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The Safety and Efficacy of Balance Training on Stroke Patients With Reduced Balance Ability: A Meta-Analysis of Randomized Controlled Trials

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HIGHLIGHTS

- Balance training improved balance ability and ambulation function after stroke.
- Balance training in stroke patients with reduced balance ability seems to be safe.
- For stroke patients with reduced balance ability, balance training is recommended.

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Conflict of Interest
The authors have no potential conflicts of interest to disclose.

ABSTRACT

To investigate the safety and efficacy of balance training for stroke patients with reduced balance ability by performing a meta-analysis of randomized controlled trials. The PubMed, Embase, and Cochrane Central Register of Controlled Trials databases were searched up to February 2022. Quality assessment was performed using the using the Cochrane risk of bias tool. Studies were included if: 1) patient allocation was randomized; 2) the participant was composed of stroke patients with reduced balance ability (Berg Balance Scale [BBS] ≤ 40, Timed-Up and Go ≥ 14 seconds, or Mini-Balance Evaluation Systems Test ≤ 17.5); and 3) intervention was additional balance training for the experimental group. Six studies including 466 patients were included in the final analysis. The meta-analysis showed a significant improvement in the BBS (mean difference [MD], 8.14; 95% confidence interval [CI], 4.65, 11.64) and Trunk Impairment Scale (MD, 4.71; 95% CI, 3.45, 5.96) after balance training relative to the comparison group. Ambulation function was significantly improved (standardized MD, 0.98; 95% CI, 0.46, 1.49) after balance training. There was one report of a femur fracture among 230 participants in the balance training group. Balance training in addition to conventional rehabilitation program in stroke patients with reduced balance ability appears to be effective and safe.

Keywords: Stroke; Postural Balance; Rehabilitation; Systematic Review; Meta-Analysis

INTRODUCTION

Stroke is the second-leading cause of death and a major cause of disability worldwide, with significant impacts on patients' quality of life and independence [1]. Among the various impairments that stroke survivors experience, reduced balance ability is one of the most common and debilitating consequences. The ability to maintain balance is fundamental to performing activities of daily living (ADL), mobility, and preventing falls.

Balance impairment affects up to 83% of stroke survivors, persisting long after the acute phase of recovery [2]. This high prevalence highlights the need for targeted interventions focused on balance rehabilitation. Emerging research suggests that balance ability is not only a key rehabilitation target but also a strong predictor of overall functional recovery after stroke [3]. Improvements in balance have been associated with enhanced mobility, increased independence in ADL, and better quality of life. This underscores the potential for balance-focused interventions to have wide-ranging benefits for stroke survivors.

In stroke patients with decreased balance ability, performing balance training itself could increase the risk of falls and related fractures, so it is necessary to elucidate whether applying balance training to these populations is safe and effective. Therefore, this study aimed to clarify the current evidence and to determine the efficacy and safety of balance training for stroke patients with reduced balance ability by performing an updated systematic review and meta-analysis of currently available data of randomized controlled trials.

MATERIAL AND METHODS

This systematic review was reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. Study selection, eligibility criteria application, data extraction, and statistical analysis were performed in accordance with the Cochrane Collaboration guidelines [4].

Search strategy and study selection

We searched for references in the MEDLINE (PubMed), Embase, and Cochrane Central Register of Controlled Trials databases up to February 28, 2022 without any date restriction. Key terms used to conduct the literature search were selected and combined with the following English terms and their equivalents: "stroke" AND ("balance" or "fall"). The search strategies per database are outlined in **Supplementary Data 1**. Studies were included if: 1) patient allocation was randomized; 2) the participant was composed of stroke patients with reduced balance ability (Berg Balance Scale [BBS] ≤ 40 [5], Timed-Up and Go (TUG) ≥ 14 seconds [6], or Mini-Balance Evaluation Systems Test ≤ 17.5 [7]); and 3) intervention was additional balance training for the experimental group. Studies with lack of information on the objective balance ability for stroke patients were excluded. Abstracts and conference proceedings were excluded if they lacked sufficient reporting details. Review articles, editorials, and other nonclinical trials were also excluded.

Two reviewers (SYY and YWK) independently reviewed the titles and abstracts of the articles to determine their eligibility for inclusion. Studies that clearly failed to meet the inclusion criteria were not reviewed further. Those that could not be excluded were retrieved, and the full text was reviewed by the 2 reviewers. Studies that met the criteria were retrieved and reviewed in detail.

Data extraction and quality assessment

The following information was extracted from the included studies: first author, year of publication, patients' demographics and clinical presentations, exercise protocols, total sample size and sample size per arm (balance training and comparison groups), scales and measures used to evaluate the efficacy of the interventions, and adverse events. The outcomes of interest were measures of balance ability, such as BBS or Trunk Impairment Scale (TIS), ambulation function, and ADL.

Study quality was assessed by rating the risk of selection bias, performance bias, detection bias, attrition bias, reporting bias, and other sources of bias using the Cochrane risk of bias tool [4]. Two reviewers (SYY and YWK) independently assessed whether each of the following domains was adequate (i.e., low, unclear, or high risk of bias): "sequence generation," "allocation concealment," "blinding," "incomplete outcome data addressed," "selective outcome reporting," or "other bias." The certainty of evidence in meta-analyses that included studies was assessed using the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) tool, which encompasses 5 aspects: 1) risk of bias, 2) inconsistency, 3) indirectness, 4) imprecision, and 5) publication bias. Ratings for the certainty of evidence were categorized as high, moderate, low, or very low.

Data synthesis and statistical analysis

A summary of the intervention effect was reported as the mean difference (MD) for balance ability and standardized mean difference (SMD) for ambulation function and ADL. Analyses were conducted using the RevMan 5.3 software (The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark). The degree of heterogeneity was assessed using I^2. These statistics, expressed as a percentage between 0 and 100, can be interpreted as the percentage of heterogeneity in the system or basically the amount of total variation accounted for by between-study variances [8]. We used 2-tailed p values, and p values of < 0.05 were considered statistically significant.

RESULTS

A flowchart of the search process is shown in **Fig. 1**. A total of 18,897 studies were identified in the initial search. After duplications were removed, 14,206 studies remained. After screening titles and abstracts, the full texts of the 25 remaining articles were assessed for eligibility. Finally, 6 studies [9-14] including 466 participants fulfilled the inclusion criteria and were included in the meta-analysis. The results of the risk of bias assessment for the 6 studies are presented in **Fig. 2**. The quality of evidence based on GRADE tool was estimated to be moderate.

Study characteristics

The number of participants in the included studies ranged from 33 [11] to 180 [14]. Five studies performed additional core muscle training [10-14], and one study performed feedback training for postural balance improvement [9]. All 6 studies included in the meta-analysis reported BBS as an outcome variable [9-14], and TIS was reported in 3 studies [10-12]. Ambulation function [11-13] and ADL [9,12,13] were reported in 3 studies, respectively. **Table 1** summarizes the characteristics of the included studies.

Add-on effects of balance training for stroke patients with reduced balance ability

The 6 studies reported the BBS to reflect balance ability, and the meta-analysis showed a significant improvement in the BBS (MD, 8.14; 95% confidence interval [CI], 4.65, 11.64) after balance training relative to the comparison group (**Fig. 3**). Three studies assessed TIS, and TIS (MD, 4.71; 95% CI, 3.45, 5.96) was also significantly improved (**Fig. 4**). There were 3 studies evaluated ambulation function, and the meta-analysis showed significant improved ambulation function (SMD, 0.98; 95% CI, 0.46, 1.49) after balance training (**Fig. 5**). Three studies accessed ADL, and there were no significant differences in ADL between the 2 groups (SMD, 1.04; 95% CI, −0.05, 2.13) (**Fig. 6**).

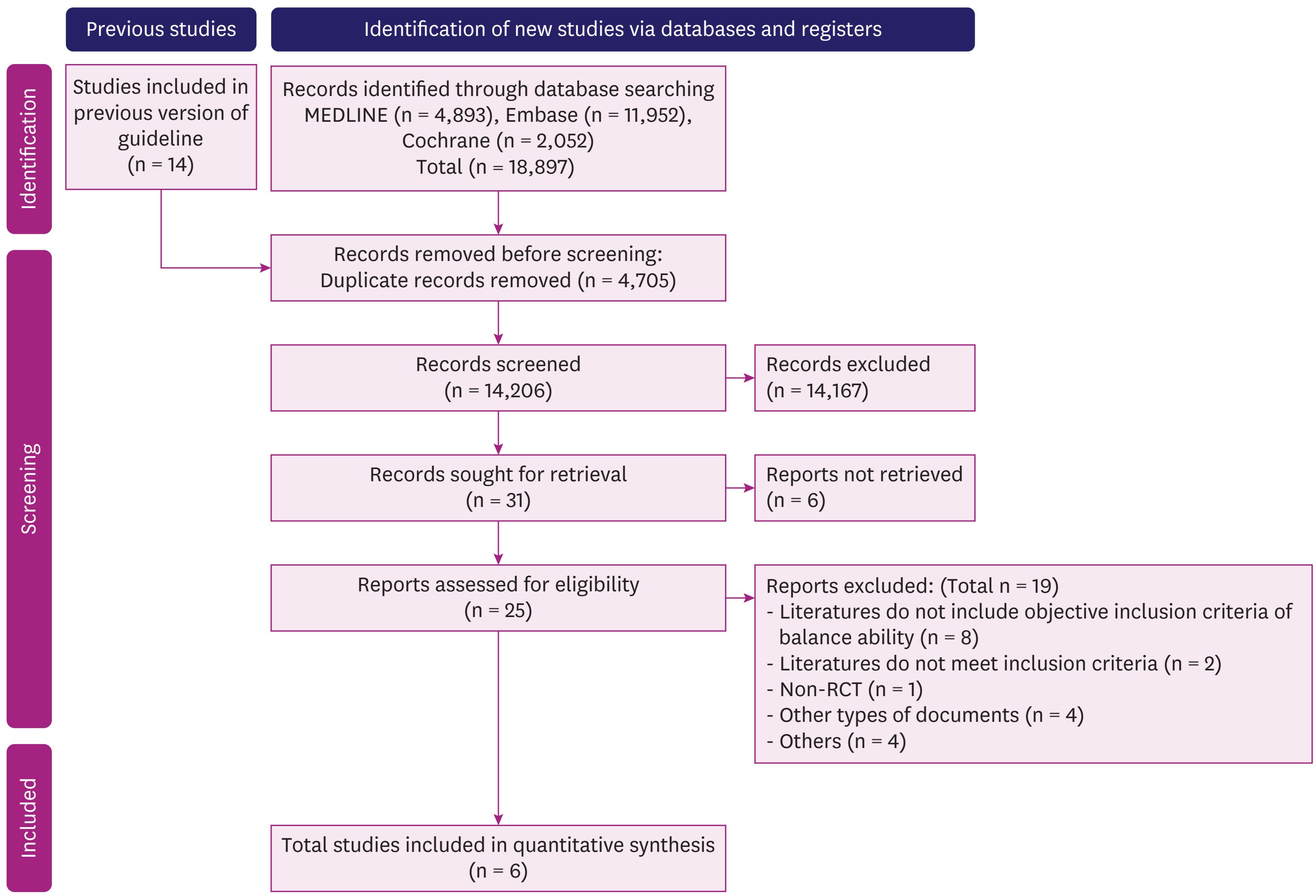

Fig. 1. Flow chart of study search and selection methods.
RCT, randomized controlled trial.

Adverse events

Of the 6 studies included in this review, there were no reports about falls during balance training in patients with reduced balance ability. One study reported a femur fracture in the experimental group [12], but the study did not clearly state whether the femur fracture occurred during balance training. The number of participants of the experimental group in this meta-analysis was 230, and the frequency of fracture was estimated approximately 0.4%.

DISCUSSION

This systematic review and meta-analysis aimed to evaluate safety and efficacy of balance training for stroke patients with reduced balance ability. The meta-analysis showed significant improvement in balance ability and ambulation function in patients who performed additional balance training compared to those who performed only conventional rehabilitation programs. However, there was no significant improvement in ADL after additional balance training. There was only one report of a femur fracture among 230 participants who performed balance training.

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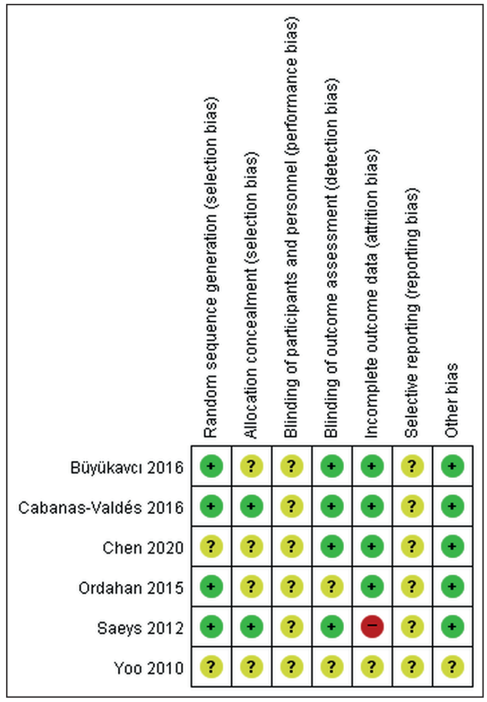

Fig. 2. Risk of bias summary.

Although the incidence of stroke has gradually increased, mortality after stroke has decreased by 12.8% from 2014 to 2019 [15]. Many stroke survivors suffer from long-term sequelae, and reduced balance impairment is one of the most common problems after stroke. Reduced balance ability has a negative impact on functional independence and are one of the most important risk factors causing falls [16]. The ability to keep postural stability in sitting and standing positions is essential for functional activities such as transfer, walking, and even ADL [17]. There have been several evidences to support the effects of balance training in patients after stroke [18,19]. However, whether performing balance training in stroke patients with high risk of falls or reduced balance ability is safe and effective has not been elucidated yet. Therefore, in this meta-analysis, we investigated the effects of add-on balance training in stroke patients with reduced balance ability and whether it can be performed safely.

Our results showed that balance training in addition to conventional rehabilitation program improved balance ability and ambulation function even for stroke patients with balance impairment. One femur fracture was reported on balance training group, however there was no clear information whether the femur fracture was occurred during balance training. And the estimated incidence rate of fracture was 0.4%. Therefore, it appears that balance training can be performed in stroke patients with reduced ability safely. On the other hand, ADL was not improved after balance training in our study. Performing ADL is affected by cognition and hand fine motor function as well as balance ability [20,21], which can be a possible explanation for our results.

Of 6 studies included in this meta-analysis, 5 studies performed core muscle exercise [10-14]. Previous studies have suggested that stability exercises would a viable strategy for improving trunk performance and dynamic sitting balance, standing balance, and gait in post-stroke patients [22,23], which is inline with our results. One study investigated the effectiveness

Table 1. Characteristics of the included studies

1st author	Year	Experimental group	Intervention	Comparison group	Follow-up	Outcome measures
Büyükavcı	2016	Conventional exercise program + truncal exercise (n = 32)	Trunk exercises 2 hours/day/ 3 weeks	Conventional exercise program (n = 32)	3 month	1. BBS 2. TIS 3. FIM 4. Rivermead Mobility Index
Cabanas-Valdés	2016	Conventional PT + core stability exercises (n = 40)	Core stability exercises for 15 min/day	Conventional PT (n = 40)	Post Tx.	1. TIS 2. Function in sitting test 3. BBS 4. Tinetti Test 5. Brunel Balance Assessment 6. Postural Assessment Scale for Stroke 7. Barthel index
Chen	2020	Conventional hemiplegia rehabilitation therapy + core muscle stability training (n = 90)	Five times a week for a total of 8 weeks	Conventional hemiplegia rehabilitation therapy (n = 90)	Post Tx.	1. BBS 2. Brunnstrom staging 3. Fugl-Meyer motor assessment 4. 10 meter walking speed 5. Abdominal muscle thickness
Ordahan	2015	Trained with balance trainer in addition to conventional rehabilitation program (n = 25)	20 minutes a day, 5 days a week for a total of 6 weeks (30 sessions/600 minute in total) with the balance trainer (BALANCE-trainer, art.nr. 07001-001TM)	Conventional rehabilitation program (n = 25)	Post Tx.	1. Timed-Up and Go Test 2. BBS 3. FIM
Saeys	2012	Conventional therapy + truncal exercise (n = 18)	16 hours of truncal exercises	Conventional therapy + 16 hours sham Tx. (arm therapy) (n = 15)	Post Tx.	1. TIS 2. Tinetti Test 3. Romberg test 4. Four Test Balance Scale 5. BBS 6. Rivermead Motor Assessment Battery 7. Functional Ambulation Categories 8. Dynamic Gait Index
Yoo	2010	Conventional PT + additional core strengthening program (n = 28)	30 minutes a day, 3 days per week for 4 weeks	Conventional PT (n = 31)	Post Tx., 4 weeks	1. Trunk Control Test 2. TIS 3. BBS

BBS, Berg Balance Scale; TIS, Trunk Impairment Scale; FIM, Functional Independence Measure; PT, physical therapy; Tx., treatment.

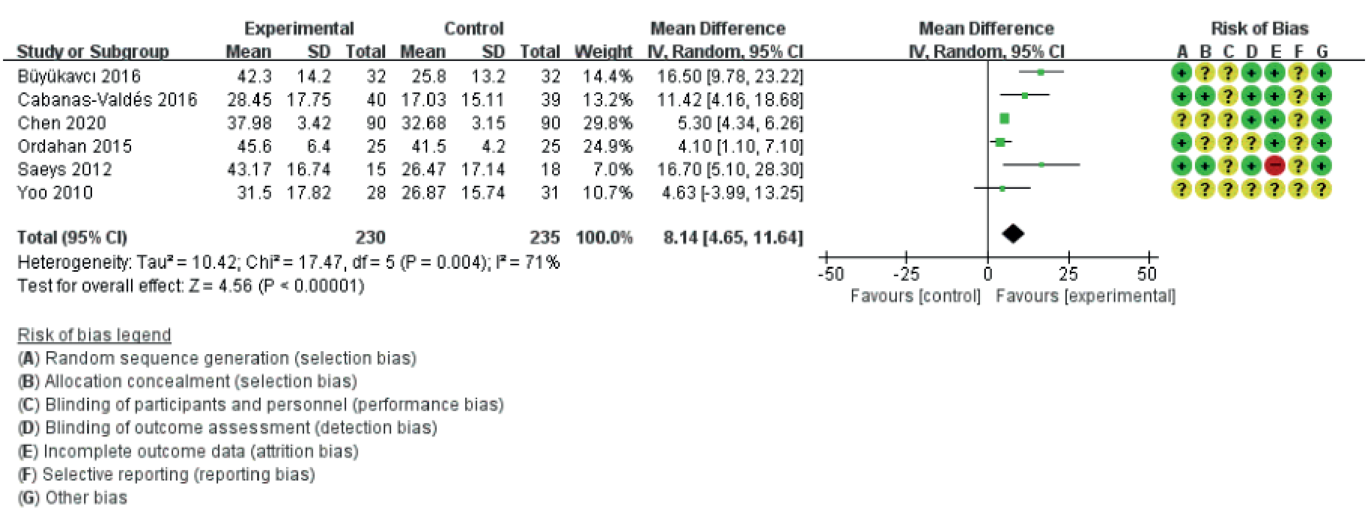

Fig. 3. Meta-analysis of additional balance training for Berg Balance Scale.
SD, standard deviation; CI, confidence interval; IV, inverse variance.

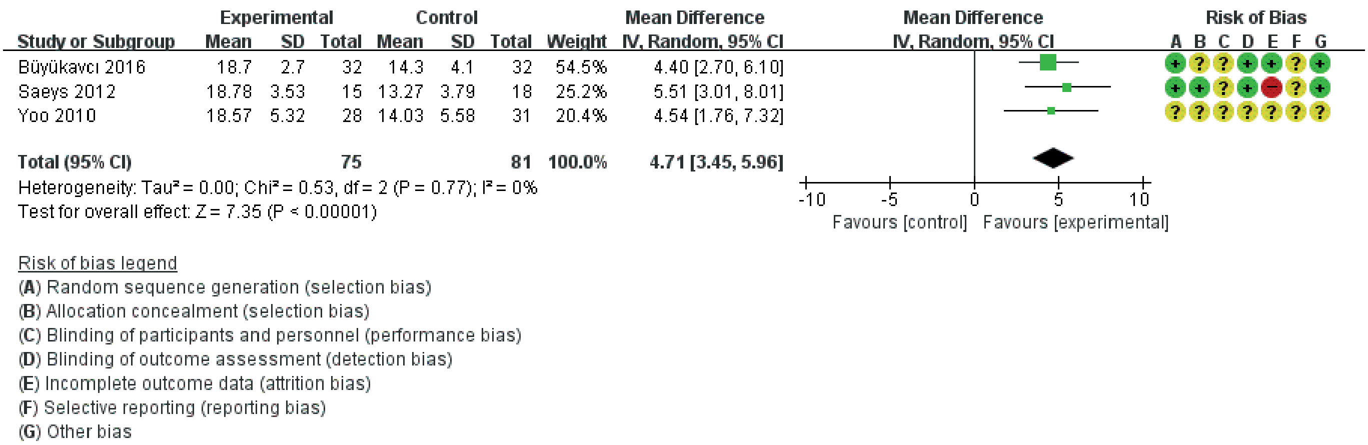

Fig. 4. Meta-analysis of additional balance training for Trunk Impairment Scale.
SD, standard deviation; CI, confidence interval; IV, inverse variance.

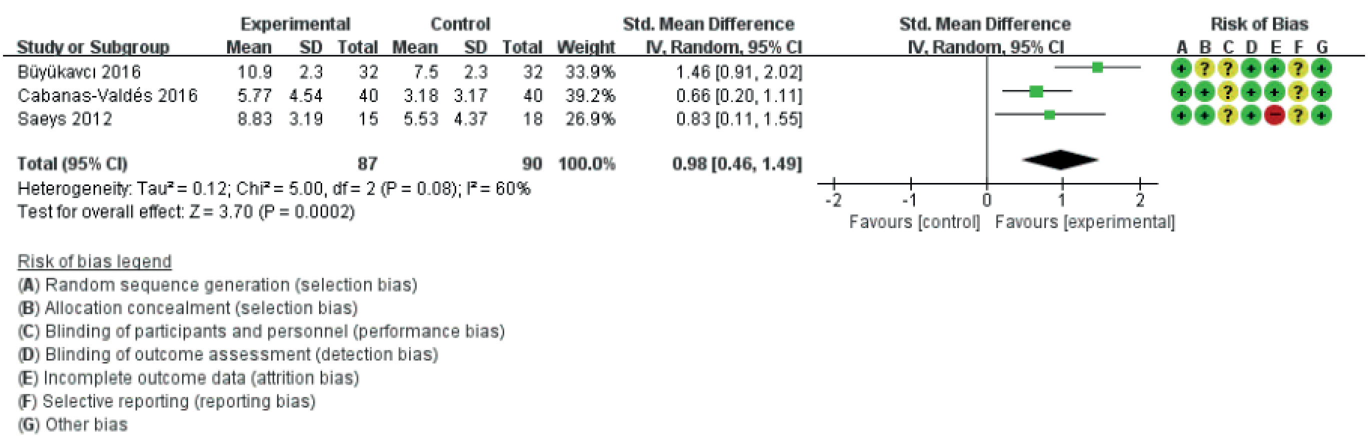

Fig. 5. Meta-analysis of additional balance training for ambulation function.
SD, standard deviation; CI, confidence interval; IV, inverse variance.

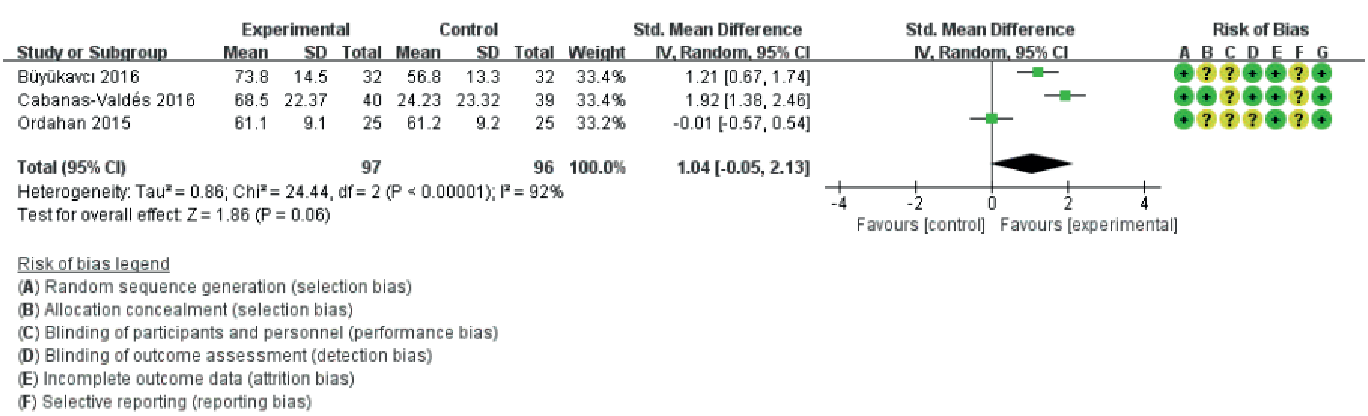

Fig. 6. Meta-analysis of additional balance training for activities of daily living.
SD, standard deviation; CI, confidence interval; IV, inverse variance.

of visual feedback balance training [9], and participants were trained to maintain their posture steadily and symmetric while weight bearing and adapting to different static sensory conditions, through verbal and tactile cues. And the proposed mechanisms of feedback training consists of increasing the activity of the receptor organ in the inner ear during exercises, activating the integrating central nervous system by offering varying sensory inflow, and training the neuromuscular effecter system [24].

Our study has several limitations to be considered. First, the total number of included studies and participants was small. Although there have been many studies on the effects of balance training in patients after stroke, the number of studies which focused on stroke patients with reduced balance ability was small. Second, the diversity of the exercise protocols performed in each study, including exercise frequency and duration, may have caused variation in the results. With these various parameters and the low number of included studies, we could not perform subgroup analysis and draw conclusions on the optimal protocols of balance training.

In this study, we investigated the efficacy and safety of balance training in stroke patients with reduced balance ability. According to our results, adding balance training to conventional rehabilitation program appears to be effective and safe. Future studies are required to determine exercise types and optimal protocols of each exercise for stroke patients with reduced balance ability.

SUPPLEMENTARY MATERIAL

Supplementary Data 1

Search strategies

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