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Efficacy of ankle mobilization on postural control in older people: A systematic review with meta-analysis

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A R T I C L E I N F O

Keywords:
Manual therapy
Ankle
Postural balance
Older adult

A B S T R A C T

Objective: To determine whether manual therapy based on joint mobilization techniques applied to recover a limited range of motion (ROM) in older adults could have a beneficial effect on balance.
Methods: Systematic review from MEDLINE, Embase, Cochrane Library, PEDro, WOS, Scopus, and Scielo, including studies with participants over 60, an experimental intervention based on ankle joint mobilization techniques, oriented to restore ankle ROM and assessing the effects on balance and ROM. A descriptive synthesis and a meta-analysis were conducted to estimate the effect of the interventions on balance and ROM, based on mean differences, with CI set at 95 %. Quality was assessed with PEDro scale and risk of bias with the Cochrane tool.
Results: A total of 8 studies were included in the qualitative and 5 in the quantitative synthesis. Manual therapy was shown to be effective, by overall increasing the ankle ROM by 11.3° (95 % CI 6.4 to 15.6). The monopodal stability was improved in 5.8 s (95 % CI 0.1 to 11.4) and the margins of stability in 4.4 cm (95 % CI 0.6 to 8.6). The static balance improved in terms of the center of pressure swayed area with a decrease of 78.4 mm^2 (95 % CI 46.1 to 110.6), but not of velocity (95 % CI 24.7 to −36.7). The Timed up and go time decreased by 0.86 s (95 % CI 0.38 to −2.08).
Conclusions: Manual therapy based on joint mobilization techniques is an effective approach to increase ankle ROM, with benefits on the stability of older adults.

Implications for practice

- The arthrokinematics of the ankle is important for the balance of the elderly
- Manual therapy has shown to be effective in recovering ankle ROM, with a positive effect on balance in older adults.
- Manual therapy has a positive effect on balance in older adults. Further research is necessary to identify the impact of dosage parameters.

1. Introduction

Overall, balance begins to decline in a progressive way from midlife, starting at about age 50 [1,2]. Sensory, motor and integrative systems participate and interact in postural control; any deterioration in these systems, or in the underlying mechanisms of balance, will affect this complex ability [3]. According to the systems framework for postural control [3], having a normal joint biomechanical function is one of the essential factors to adequately perform the movements and corrections

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that allow maintaining balance [4]. The foot and ankle are of especial importance [5–7], since they constitute the base of support of the body and transmit the loads to the ground [8]. However, common age-related alterations such as loss of strength and limited range of motion (ROM) due to loss of quality of the musculature or joint complex has a negative impact on balance [3,9], by altering gait patterns and increasing the risk of falls, among other consequences [10–12]. Therefore, it is important to know how different treatments for each of these limitations can affect postural control in older people.

In the case of the ankle arthrokinematics, manual therapy based on joint mobilization techniques has proven to be a useful tool to recover the normal range of movement [13–16]. Some studies found that this approach applied in the foot and ankle joints can result in a positive effect on balance [17,18]. The individual studies suggested benefits with just one session of treatment, whereas an increased number of sessions could be even more beneficial [19]. However, no current review has comprehensively and quantitatively synthesized the available evidence on the topic [20,21]. Given the above factors, this systematic review sought to answer the question of whether manual therapy – based on joint mobilization techniques – applied to restore or improve ankle ROM in older adults, could have a beneficial effect on balance.

2. Methods

This was a systematic review of the literature that adhered to the PRISMA statement and was prospectively registered in the Prospero International Prospective Register of Systematic Reviews (XXX-XXXXX) [22]. There was no link or financial commitment in any organization or entity with a direct economic interest in the matter dealt with in this work.

2.1. Eligibility criteria

The eligibility criteria were as follows: experimental studies, including participants aged over 60, in which the experimental intervention was based on applying a manual therapy technique to mobilize the joint of the ankle and/or foot to improve postural balance. Overall manual therapy is considered a specialized area of physiotherapy and related disciplines for the management of neuro-musculoskeletal conditions, based on clinical reasoning, using highly specific treatment approaches including manual techniques and therapeutic exercises [23, 24]. In this review, we considered those treatments based on manual techniques applied by the caregiver, applied at high or low speed, and graduated in intensity, with an undetermined duration of time. Those interventions in which manual techniques were applied by the patient, even if they were supervised, were not considered. If the studies had control interventions, this could be a placebo, no intervention, or the same intervention as in the experimental group but without applying manual therapy treatment. The studies had to assess the effects of the intervention(s) on balance and, if possible, on ankle ROM.

2.2. Data sources and search strategy

MEDLINE, Embase, Cochrane Library, PEDro, WOS, Scopus, and Scielo were the databases searched. The searches were conducted from inception – no time limitation – to June 2023. The search terms were based on the PICO strategy [25], considering that the population were older adults, the intervention was manual therapy techniques, and the outcomes were postural balance or ankle ROM. The PICO categories were linked with the Boolean index AND, and the terms within the same category with OR. The symbol * was used to add all derivations for each term. The literature was limited to randomized trials written in the English or Spanish language and to human subjects. An example of the search strategy is shown in Appendix 1 and 2.

2.3. Identification of studies and data extraction

Two independent reviewers performed the searches. The articles that potentially met the inclusion criteria according to titles and abstracts were pre-included, and the full-text versions were extracted and read in-depth to check compliance with the eligibility criteria. The articles that did not meet such criteria were excluded. Subsequently, the reviewers collated the information and discussed the results. In case of disagreement, a third author was consulted. The reliability in study identification was assessed using Kappa (k) coefficients by ordering categories – potentially include, include, or not include – and considering the poor, reasonable, moderate, good agreement, or very good agreement with cutoff scores for k categories being 0.2, 0.4, 0.6, and 0.8 respectively.

Once an inclusion agreement was achieved, the generic information of each article was extracted by the same reviewers, including the name of the author, the year of publication, and the title. In addition, the information considered relevant was also extracted, including the study design, characteristics of the sample, the interventions (experimental, control, duration of intervention, number of sessions, etc.), and outcomes (i.e., measures and assessment time points). The reliability of this process was also verified with k coefficients. The forms and procedures of extraction were those estimated before resolving the disagreements between the reviewers by consensus.

2.4. Outcomes

The primary outcome was balance. Any measure used by the studies to assess this outcome was considered [26]. Accordingly, we a priori classified possible balance measures considering the following categories and definitions: dynamic balance [27], defined as the ability to maintain postural control while switching between positions and regardless of whether the base of support changed; static balance [28], as the ability to maintain balance in a static position without movement of the base of support; stability [29], assessed by any measure that tested the limits or margins of stability; and the overall state of balance, assessed by outcome measures or questionnaires that collected information of the previous categories. The ankle ROM was also an outcome of interest, regardless of whether it was measured in active or passive movement, or while bearing the weight or not.

2.5. Quality assessment and risk of bias

The methodological quality of the selected studies was scored using the PEDro scale [22]. The values were taken from the PEDro database. The score can range from 0 to 10 and, for its interpretation, the studies can be classified for its poor (<3), fair (4–5), good (6–8), or excellent quality (>8). Two reviewers extracted the individual scores from the PEDro database when they were available or rated the articles when they were not. In addition, The Cochrane Collaboration tool was used to assess risk of bias and internal validity of the included randomized trials. This tool covers six domains of bias: selection bias, performance bias, detection bias, attrition bias, reporting bias, and other sources of bias [30]. The tool prompts the user to assign a judgment of low, high or unclear to the risk of bias. The information was provided with the scoring criteria and the motivation for its use.

2.6. Data synthesis

First, a narrative synthesis was undertaken. A qualitative analysis was performed through a thematic analysis. The characteristics of the studies were tabulated, classifying the type of study and design, characteristics of the sample, design of the interventions, including the type of maneuvers, duration, intensity, and measurement times, as well as the scoring systems used to estimate the balance and ankle ROM of the older adult. The effects of the interventions were established according to the strength of association estimated at 95 %, since all the studies proposed this interval. When possible, the effects of the intervention were quantitatively synthesized with meta-analysis, which was conducted with the Reviewer Manager Software 5®. This analysis compared the experimental (manual therapy) and control interventions. The comparisons were conducted using the rate of baseline-to-time point improvement (i.e., mean difference or percentage change). The time point closest to the end of the experimental intervention was considered. The mean, standard deviation, and sample size were used to estimate the effects of the interventions; otherwise, these were pooled from the available data. The included studies used consistent scoring systems to assess the same outcome categories, so the calculations were conducted with mean differences and confidence intervals at 95 %. The analysis was conducted using the random effect model, assuming variations in true effect due to heterogeneity in the study design. The heterogeneity assessment was based on I^2 statistics and was considered high over 50 %. The summary value was represented in forest plots.

The Grade of Recommendation Assessment, Development, and Evaluation (GRADE) was used to determine the strength of the resultant evidence and external validity of findings and suggested the overall certainty for each outcome. Based on the cumulative interpretation of five criteria, the evidence was downgraded from high to moderate, low or very low, the criteria being: 1) methodological quality and risk of bias, which was downgraded if more than 25 % of the participants were from studies with poor methodological quality; 2) inconsistency of results, which was downgraded if significant heterogeneity or if I^2>50 %; 3) indirectness or generalizability of the findings, which was downgraded if the participants were not equally distributed between the groups, e.g., more than 55 % of the participants were outside the target group or intervention established in the eligibility criteria; 4) imprecision, downgraded if the 95 % confidence interval around the best

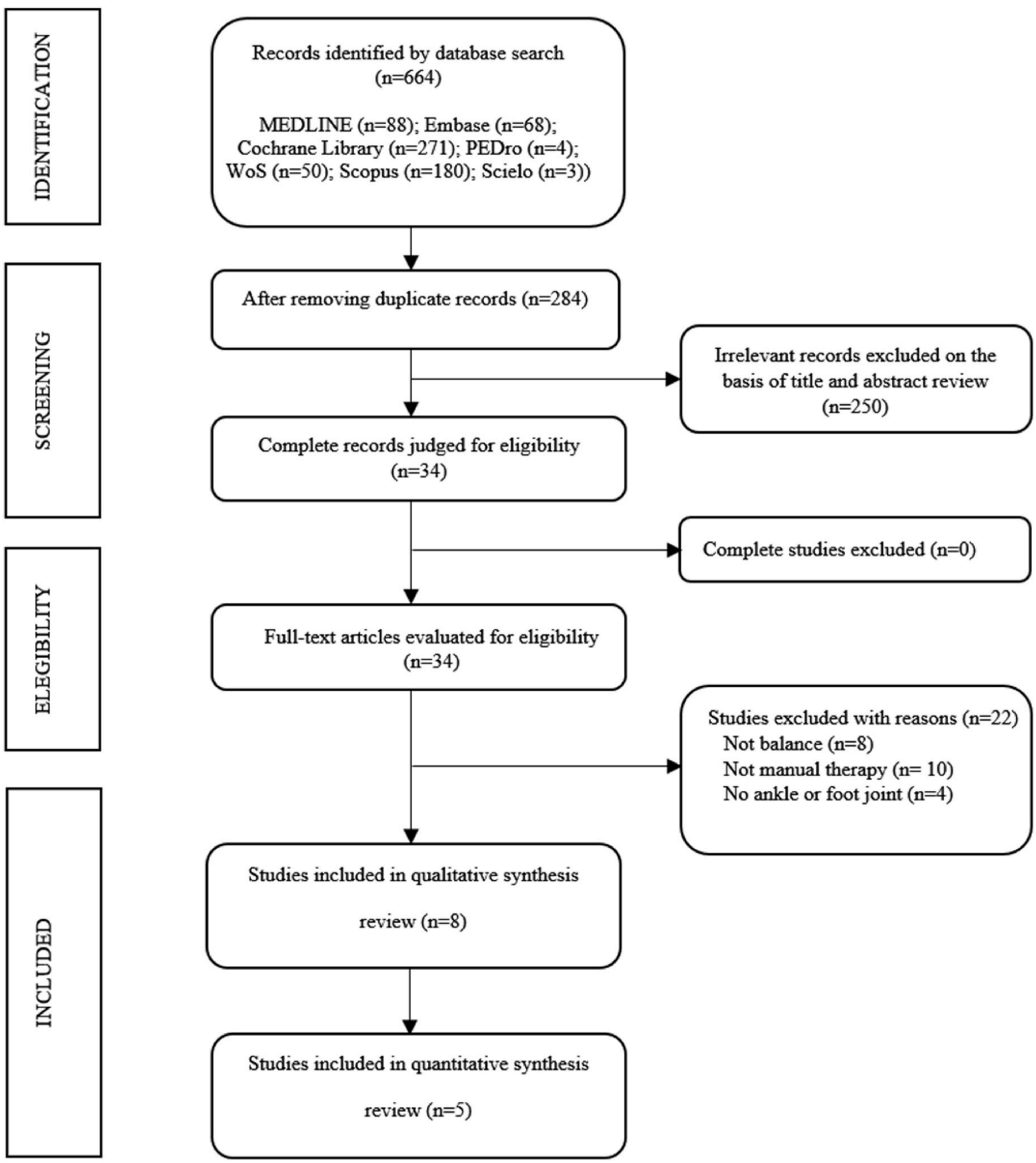


Fig. 1. Flowchart of studies.

estimate of the absolute effect was wide, or when the effect estimates came from only one or two small studies or if there were few events [34]; 5) other factors, such as reporting or publication bias.

3. Results

3.1. Included studies

The search carried out from inception to June 2023 resulted in a total of 664 articles. After a first screening and removing duplicates, 34 articles were downloaded and read in depth. Eight of them fully met the inclusion criteria and were included in the synthesis. Of these, six were randomized clinical trials [21,31–35] – one with a cross-over design [35], and another applied manual therapy as a complementary intervention [36], and the two studies with one group of participants undergoing the experimental intervention (Fig. 1) [20,37]. In the end, five studies with both, experimental and control groups, were included in the meta-analysis [20,21,31,34,35]. The consistency in study identification was perfect with $k = 1$, and in data extraction was very good $k = 0.84$.

3.2. Methodological quality and risk of bias

As shown in Table 1, the quality as assessed with the PEDro scale was fair to good in five studies [31–35], and high in one [21]. The summary risk of bias assessed with the Cochrane Collaboration tool suggested that the highest risk of bias in studies was the item *Measurement of the outcome*, while *Timing of identification or recruitment of participants* and *Missing outcome data* were the lowest (Appendix 3).

3.3. Participants and characteristics of interventions

A total of 237 participants with a mean age of 72.5 (SD = 4.7) years were included. The experimental interventions were oriented to mobilize the ankle joint [20,21,31], but also the ankle and joints of the foot too [32,33,35,37]. The number of sessions ranged from one to 12, with four studies applying just one session [20,21,35,37]; one study four [33], six [34], or 12 sessions in two studies [31,32]. The intensity applied in the interventions varied between grade III [21,31,33] and grade IV [32,34], whereas three studies did not specify the treatment intensity [20,35,37]. As for those studies with control group, either the control group received no intervention [31–33], or a placebo treatment similar to that of the experimental group but with no force or pressure applied [21,34], or simulating a treatment with demagnetized magnets [35]. In one study, both groups also performed exercise to improve balance, and manual therapy was the differentiating factor of the intervention [33]. All the details are shown in Table 2.

3.4. Outcomes and use in meta-analysis

All the balance categories that were established a priori were analyzed. Specifically, four studies included the Timed up and go [21, 31,34,35], a timed test of general mobility normally used to assess dynamic balance; therefore, these data were used to estimate the impact of the experimental intervention on dynamic balance. The effects on stability were estimated with the lateral and functional reach test (margins of stability) [31,34,35], and with the single-leg balance test (monopodal stability) results [21,31,34,35]. Five studies used dynamometric platforms to assess the effects on static balance [20,21,32,34,37], and two of them could be included in meta-analysis [32,34], that determined the improvements in the swayed area and velocity of the center of pressure while standing. As for the effects on ankle ROM, the studies presented the measures in different ways (e.g., overall, dorsiflexion, plantarflexion ROM). Baseline improvements in the overall ROM were estimated from the extracted data to synthesize this outcome [21,31,32,34].

3.5. Effects of interventions

The experimental intervention decreased the time needed to complete the Timed up and go test in 0.85 (95 % CI 0.38 to −2.08) seconds, with low overall quality of this evidence, downgraded due to inconsistency and imprecision. The monopodal stability was improved in 5.8 s (95 % CI 0.1 to 11.4) and the margins of stability increased in 4.4 cm (95 % CI 0.6 to 8.6), with moderate quality of this evidence. The static balance improved in terms of the center of pressure swayed area with a decrease of 78.4 mm^2 (95 % CI 46.1 to 110.6), but not of velocity (95 % CI 24.7 to −36.7) as shown in Table 3, the quality of the evidence according to GRADE is shown in Table 4. As for the ankle ROM, the experimental intervention shown to be effective, by overall increasing 11.3° (95 % CI 6.4 to 15.6) the ankle range of motion, as shown in Table 5, despite the elevated heterogeneity of the studies included there was a moderate overall quality of this evidence. An additional qualitative synthesis of the eight included studies is shown in Appendix 4.

4. Discussion

This study found that the participating older adults undergoing a manual therapy intervention increased their ankle range of motion with a likely positive effect on balance. According to the findings of the quantitative synthesis, manual therapy overall improved ankle ROM by more than 11°, and this could enhance balance in some, but not all, of the measured aspects. Specifically, the main positive effect was produced in measures of stability, but not in general mobility (i.e., dynamic balance). The results of the qualitative synthesis were consistent with these findings. However, some of the statements are based on limited evidence, as is further discussed.

The results suggested improvements, mainly in terms of stability measures and static balance, supporting the hypothesis that improving the ankle ROM can have a positive effect on balance of older adults. However, not all the balance aspects that were evaluated improved, what limits the interpretation of such statement. In addition, the studies presented heterogeneity in their methods; for instance, some studies only mobilized the ankle joint, but others also foot joints. The number of mobilizations, the time spent in treatments – not always reported – or even the number of sessions, that ranged from one to 12, were not consistently applied. Therefore, our synthesis did not allow us to synthesize the most effective parameters of the intervention.

Table 1
PEDro scale scores of included articles.

Studies	1[a]	2	3	4	5	6	7	8	9	10	11	Total[a]
Cho (2012)	0	1	0	1	0	0	0	1	1	1	1	6
Gong (2011)	1	1	0	1	0	0	0	1	1	0	1	5
Hernández-Guillén (2019)	1	1	1	1	0	0	1	1	1	1	1	8
Hernández-Guillén (2022)	1	1	1	1	0	0	1	1	1	1	1	8
Pertille (2012)	1	1	1	1	1	0	1	1	1	1	1	9
Vaillant (2009)	1	0	0	1	1	0	0	1	1	1	1	6

[a] Point 1 is not used to calculate the total score; 1: specified selection criteria; 2: random assignment; 3: hidden assignment; 4: similar groups at the beginning of the study; 5: blinding of the participant; 6: blinding of the therapist; 7: blinding of assessor; 8: <15 % dropouts; 9: intention-to-treat analysis; 10: difference between groups reported; 11: point estimate and reported variability.

Table 2
Summary of the included studies.

Studies		Participants	Intervention	Outcomes and measures
Chevutschi (2014)	IS	n = 19 Age = 83.1 (6.0) Gender = n.a.	Exp = Foot and ankle mobilizations (anterior-posterior talocrural joints; posterior-anterior tibial glides; flexion, extension, adduction, abduction, pronation and supination of the calcaneus); 1 session; 20 min; 30 s/mobilization; 10 repetitions; intensity = n.a.	Posturographic platform (COP) •ML – EO •AP – EO •Sway Path Lenght – EO •Area – EO •Dynamic ML – EO •Dynamic AP – EO •Dynamic Sway Path Lenght – EO •Dynamic Area – EO ROM •NWB – PDF (R, L) •NWB – PPF (R, L) Measures, follow-up: Baseline; Post-treatment (0 wk)
Cho (2012)	RCT	n = 33 (Exp 18, Con 15) Age = Exp 68.11 (4.1) Con 72.3 (6.8) Gender = 25 W (Exp 13, Con 12), 11 M (Exp 1, Con 2)	Exp = Ankle mobilization (traction, anterior and posterior gliding of the talocrural joint); 12 sessions; n.a. min; 30 s/mobilization; 3/week; intensity = grade III. Con = No intervention	Balance •TUG •OLB •LR ROM •NWB – ADF (Aver) •NWB – APF (Aver) Measures, follow-up: Baseline; Post-treatment (4 wk)
Gong (2011)	RCT	n = 40 (Exp 20, Con 20) Age = Exp 76.8 (6.8) Con 66.2 (3.5) Gender = 19 W (Exp 11, Con 8), 14 M (Exp 7, Con 7)	Exp = Foot and ankle mobilizations (anterior-posterior talocrural joints; mediolateral subtalar joints; anterior-posterior, torsion, flexion and extension in midtarsal points; anteroposterior glidind and rotation to tarso-metatarsal joints); 12 sessions; 20 min; 3/week; intensity = grade III - IV Con = No intervention	Posturographic platform (COP) •Area – EO •Sway Path Length - EO •Speed - EO ROM •NWB – ADF (R, L) •NWB – APF (R, L) Measures, follow-up: Baseline; Post-treatment (4 wk)
Hernández-Guillén (2019)	RCT	n = 28 (Exp 14, Con 14) Age = Exp 69.50 (4.38) Con 68.90 (5.53) Gender = n.a.	Exp = Balance training; 8 sessions; 40 min; 4 weeks + Foot and ankle mobilizations (anterior-posterior talar joint, mediolateral subtalar joint, superior-inferior and mediolateral mid-foot and anterior foot joints); 4 sessions; 15 min; 1/week; intensity = grade III Con = Balance training; 8 sessions; 40 min	Balance •Overall BBS ROM •NWB-Overall (Aver, R, L) Measures, follow-up: Baseline; Post-treatment 4 wk; 12wk
Hernández-Guillén (2022)	RCT	n = 40 (Exp 19, Con 21) Age = Exp 69.12 (3.33) Con 68.43 (3.40) Gender = 29 W (Exp 15, Con 14), 11 M (Exp 4, Con 7)	Exp = Anterior to posterior talus mobilization; 6 sessions; 3 mobilizations x 30 s; intensity = grade IV Con = Sham treatment: manual contact without pressure or movement; 6 sessions; 3 mobilizations x 30 s	Balance •TUG •OLB •FR Posturographic platform (COP) •Area – EO •Area – EC •Speed – EO •Speed - EC ROM •WB-Lunge (Aver, R, L) •NWB-Overall (Aver, R, L) Measures, follow-up: Baseline; Post-treatment (2 wk)
Pertille (2012)	RCT	n = 32 (Exp 16, Con 16) Age = Exp 71.9 (7.9) Con 72.9 (9.5) Gender = 32 W, 0 M	Exp = Anterior to posterior talus mobilization; 1 session; 6 mobilizations x 30 s; intensity = grade III Con = Sham treatment: manual contact without pressure or movement; 1 session; 6 mobilizations x 30 s	Balance •TUG •FR Posturographic platform (COP) •ML - EO •ML - EC •AP - EO •AP - EC ROM •NWB-APF (R, L) •NWB-ADF (R, L) Measures, follow-up: Baseline; Post-treatment (0 wk)
Vaillant (2008)	IS	n = 17 Age (yr) = 75.4 (9.6) Gender = 0 W, 17 M	Exp = Massage and foot and ankle mobilization (talar fibular, subtalar, midtarsal, tarsometatarsal, metatarsophalangeal, interphalangeal joints; 1 session; 20 min; intensity = n.a.	Posturographic platform (COP) •ML •AP Measures, follow-up: Baseline; Post-treatment (0 wk)
Vaillant (2009)	RCT-COS	n = 28 (Exp 28, Con 28) Age (yr) = 78.8 (8.5) Gender = 15 W, 13 M	Exp = Massage and mobilization of ankle and foot; 1 session; 20 min; 3 repetitions/movement; intensity = n.a. Con = Placebo treatment: application of demagnetized magnets in the region of the fifth metatarsal; 1 session; 20 min	Balance (functional) •TUG •OLB •LR Measures, follow-up: Baseline; Post-treatment (0 wk)

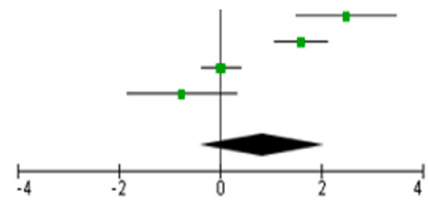
IS = Interventional Study (1 group); COS = Cross-Over Study; RCT = Randomized controlled trial; W = Women; M = Men; Exp = Experimental intervention; Con = Control intervention; n.a. = Not announced; wk = week OLB = One Leg Balance; TUG = Test Up and Go; FR = Functional Reach; LR = Functional Lateral Reach; ROM = Range of Movement; NWB = Non-weight bearing; WB = Weight bearing; APF = Active plantar flexion; ADF = Active dorsal flexion; COP = Centre of foot pressure; ML = Medio-lateral; AP = Antero posterior; EO = Eyes opened; EC = Eyes closed; Lunge = Lunge test; Overall = All the ankle range, from maximum dorsiflexion to maximum plantar flexion; BBS = Berg Balance Test; PDF = Passive dorsal flexion; PPF = Passive plantar flexion.

Table 3
Effects on balance. The figure shows the effects of the intervention on dynamic balance, static balance and stability.

1. Dynamic Balance (TUG) [s]

	Experimental			Control				Mean difference
Study	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95 % CI
Cho 2012	2.8	1.9	18	0.3	0.9	15	23.6 %	2.5 [1.51, 3.49]
Hernández-Guillén 2022	1.6	0.8	19	0	0.9	21	26.5 %	1.60 [1.07, 2.13]
Pertille 2012	0.15	0.34	16	0.13	0.71	16	27.1 %	0.02 [−0.37, 0.41]
Vaillant 2009	−0.92	2.63	28	−0.17	1.24	28	22.9 %	−0.75 [−1.83, 0.33]
Total (95 % CI)			**81**			**80**	**100.0 %**	**0.85 [−0.38, 2.08]**

Mean difference IV, Random, 95 % CI



Heterogeneity: Tau [2] = 1.41; Chi [2] = 42.67, df = 3 (P < 0.00001); I^2 = 93 %

Test for overall effect: Z = 1.35 (P = 0.18)

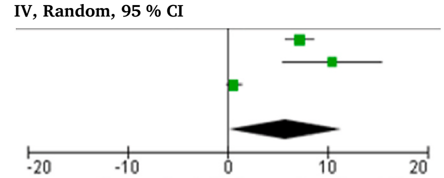
Favors [control] Favors [experimental]

2. Stability

2.1 Monopodal stability (OLB) [s]

Study	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95 % CI**
Cho 2012	6.8	2.7	18	−0.4	1.5	15	35.5 %	7.20 [5.74, 8.66]
Hernández-Guillén 2022	9.9	10.3	19	−0.6	3.9	21	28.4 %	10.50 [5.58, 15.42]
Vaillant 2009	1.05	1.65	28	0.41	1.19	28	36.1 %	0.64 [−0.11, 1.39]
Total (95 % CI)			**65**			**64**	**100.0 %**	**5.77 [0.14, 11.40]**

IV, Random, 95 % CI



Heterogeneity: Tau [2] = 22.68; Chi [2] = 72.42, df = 2 (P < 0.00001); I^2 = 97 %

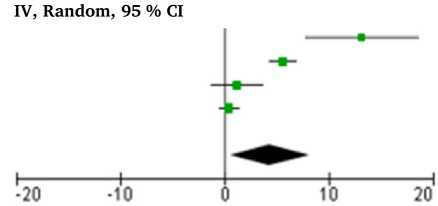
Test for overall effect: Z = 2.01 (P = 0.04)

Favors [control] Favors [experimental]

2.2 Margins of stability (FR, LR) [cm]

Study	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95 % CI**
Cho 2012	13.6	11.5	18	0.4	2.2	15	18.1 %	13.20 [7.77,18.63]
Hernández-Guillén 2022	5.4	2.2	19	−0.2	1.7	21	27.9 %	5.60 [4.37, 6.83]
Pertille 2012	1.14	3.06	16	−0.05	3.86	16	25.8 %	1.19 [−1.22, 3.60]
Vaillant 2009	1.28	2.27	28	0.83	1.25	28	28.3 %	0.45 [−0.51, 1.41]
Total (95 % CI)			**81**			**80**	**100.0 %**	**4.38 [0.60, 8.16]**

IV, Random, 95 % CI



Heterogeneity: Tau [2] = 12.91; Chi [2] = 58.07, df = 3 (P < 0.00001); I^2 = 95 %

Test for overall effect: Z = 2.27 (P = 0.02)

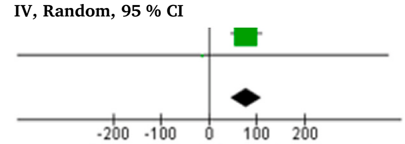
Favors [control] Favors [experimental]

3. Static balance (Platform)

3.1 Swayed area [mm^2]

Study	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95 % CI**
Gong 2011	85.7	70.42	20	6.7	22.02	20	99.3 %	79.00 [46.66, 111.34]
Hernández-Guillén 2022	5.9	639.3	19	17.9	602	21	0.7 %	−12.00 [−397.91, 373.91]
Total (95 % CI)			**39**			**41**	**100.0 %**	**79.37 [46.14, 110.59]**

IV, Random, 95 % CI



Heterogeneity: Tau [2] = 0.00; Chi [2] = 0.21, df = 1 (P < 0.00001); I^2 = 0 %

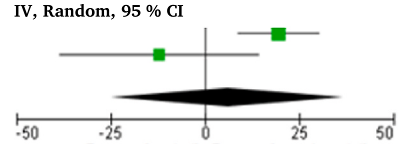
Test for overall effect: Z = 4.77 (P < 0.00001)

Favors [control] Favors [experimental]

3.2 Velocity [ms^{-1}]

Study	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95 % CI**
Gong 2011	23.5	24.16	20	4	4.06	20	57.5 %	19.50 [8.76, 30.24]
Hernández-Guillén 2022	−13.6	57	19	−1.4	13.9	21	42.5 %	−12.20 [−38.51, 14.11]
Total (95 % CI)			**39**			**41**	**100.0 %**	**6.02 [−24.70, 36.74]**

IV, Random, 95 % CI



Heterogeneity: Tau [2] = 397.34; Chi [2] = 4.78, df = 1 (P = 0.03); I^2 = 79 %

Test for overall effect: Z = 0.38 (P = 0.70)

Favors [control] Favors [experimental]

TUG = Timed up and go; OLB = one leg balance; FR = functional reach; LR = lateral reach; COP = center of pressures).

However, we can draw some conclusions. Overall, all the studies assessing the ankle ROM found improvements [20,32,34]. The studies suggesting a greater basal evolution in balance and ankle ROM were those applying a greater number of sessions [31,32,34]. A single session proved to be effective in most, but not all the studies [21], while the evidence seem to suggest that the ankle ROM may continue to improve slightly if the treatment volume is increased [19]. On the other hand, the trials agreed that the intensity should be at least a Grade III level according to Maitland [19], although in others it was opted to increase the intensity up to a Grade IV.

Regarding the reliability of the evidence on balance, some aspects should be noted. On the one hand, the synthesis was consistent in stating that the effects on balance were positive, with significance levels at 95 %. The scoring systems used to assess all balance aspects were also consistent, so it was not necessary to estimate effect sizes based on standardized mean differences, but on mean differences, providing a more realistic view of improvements. By contrast, the heterogeneity (I^2) in most estimations was high, which is a limiting factor, while the overall quality of the resultant evidence was low or very low in some outcome, specifically in terms of dynamic balance and velocity of the swayed area, as described in the GRADE table. Moreover, the synthesis of static balance was based on only two studies and the analysis of the individual studies showed non-consistent results. For this reason, and especially in terms of static balance, the findings should be interpreted with caution, and future studies should be oriented to research such effects.

Table 4
GRADE quality of the resultant evidence.

Outcome	Certainty assessment							Participants			Effect	Certainty
	n	Design	Quality	Inconsistency	Indirectness	Imprecision	Others	Manual therapy	Control	Total	Absolute (95 % CI)	
Balance												
1. Dynamic balance	4	RCT	(+)	(−)	(+)	(−)	None	81	80	161	0.8 (−0.4 to 2) s	Low
2. Stability												
1.2.2.1. Monopodal stability	3	RCT	(+)	(−)	(+)	(+)	None	65	64	129	5.8 (0–11) s	Moderate
2.2. Margins of stability	4	RCT	(+)	(−)	(+)	(+)	None	81	80	161	4.4 (0.6–8.2) cm	Moderate
3. Static balance												
3.3.1. Swayed area	2	RCT	(−)	(+)	(+)	(+)	None	39	41	80	78 (46–110) mm^2	Moderate
3.2. Velocity	2	RCT	(−)	(−)	(+)	(−)	None	39	41	80	6 (−24 to 36) m/s	Very low
Ankle ROM												
Ankle ROM	4	RCT	(+)	(−)	(+)	(+)	None	73	72	145	11 (6–15) degrees	Moderate

Table 5
Effects on the ankle range of motion (ROM).

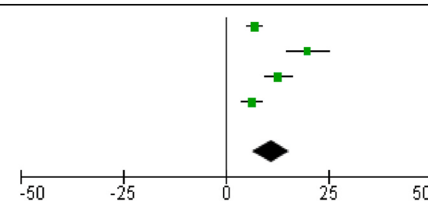
1. Dynamic Balance (TUG) [s]

Study	Experimental			Control				Mean difference
	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95 % CI
Cho 2012	7	3.8	18	0	1	15	27.5 %	7.00 [5.17, 8.83]
Gong 2011	24	11.5	20	4.1	2.8	20	21.0 %	19.90 [14.71, 25.09]
Hernández-Guillén 2022	10.1	5.3	19	−2.8	5.2	21	25.1 %	12.90 [9.64, 16.16]
Pertille 2012	5.7	4	16	−0.7	3.1	16	26.5 %	6.40 [3.92, 8.88]
Total (95 % CI)			**73**			**72**	**100.0 %**	**11.03 [6.44, 15.62]**

Heterogeneity: Tau [2] = 19.08; Chi [2] = 30.88, df = 3 ($P < 0.00001$); $I^2 = 90$ %

Test for overall effect: $Z = 4.71$ ($P < 0.00001$)

Mean difference
IV, Random, 95 % CI



Overall, the importance of this study is to support that manual therapy based on joint mobilization techniques, when applied to older adults with age-related limited ankle ROM, is effective in enhancing stability and static balance. It also reinforces the fact that ankle function is essential in balance. The potential clinical impact of this intervention is its ability to overcome ankle functional limitations and improve balance in a different way than conventional training methods. However, there are also limitations, most of which have been afore-discussed. The search was limited to articles in English and Spanish. In addition, it is worth considering the heterogeneity in the design of the interventions, the amount of evidence, which was limited in the quantitative synthesis of static balance – preventing us drawing reliable conclusions on this outcome –, the methodological quality of some studies, and the risk of bias in aspects such as the measurement of the outcomes.

5. Conclusion

Manual therapy based on joint mobilization techniques could be considered as an effective approach to increase ankle ROM of older adults, having a positive impact on stability outcome. Future research should be oriented to determine the effects on static balance.

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Ethical approval

Not applicable.

CRediT authorship contribution statement

David Hernández-Guillén: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Carmen García-Gomariz:** Conceptualization, Methodology, Resources, Writing – original draft, Writing – review & editing, Supervision. **Sergio Roig-Casasús:** Conceptualization, Investigation, Methodology, Software. **Beatriz Díaz-Díaz:** Investigation, Methodology. **Fernando Domínguez-Navarro:** Conceptualization, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **José Pérez-Maletzki:** Conceptualization, Formal analysis, Methodology, Resources. **José-María Blasco:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijosm.2024.100722.

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