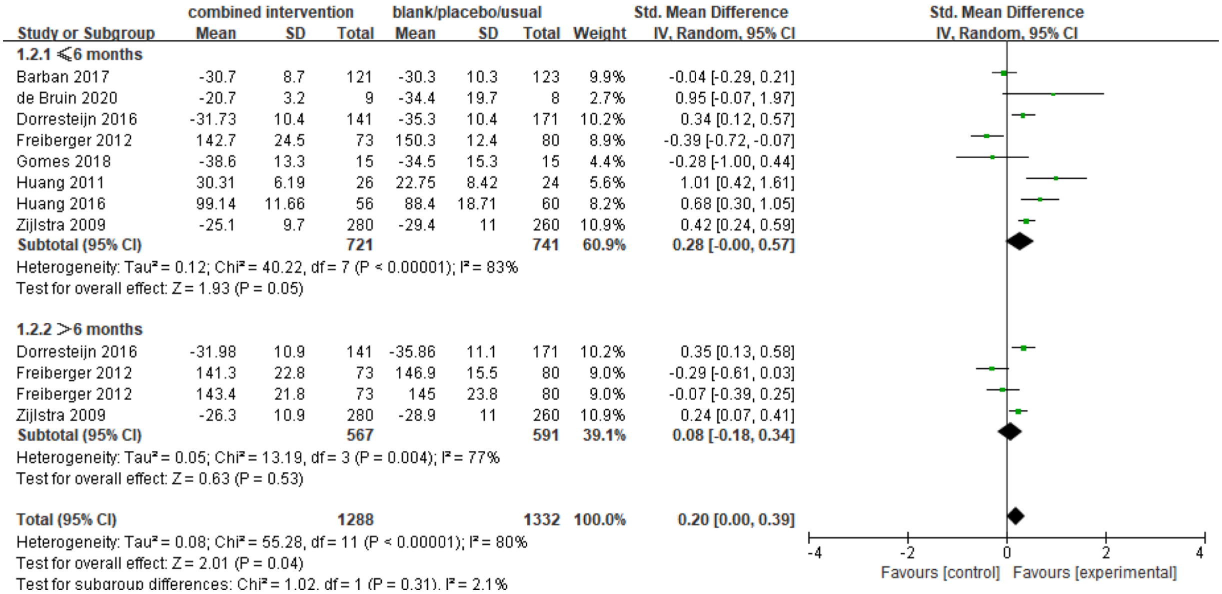

Fig. 5. Forest plot of the retention effect of the combined intervention on FOF in older adults compared with the blank/placebo/conventional intervention.

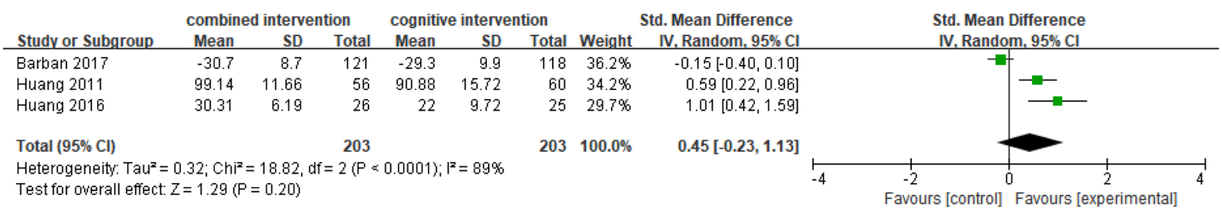

Fig. 6. Forest plot of the retention effect of the combined intervention on FOF in older adults compared with the cognitive intervention.

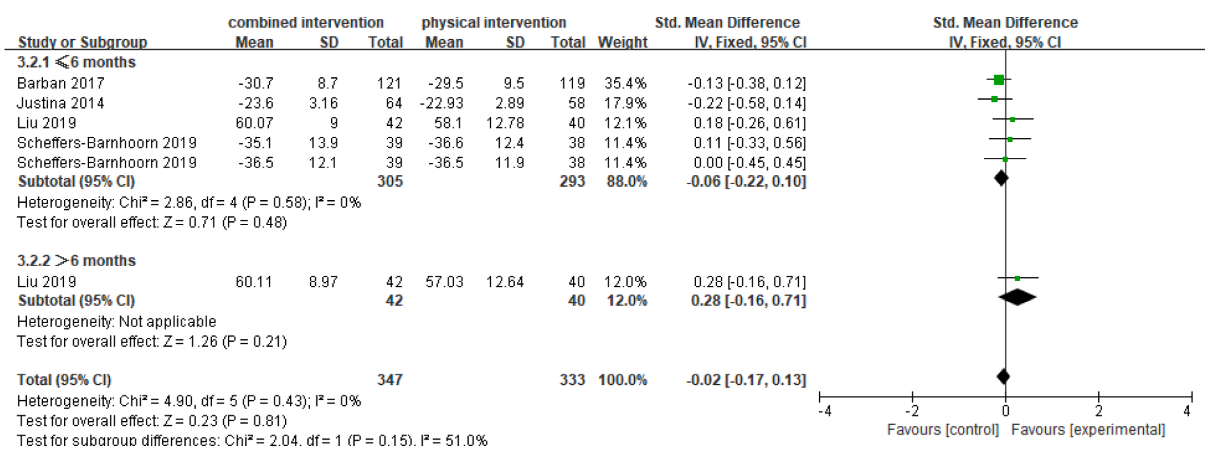

Fig. 7. Forest plot of the retention effect of the combined intervention on FOF in older adults compared with the physical intervention.

intervention vs. single physical intervention, indicated that the results were consisted with the above analyses. However, there was no robust result between the combined intervention and cognitive intervention. After the studies with high overall risk bias were excluded, no different results were found, suggesting that the results of the present study were robust. More details could be seen in Supplementary Material, Fig. S6.

3.8. Publication bias

The funnel plot and Egger's test indicated no publication bias in the immediate post-intervention effect of combined intervention on FOF (please see Supplementary Material, Fig. S7).

4. Discussion

This review explored the immediate post-intervention and retention effects of combined physical and cognitive intervention on fear of falling in older adults. The results showed the combined intervention had a small to moderate effect on FOF, in comparison with blank/placebo/usual control. Moreover, a small effect size on FOF was observed in the combined intervention vs. cognitive intervention, while there was no positive effect when comparing the combined intervention with a single physical intervention. In a short-term retention effect, only the combined intervention had a positive effect compared to blank/placebo/usual control. Furthermore, no effect was found in a long-term retention effect of combined interventions on reducing FOF.

The results suggested that in comparison with blank/placebo/usual control, the combined interventions were linked to a small to moderate reduction in FOF among older adults immediately post-intervention (SMD = 0.37, 95% CI 0.14–0.60, $P = 0.001$). This finding was consistent with the results of a meta-analysis of randomized controlled trials investigating the effect of physical intervention on FOF in older adults (SMD = 0.37, 95% CI 0.18–0.56, $P = 0.0001$)(Kumar et al., 2016). The similar effect sizes indicated that combined interventions did not appear to have additional benefits for reducing FOF. However, on account of the differences in the characteristics of participants, control intervention, and study design between the two reviews, the result should be interpreted with caution.

Additionally, to explore the additional benefits of the combined intervention, the present study compared the effect of the combined intervention in reducing FOF with a single intervention. In comparison with single physical intervention, the combined intervention also did not produce additional benefits on FOF in older adults (SMD = −0.09, 95% CI −0.27–0.08, $P = 0.29$). One possible explanation is that FOF is mainly caused by the deterioration of physical function. Previous studies suggested that FOF was strongly associated with poorer balance performance, lower extremity function, walking mobility, muscle strength, and perceived physical health (Kumar et al., 2014; Oh et al., 2017). Furthermore, physical exercise had already been proven to be effective in enhancing balance ability, strength, and physical performance (Lam et al., 2018; Papalia et al., 2020). Thus, this may be the reason why combined interventions did not produce additional benefits, compared with physical interventions. In contrast, there was a positive effect on reducing FOF when comparing combined intervention with single cognitive intervention (SMD = 0.20, 95% CI 0.01–0.39, $P = 0.04$). However, only four trials were included for this outcome, more research is needed in the future to explore whether the combined intervention can lead to additional effects compared to the single intervention.

The subgroup analysis revealed that the effect of the combined interventions on FOF varied by the duration of trials ($\chi^2 = 5.37$, df = 1, $P = 0.02$), compared with blank/placebo/ usual control. The duration of trials $\leq$ eight weeks had a significant effect on improving FOF (SMD = 0.63, 95% CI 0.26–1, $P = 0.0008$), while no effect was observed when the duration of trials was more than 8 weeks (SMD = 0.12, 95% CI −0.09–0.34, $P = 0.27$). The possible reason may be excessive perceived stress and cognitive fatigue in older adults. The extended duration of the combined intervention may lead to less participation (Holtzer et al., 2011), and ultimately has an negative impact on the effectiveness of the intervention. The result shows that there is a nonlinear relationship between the effect of the combined intervention and the duration of intervention. To ensure cost-effectiveness, more well-designed studies are needed to explore the optimal length of intervention for combined interventions.

In long-term follow-up retention effects, no statistically significant difference was observed (Combined intervention vs. Blank/placebo/ conventional intervention: SMD = 0.08, 95% CI −0.18–0.34, $P = 0.53$; Combined intervention vs. Single cognitive intervention: SMD = 0.45, 95% CI −0.23–1.13, $P = 0.20$; Combined intervention vs. Single physical intervention: SMD = −0.02, 95% CI −0.17–0.13, $P = 0.81$). The reason for this result could be that after the intervention ended, older adults do not adhere to a regular training routine, resulting in insignificant intervention effects(Huang et al., 2016; Liu et al., 2019). Future research should focus on the follow-up retention effects of the combined intervention on reducing FOF.

4.1. Clinical implications

FOF is a common psychological problem in older adults and is associated with many adverse health outcomes. Therefore, to improve the quality of life in later life, implementing interventions to reduce FOF in older adults is essential. The present study shows that combined physical and cognitive intervention and single physical intervention have similar effects on reducing FOF in older adults. Considering the simplicity of the intervention and the feasibility of clinical practice, a single physical intervention may be an optimal choice. Clinical practitioners should develop tailored exercise intervention programs to reduce FOF in older adults and improve the quality of life in later life.

4.2. Study limitations

This systematic review and meta-analysis has several limitations. First, only studies written in English are included, which may have missed some studies. Second, most of the studies included in this review have high risks of performance bias, due to the difficulty of blinding participants and researchers simultaneously. Third, sample sizes for some studies are relatively small, and these studies may have limited power to explore intervention effects. In additon, age, as an affecting factor for fear of falling in older adults, has the possibility of influencing the effectiveness of interventions. Therefore, a more detailed delineation of the age of older adults and exploring the best interventions for different age groups should be the direction of future research. Fourth, there are no standardized outcome measures to evaluate FOF, which may impede the comparability and reliability of the results. Focusing on different measurement purposes, the FOF has a variety of measurement tools (Jorstad et al., 2005). A systematic review and meta-analysis showed that FES-International (FES-I) had high-certainty evidence to support the responsiveness, however, future studies are still needed to explore the efficacy of measurement properties of FES-I variants and application in different settings (McGarrigle et al., 2023). Future studies are needed to explore the optimal measurement for FOF in different contexts. Fifth, although seven databases were searched for this study, the funnel plot and Egger's test did not reveal the publication, there is a discrepancy between the study protocol and the amount of published research(Komukai et al., 2023). Publication bias is likely to exist in this study and lead to an overestimation of the intervention outcome. Last, a small number of studies have investigated the follow-up retention effects of combined interventions, which may lead to inaccurate synthesized effect sizes.

5. Conclusion

In summary, the results showed that combined physical and cognitive groups have a positive immediate post-intervention effect on reducing FOF in older adults in comparison with blank/placebo/usual control or single cognitive intervention. Only combined interventions had a small effect compared to blank/placebo/usual control in short-term retention effects. The immediate and long-term effects of the combined intervention were not preferable to those of the physical intervention. However, only small number of trials explored the retention effects of the combined intervention, and the characteristics of trials, which can lead to long-term effects on FOF in older adults, remain unclear. Thus, to clarify the feasibility of the combined intervention, in the future, more studies are required to explore the retention effects of the combined intervention and to demonstrate whether it can provide additional benefits than single interventions.

CRediT authorship contribution statement

Yue Hu: Conceptualization, Data curation, Methodology, Software, Writing – original draft, Writing – review & editing. **Kun Wang:** Data curation, Writing – original draft. **Jiaxin Gu:** Writing – review & editing, Formal analysis. **Zhixuan Huang:** Methodology, Software, Supervision. **Ming Li:** Conceptualization, Methodology.

Declaration of Competing Interest

None.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.archger.2023.105173.

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