Do physiotherapy interventions on the ankle have an impact on the balance of older adults: a Systematic Review and Meta-Analysis of Randomised Controlled Trials.

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received : 26 May 2023
accepted: 15 March 2024

ISSN: 2823-989X
DOI: 10.52057/erj.v4i1.36

ABSTRACT

Background: Falling and its disastrous consequences in the ageing population are a public health issue in terms of both morbidity and mortality. Several authors put forward the hypothesis that increasing ankle range of motion (ROM) or strength could improve balance in this population. **Objective**: The purpose of this systematic review and meta-analysis is to gather data to evaluate the effect of these two parameters on static and dynamic balance. **Method**: Databases as well as grey literature were systematically searched from inception until May 2023. The level of evidence and the corresponding GRADE approach were attributed. Meta-analysis included subgroup analyses to determine the effect of techniques that aimed to improve ankle ROM and techniques to strengthen ankle muscles. **Results**: Among the 884 studies identified, 10 randomised trials were included for the qualitative analysis and 8 for the meta-analysis. The mean PEDro score was 4.8/10. The GRADE approach revealed low-to-moderate certainty for static balance in relation to ankle ROM interventions, moderate for static balance in relation to ankle strengthening interventions and low-to-moderate for dynamic balance in relation to ankle ROM interventions. The meta-analysis demonstrated an improvement in static balance with grade III and IV ankle mobilisation (pooled SMD = 2.06; 95% CI = 0.15 to 3.97; P = 0.03). **Conclusion**: Among the different physiotherapy interventions for the ankle, only passive mobilisations seem to improve static balance. Results should be considered with caution due to high heterogeneity.

KEYWORDS: Ankle, Balance, Mobilisation

Introduction

Falls among older adults are a significant public health issue. According to data from 2010, in France, falls rise up to 71% in people from the ages of 65 to 69, 78% in 70-74 year olds (yo), 85% in 80-84 yo, 93% in 85-89 yo and up to 95% in people that are 90 years old and over [1]. Hence, falls have been estimated to be the most common daily life accident in this country with, on average 400 000 falls per year. In 2014, 76 100 hospitalisations were due to fractures of the upper femur in individuals aged 65 years old and over. Ninety percent of these fractures were the result of falls. About 40% of people over 65 have fallen at least once over the last 6 months. In the US in 2015, the average cost attributed to falls in institutionalised older adults rose up to $50 billion dollars each year [2]. However, it should be pointed out that despite such investments, the number of falls has not reduced significantly yet.

Falls can be considered as a multi-factorial phenomena resulting from disturbances in motor function, cognitive function, social conditions, the daily living environment, nutritional status and other factors [3, 4]. Among them, functional status (including balance) seems to be a key factor[5].

The maintenance of balance is influenced by a range of sensorimotor functions including muscle strength, proprioception, and the visual and vestibular sensory systems. Postural sensory inputs degenerate with age [6]. In healthy seniors, 70% of sensory information destined to the central nervous system comes from the somatosensory system [7] such as the ankle

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which is often cited as an essential joint in the rehabilitation of balance disorders in the elderly. Some authors [8] make a link between a decrease in dorsiflexion and balance in institutionalised elderly patients. The ankle regulates minor imbalances while the hip is involded in greater imbalances [9, 10]. For any type of imbalance, ankle solicitation is diminished in favor of hip solicitation [10]. Dorsiflexion range of motion is often decreased in the older population, this is correlated with lack of balance and even falling [5, 11, 12]. Moreover, the range of dorsiflexion influences plantar flexor strength [13]. These muscles are tonic postural muscles and are related to postural stability [5, 14]. Their lack of contractility has been cited as a sign of ageing [15]. On the other hand, some authors believe that strength (particularly the explosiveness of plantar flexors) is reduced in seniors due to an alteration in balance performance [13].
Considering the above-mentioned scientific literature, several authors [5, 12, 16] suggest improving ankle joint range of motion (R.O.M) and muscle strength to improve balance in older adults. Thus, in order to clarify the real impact of these two types of rehabilitation in this context, it seems appropriate to carry out a systematic review with meta-analysis. To the best of our knowledge, no such study has been conducted in this field.

Methods

This review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). This meta-analysis is registered at the Lille 2 university.

Data Sources and Searches

Five electronics databases were searched from inception to May 2023: PEDro, ScienceDirect, EMBASE, MEDLINE (via PubMed) and LILACS. The following search terms were used by combining PICO concepts with boolean operators « AND » or « OR »: participants (elders, elderly, aging), intervention: (mobilisation, strength training, training program, rehabilitation), balance. Filters such as « random controlled trials » were applied when it could be (supplementary materials 1).

Study Selection

Inclusion criteria for the selected articles were:

- RCT (control group: sham, other intervention, another joint).
- evaluation of the effects of an intervention on the ankle in terms of joint R.O.M. and/or muscle strength gains, on balance.
- population: adults 65 years of age or older.
- language had to be in English, Spanish or French.
- peer-reviewed trials.
- full text available.

We did not include studies that mentioned a disease, comorbidities, a trauma or surgery and orthotic devices. Studies that involved the entire lower limb or included the knee or any toe were excluded.
Two independent reviewers (FB, AK) screened titles, abstracts, and full texts for eligibility based on the pre-defined inclusion criteria. Any disagreements between reviewers were resolved by consultation with the third independent reviewer (FM).

Data Extraction and outcomes measures

A data collection form was developed and used to extract data from the included studies by one reviewer (FB) and cross-checked by a second reviewer (AK). The following data items were extracted: author's name, year of publication, participant characteristics (sample size, sex, age, notion of statistical homogeneity of groups), intervention type and setting, and outcomes measures (ankle R.O.M, strength and balance test results). For the outcomes, we opted [17] for the single leg stance (SLS) in the first instance, for the functional reach test (FRT) in the second, then for the length of the COP trajectory. For dynamic balance, we preferred the TUG and then the 10m walk test (10MWT) whose minimum clinically detectable (MCID) change is 0.13 m/s [18], when appropriate.

Quality evaluation and risk of bias assessment

Each RCT was assessed using the PEDro scale and scores were extracted using the PEDro website or by the authors if the score was missing. There are three levels of quality in this scale: poor (< 4/10), average (score between 4 and 6) and good (> 6) [19].
In addition, The Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach was also used to assess certainty in the body of evidence for each outcome by 1 reviewer (FB) and cross-checked by another reviewer (AK). Evidence was rated as high, moderate, low, or very low.

Statistical analysis

We used a statistical method of inverse variance for continuous data. The data used in the meta-analyses were standardised mean differences (SMD) and 95% confidence interval (CI). A random-effect model was used for this meta-analysis.
We used Review Manager version 5.4.1. (Cochrane collaboration, Copenhagen, Denmark). The RCTs were divided into 2 subgroups. The first group included studies with interventions that aimed to increase ankle R.O.M. (mentioned as ankle R.O.M. interventions) and the second group included studies that aimed to strengthen ankle muscles. Statistical significance was set at P value of <.05.
Publication bias would be assessed using a funnel plot based on a minimum of 10 studies [20].

Additional analysis

In case of high heterogeneity (> 70%), a sensitivity analysis would be performed for all primary outcomes by changing the model effect, the scale or excluding results from a study with a particular bias.

Role of the Funding Source

The funders played no role in the design, conduct, or reporting of this study.

Results

Study Selection

The study selection process is outlined in Figure 1.
The total amount of articles identified was 911 and after checking titles and abstracts, 25 articles were selected for full-text review. After this step, 10 RCTs were included for the systematic review and 8 articles were used for the statistical analysis. The reasons for exclusion are detailed in supplementary material 2.

Study characteristics

All data are available in Table 1.

Population

The 10 randomised trials were published from 2004 to 2020. The sample sizes ranged from 21 to 40 individuals aged 64 to 91 years (mean: 70.6) for a total of 320 participants (209 women and 111 men) without apparent comorbidities.
Participants were recruited from social centers or sports clubs for seniors, by a registry from rehabilitation centers or other hospital care structures or from institutions.

PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only

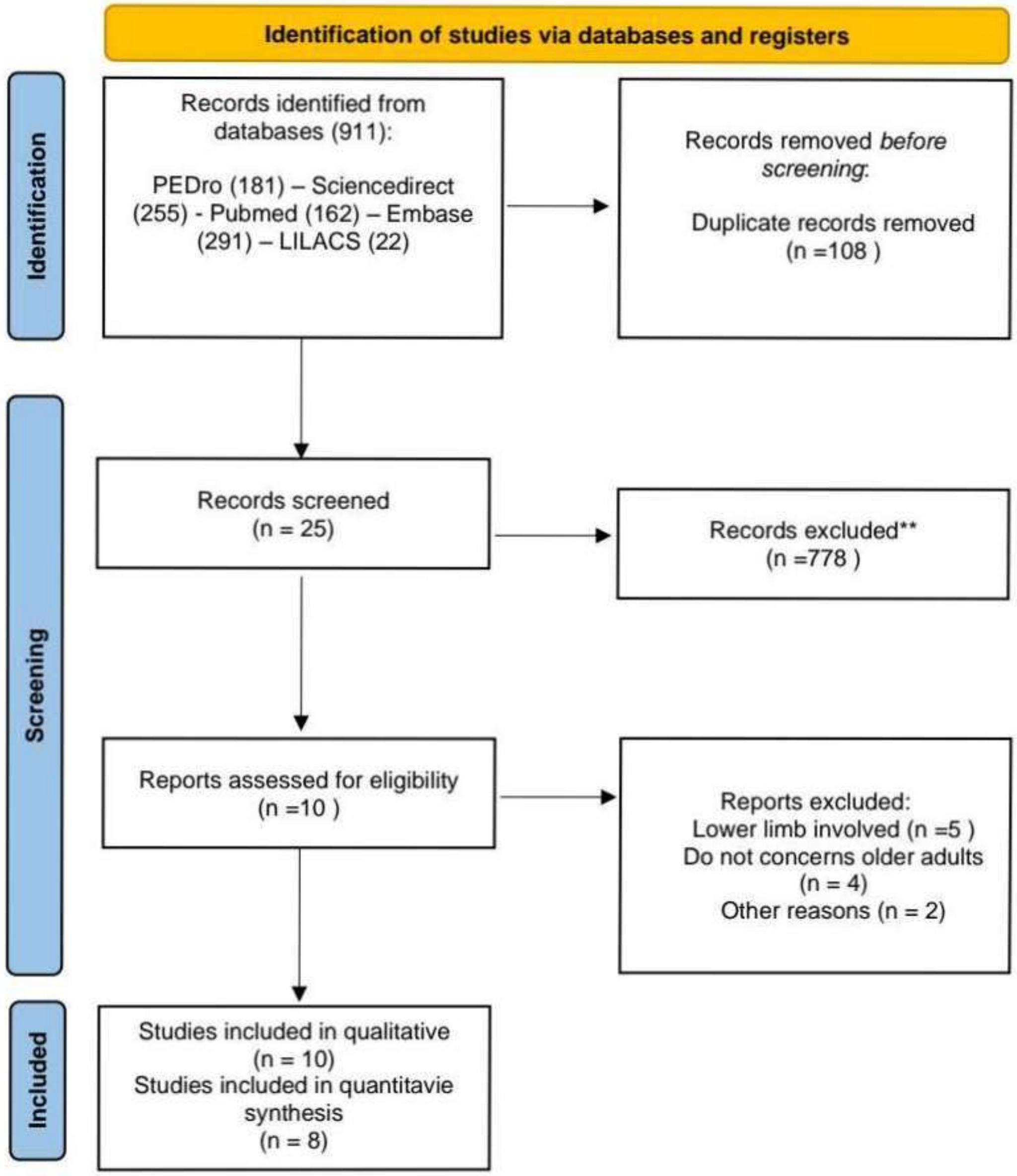

Figure 1 Flowchart describing search and selection process.

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021; 372:n71. doi: 10.1136/bmj.n71

Table 1 a) Ankle R.O.M. interventions

Authors	Population	Intervention	Outcomes	Results	PEDro score
Gajdosik et al., 2005	Ne=10 women (73.1 SD 6.8 years) Nc= 9 women (75.3 SD 8.3 years).	The subjects, lying down, perform a maximal dorsiflexion under EMG control for 15s repeated 10 times, this 3 times a week over 8 weeks.	− Static balance +FRT Dynamic balance: +TUG modified (called timed agility run) +10MWT.	Improvement for Ne in maximal dorsiflexion range, passive resistance strength, and dynamic balance by decreasing time on the modified TUG and 10MWT. No improvement in static balance by FRT. Static balance (FRT): +Experimental group: μd = 0.35 cm and SD= 3.11 cm +Control group: μd= 1.17 cm and SD= 3.24 cm Dynamic balance (10MWT): +Experimental group: μd= 0.45 sec and SD= 0.81 sec +Control group: μd = 0.4 sec and SD= 1.04 sec.	6
Gong et al., 2010	− Ne=20 women (69.50 SD 4.38 years) Nc=20 women (68.90 SD 5.53 years).	20 min of grade III and IV mobilizations, 3 times a week for 4 weeks.	Static balance: +surface of the trajectory (mm^2) +length of the trajectory (mm) +maximum velocity of the trajectory (mm/s).	Significant improvement for Ne in joint ranges and balancing ability for all stabilometric tests (paired sample t-test, α=0.05). Static balance (COP path length): +Experimental group: μd= −82 mm and SD= 30.43 mm +Control group: μd= −1.7 mm and SD= 24.85 mm No dynamic test.	3
Cho, Ko, et Lee 2012	Ne=18 (68.11 SD 4.1 years) of 7 men and 11 women Nc=15 (66.2 SD 3.5 years) of 7 men and 8 women.	Grade III mobilization of 30 sec of the tibio-astragalar joint 3 times a week for 4 weeks.	Static balance: +SLS (in s). +LR (in mm). Dynamic balance: +TUG (in s).	Significant improvements in ankle dorsiflexion amplitude, SLS, TUG and FRT. Static balance (SLS): +Experimental group: μd= 6.8 sec and SD= 2.7 sec +Control group: μd=−0.4 sec and SD=1.5 sec Dynamic balance (TUG): +Experimental group: μd= 2.8 sec and SD= 1.9 sec +Control group: μd= 0.3 sec and SD= 0.9 sec	5
Pertille et al., 2012	− Ne=16 women (69.12 SD 3.40 years) Nc=16 women (68.43 SD 3.33 years).	3 series of 30 sec each of grade III mobilization of the tibio-astragalar joint.	Static balance: + FRT (in cm). + COP trajectory (using baropodometric platform: in mm). Dynamic balance: nwline + TUG (s).	There was no significant improvement in balance and ankle amplitudes for the control group. Static balance (FRT): +Experimental group: μd=1.14 cm and SD= 3.39 cm +Control group: μd= −0.05 cm and SD= 4.29 cm Dynamic balance (TUG): +Experimental group: μd= −0.15 sec and SD= 0.38 sec +Control group: μd= −0.13 sec and SD= 0.80 sec	6
Shafizadegan et al., 2019	N=80 Nstretching=40 subjects (20 young and 20 old (10 men and 10 women 67.43 SD 5.44 years). Ne=10 stretching Nc=10 KT	Gastrocnemius stretching 4 times for 60 sec vs. performing a calf k-taping.	Static balance: + SLS test alone (s) + by stabilometry: • excursion of the COP (mm) • COP trajectory (mm) • COP velocity (mm/s)	Improvement of OLB time in elderly subjects after stretching. Gastrocnemius stretching is more effective than KT in improving static balance. Article not retained for quantitative analysis (lack of normality).	6

BMI: Body Mass Index -KT: K-Taping © - Nc (e): number of participants in control (experimental) group - SD: Standard deviation - μd: mean

Table 1 b) Strengthening interventions

Authors	Population	Intervention	Outcomes	Results	PEDro score
Amiridis et al., 2005	— Ne=10 men (72.4 SD 3.5 years) Nc=11 men (71.9 SD 7.1 years)	40 min of electrostimulation of the TA accompanied by active isometric dorsiflexion of the ankle 4 times a week for 4 weeks.	Static balance: AP and ML COP displacements (in cm) in RS (feet together) and SLS conditions.	Improvement in dorsiflexion moment increases postural balance. Reductions in postural sways after electrostimulation of the tibialis anterior and increase in the contribution of the ankle muscles to postural control COP trajectory length in SLS condition and in the anteroposterior axis: +Experimental group: μd= 0.38 mm and SD= 0.06 mm +Control group: μd= − 0.28 mm and SD= 0.04 mm	4
Kobayashi et al., 2015	Ne: 17 men (73 SD 5 years) and 15 women (70 SD 7 years) Nc:14 men (72 SD 5 years) and 10 women (70 SD 5 years).	Maximum plantar flexion as fast as possible every 5 sec, 10 times, sitting on a chair, in series of 3. Performed in the laboratory 2 days a week for 4 weeks.	Static balance: length of movement and surface of the COP in SLS condition.	Explosive-type muscle strengthening improves the rate of force moment development but not postural stability COP path length in SLS condition: Experimental group: μd= −23.97 mm and SD= 49.09 mm Control group: μd= 27.75 mm and SD= 35.54 mm	4
Ema et al., 2017	Nt:34 (17+17) men (73 SD 5 years).	Performed 3 sets of 10 heel-raises as fast as possible for 8 weeks, 3 times per week.	Static balance: speed (mm/s) of the COP trajectory in OLB condition.	Training increases plantar flexion force production capacity as well as maximum activation capacity of the sural triceps but does not improve postural balance. COP movement speed in SLS condition: Experimental group: μd= 12% and SD= 21% Control group: μd= 12% and SD= 25%	5
Barbosa et al., 2020	Nt=30 women (65.7 SD 5.1 years) nwline Nc=10 (66.1 SD 4.5) Ne5%=10 (64.6 SD 4.3) Ne10%=10 (66.5 SD 6.5)	5 series for each lower limb of maintenance of plantar isometric force for 30 s once a week for 4 weeks at 5% or 10 % of MVIC for the experimental groups	Static balance (EC): • mean sway amplitude (cm) • mean sway speed (cm/s) • frequency of sway (Hz)	The stability training decreased the force variability for both groups (Ne5% and Ne10%), but it increased the postural sways COP mean sways speed in AP direction: Experimental group (Ne5%): μd= 0.3 cm/s and SD=0.22 cm/s Control group: μd= 0.01 cm/s and SD= 0.05 cm/s	

AP :antero-posterior – EC : Eyes Closed – GL:gastrocnemius lateral - GM: gastrocnemius medial - MVIC :maximum Voluntary Isometric Force - Nt: entire sample – Nc: Control group - PF :plantar flexors – RF: rectus femoralis - TA: Tibialis Anterior – TS: Triceps Surae

Table 1 c) Both ankle R.O.M. and strengthening intervention

Authors	Population	Intervention	Outcomes	Results	PEDro score
Gras et al., 2004	N ankle: 19 women (77.8 SD 5.7 years). N hip: 16 subjects including 1 man (74.3 SD 5.7 years).	Home stretching exercises performed 5 times a week for 4 min. Home strengthening exercises: 3 sets of 15 repetitions each 3 times a week. Total duration of 8 weeks.	Static balance: • SLS • time of holding foot • joints and in tandem position Dynamic balance: • Walking speed over 6m. • TUG	No improvement obtained on each of the criteria measured and between groups (α=0.05). As this study is the only one in this category, no comparison is possible.	4

Description of interventions

With regard to the variables measured, several studies evluated the link between ankle R.O.M. (dorsiflexion and plantar flexion) or strength of ankle muscles and balance.
For ankle R.O.M., several techniques were used: joint mobilisation in three studies [21, 22, 23] and stretching in two studies [24, 25]. Concerning stretching, Shafizadegan is the only author not to measure ankle R.O.M. The aim of her study was to compare the effectiveness of stretching versus k-taping ® on static balance. The measurement of dorsiflexion and plantar flexion of the ankle was obtained by goniometry [21, 22, 23, 24]. In his study Gajdosik only assessed dorsiflexion.
For the interventions that aimed to strengthen the plantar flexors (gastrocnemius or sural triceps alone), voluntary explosive contraction or 5% and 10% of Maximum Voluntary Isometric Force (MVIC) is asked to the experimental groups [13, 24, 25]. The tibialis anterior was strengthened by electrostimulation in one study [26]. The gain in muscle strength was measured by electromyogram (EMG) [13, 24, 26, 27]dynamometry [13, 24, 27], and 2D movement analysis [28] and muscle volume using ultrasound [26].
One study's goal was to observe the effects of strengthening and stretching both ankle or hip muscles on balance [29].

Primary outcomes measures

Static balance was measured by clinical tests such as SLS [23, 25], the FRT [20, 22] or Lateral Reach (LR) [23]. It was also measured using a posturology platform [13, 21, 25, 26, 27, 28] as length of the center of pressure (COP) trajectory alone or in the SLS condition, in the Romberg position with or without feet together, some authors added the COP area. Baropodometry was used in one study [22].
Dynamic balance was measured in three studies for those with ankle R.O.M. interventions using clinical tests such as the modified or unmodified TUG [22, 23, 24] or the 10MWT [24].
Dynamic balance was not evaluated in any of the studies that included strengthening exercises.

Risk of Bias Within Studies

The mean PEDro score of the selected articles was 4.8/10 [3, 4, 5, 6], which is considered as medium [19]. Nine articles had a score between 4 and 6 and only one was lower than 4. Only one study [24] concealed group assignment. In addition, no study had therapist and subject blinding. The interventions tested in these studies do not allow therapist blinding. However, an evaluator different than the therapist performed the measures in two studies [22, 29]. The study of Gong did not have comparable groups at baseline. Three studies did not follow subjects to completion, and no studies were conducted on an intention-to-treat basis.

Effects of interventions on balance

Effect of ankle R.O.M. interventions on balance

These interventions refers to mobilisation or stretching.
Among 5 studies measuring static balance, 3 observed a significant improvement [21, 23, 25]. In the statistical comparison, the study by Shafizadegan et al. was not included because he data did not followed a normal distribution.

Meta-analyses of ankle R.OM. interventions (Figure 2) revealed no effects on static balance (SMD =1.49; 95% CI = −0.15 to 3.12; P = 0.07 ; I^2 = 93%). Subgroup analyses of ankle R.OM. interventions were pooled into mobilisations and static stretching.
For the subgroup mobilisation, the meta-analysis reported a significant difference in favour of the mobilisation group on static balance (SMD =2.06; 95% CI = 0.15 to 3.97; P = 0.03 ; I^2 = 93%). On the contrary, static stretching had no improvement on static balance (SMD =−0.25; 95% CI = −1.15 to 0.66; P = 0.66).
Concerning dynamic balance, 2 studies showed a significant improvement [23, 24].

Meta-analyses of ankle R.O.M. interventions (Figure 3) revealed no dynamic balance improvement (SMD = 0.56; 95% CI = −0.46 to 1.58; P = 0.28; I^2 = 80%). Subgroup analyses of ankle R.O.M. interventions were also pooled into mobilisations and static stretching.
For the subgroup mobilisation, the results demonstrated no effect on dynamic balance (SMD =0.80; 95% CI = −0.73 to 2.33; P = 0.31; I^2 = 88%). Static stretching did not show any improvement on dynamic balance (SMD =0.05; 95% CI = −0.85 to 0.95; P = 0.91).
For all of these comparisons, the rate of heterogeneity is high (over than 80%). The sensitivity analysis does not identify a study that can worsen the overall heterogeneity.

Effect of strengthening

For the 4 studies [13, 26, 27, 28] with strengthening interventions, 3 studies did not demonstrate improvement in static balance, unlike Amiridis' study which show an improvement in static balance by electrostimulation of the tibialis anterior [28]. Three of them [13, 24, 26] concluded that there was an improvement in the moment of force of the muscles and in one, a decrease in force variability [26].

Meta-analyses of strengthening interventions (Figure 4) revealed no difference between the 2 groups on static balance (SMD = 1.01; 95% CI = −0.48 to 2.51; P = 0.18 ; I^2 = 91%).
A sensitivity analysis (Figure 5) could explain the inconsistency (I^2 = 0%) when excluding Amiridis' study (wide CI).

The funnel plot is not feasible due to the small number of studies (< 10).

Assessment of the certainty using the GRADE classification

Concerning the GRADE approach, the two outcomes (static and dynamic balance) measures for this study are reliable. The risk of bias for each outcome is serious and thus downgraded it of 1 level. Furthermore, inconsistency is very serious (I^2 > 90%) except for static balance and strengthening (heterogeneity had been explained by removing Amiridis' study). Most of the studies suffer from imprecision due to the small numbers of participants. We thus assign a low-to-moderate level of evidence of ankle R.O.M for improving static balance, a moderate level of evidence of ankle strengthening for improving static balance and a low-tomoderate level of evidence for improving dynamic balance with ankle R.O.M interventions.

Table 2 PEDro scores

	1	2	3	4	5	6	7	8	9	10	11	Total score /10
Gras *et al.*, 2004	1	1	0	0	0	0	1	0	0	1	1	4
Gajdosik *et al.*, 2005	1	1	1	1	0	0	0	1	0	1	1	6
Amiridis *et al.*, 2005	0	1	0	1	0	0	0	0	0	1	1	4
Gong *et al.*, 2010	1	1	0	1	0	0	0	0	0	0	1	3
Cho *et al.*, 2011	0	1	0	1	0	0	0	1	0	1	1	5
Pertille *et al.*, 2012	1	1	0	1	0	0	1	1	0	1	1	6
Kobayashi *et al.*, 2015	0	1	0	1	0	0	0	0	0	1	1	4
Ema *et al.*, 2017	0	1	0	1	0	0	0	1	0	1	1	5
Shafizadegan *et al.*, 2019	1	1	0	1	0	0	1	1	0	1	1	6
Barbosa *et al**., 2020	1	1	0	1	0	0	0	1	0	1	1	5

*1 Eligibility criteria, 2 Random allocation 3 Concealed allocation, 4 Groups similar at baseline, 5 Participant blinding, 6 Therapist blinding, 7 Assessor blinding, 8 <15% dropouts, 9 Intention-to-treat analysis, 10 Between-group statistical comparison, 11 Point measures and variability data. *Not extracted from PEDro website.*

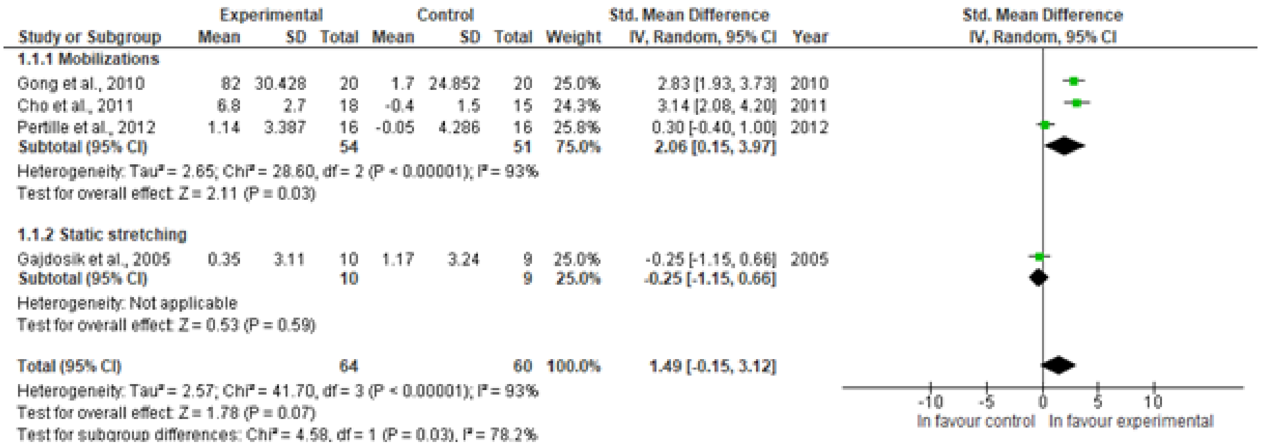

Figure 2 Forest plot of the effects of ankle R.O.M interventions on static balance

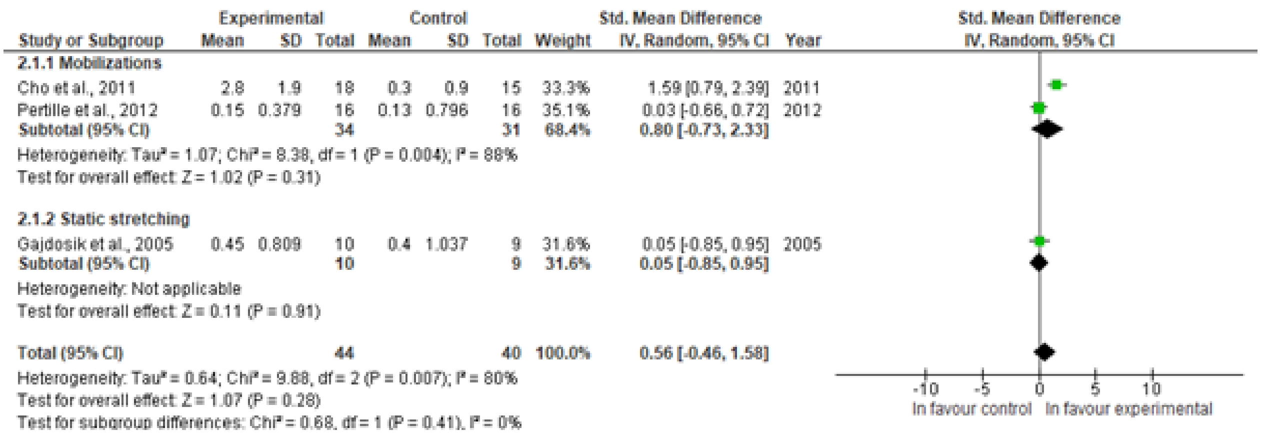

Figure 3 Forest plot of ankle R.O.M. interventions on dynamic balance

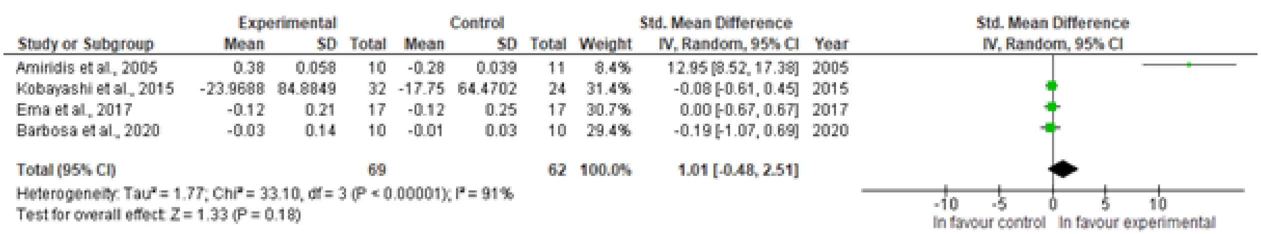

Figure 4 Forest plot of strengthening interventions on static balance

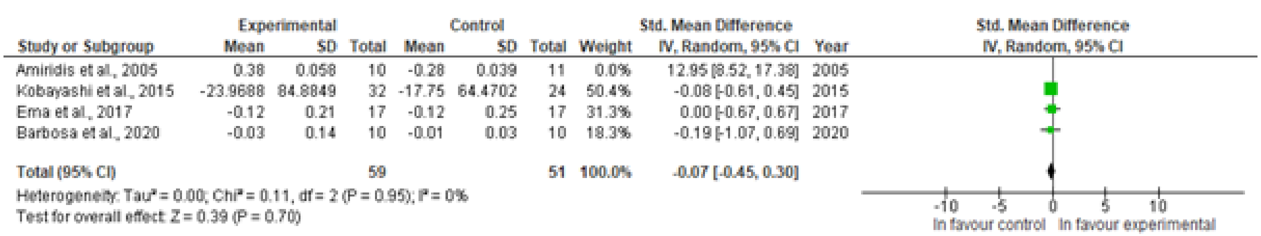

Figure 5 Forest plot of muscular strengthening on static balance, study of Amiridis removed

Discussion

Effects of mobilisations and stretching

The authors found that grade III and IV mobilisations improve static balance. These techniques are standardised and therefore lend themselves perfectly to research. The 3 studies which used these techniques [20, 21, 22] are quite comparable, except for Gong's additional mobilisation of the midfoot joints. The other differences mainly concern the different tests used (stabilometry, SLS) and the duration of treatment, which may

Table 3 Certainty assessment of evidence for each outcome

No of studies	Design	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Association	Certainty (overall score)
Outcome: Static balance by ankle ROM								
4	RCT	Serious −0.5	Very serious: −1	None	Serious	Not applicable	Not strong	2: Low to moderate
Outcome: Static balance by ankle strength								
4	RCT	Serious −0.5	None	None	Serious	Not applicable	Not strong	3: Moderate
Outcome: Dynamic balance by ankle ROM								
3	RCT	Serious −0.5	Very serious: −1	None	Serious	Not applicable	Not strong	2: Low to moderate

explain the high rate of heterogeneity. Contrary to Gong and Cho, Pertille studied the immediate effects and didn't obtain any improvement in joint amplitude or balance. For Gong and Cho, sessions performed over a minimum of 4 weeks improved static balance which is consistent with the literature [30].

The beneficial effects of repeated mobilisations over 4 weeks on static balance (back and forth movements for 7 to 8 minutes) could be explained by an excitation of the joint receptors, thus making the detection of imbalances more effective. Older adults have a less effective sense of discrimination of their ankle movements than younger adults [3].

Clinical relevance cannot be confirmed due to the lack of MCID of the different tests in scientific literature.

The stretching interventions did not show any beneficial effects on static balance. This is consistent with a study done by Han, who observed that seniors had difficulty maintaining their balance directly after static stretching [31]. We can assume that stretching transiently modifies the excitability of the neuro-muscular spindle (NMS). A delay in recalibration of these same NMS would then be necessary.

Effects of strengthening

Studies aiming to strengthen the ankle muscles did not show any improvement in static balance of older adults though they report a gain in strength. These studies are different: Amiridis noted an improvement in static balance after electrostimulation of the tibialis anterior whereas Kobayashi and Ema did not find any difference after explosive strengthening of the calf muscles.

Finally, ageing is a polymodal phenomenon. As proposed by Cattagni et al [32], it seems more appropriate for us to talk about neuromuscular ageing rather than isolated muscular ageing. When comparing fallers to non-fallers, they noted a deficit of supra-spinal origin as the cause of falls rather than a spinal origin (Ia fibers afferent to the α motor neurons), in the context of a decrease in maximal voluntary contraction of the plantar flexors. The authors noted that muscles' intrinsic changes are accompanied by an alteration of the supra-spinal structures controlling muscular contractions. Rehabilitation movements involving supra-spinal loops at a cortical and sub-cortical level would be better suited for improving balance in older adults that are subject to falling rather than muscle strengthening on its own.

To conclude, whilst dynamic balance did not improve we have seen that joint mobilisations improve static balance. The clinical tests used to study dynamic balance are the TUG and the 10MWT. In a simplistic way, we can say that dynamic balance requires much greater motor control [33] than static balance. The ageing of cortical structures (motor and premotor areas) must therefore be considered in this situation with a controlled mode of regulation, unlike static balance which acts according to a reflex mode. If the outcomes of these studies were cinematic gait analysis, the results would have been different.

Limitations

The high rates of heterogeneity could be explained for several reasons. First, as stated before, selection bias is evident. The participants ranged from people from sports associations for seniors to people hospitalised in follow-up care and rehabilitation service which is why their performances in terms of balance seem to be very different. In that way, no article included frail older adults whereas they are able to improve their performance [34].

Secondly, studies had different methods of evaluating balance. For many balance tests, the MCID is not reported therefore no clinical relevance can be established. Finally, the interventions in the various studies were also quite different.

Many questions remained unanswered here such as the kind of grade of ankle mobilisation to use, the effect of this rehabilitation on frail people and the effect of eccentric contraction on ankle muscles. Many other studies could be performed to answer these questions.

Conclusion

As seen previously, grade III and IV mobilisations improve the static balance of older adults. However, we do not know how they are performed, nor do we know what contribution they make to a rehabilitation program for balance. Stretching did show some effect on the improvement of static and dynamic balance. Then, muscle strengthening, especially of the explosive or isometric type, does not seem to improve static balance. This is to be considered in the context of important selection bias with much younger participants. It would be necessary to consider frail seniors, in particular of eccentric strengthening of the sural triceps, with regards to data on of gait analysis. Finally, no intervention showed improvement when it comes to dynamic balance, most likely because of some cortical involvement in the realisation of the movement, which was not considered in this study as it was based on the muscle and the joint. It is clear that further high-powered randomised trials are needed to improve methodological quality.

Statement and declaration

Authors' contribution

The authors confirm contribution to the paper as follows:

- FB : Contributions for concept development, design, data collection/processing, analysis/interpretation, literature search and writ-

ing.
- FM : Contributions for supervision and critical review.
- AK : Contributions for data collection/processing, analysis/interpretation, writing, supervision and critical review

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Competing Interests

None.

Disclosure statement

All authors declare they have neither financial nor non-financial interests.

Ethics

No health information was collected during the study.

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