

THE EFFECTIVENESS OF DIFFERENT LOWERBODY PLYOMETRIC EXERCISES AND HIP STRENGTHENING EXERCISE ON IMPROVING ANKLE INSTABILITY AMONG ATHLETES- A SYSTEMATIC REVIEW WITH BAYESIAN NETWORK METANALYSIS

Divya N¹, Hari Hara Subramanyan P.V¹, Parthasarathy R², Mahesh Kumar P.G³, Kamalakannan M⁴

¹Meenakshi college of Physiotherapy, Meenakshi Academy of Higher Education and Research, Chennai, Tamil Nadu, India. Email: ndivya@maherfpt.ac.in

¹Meenakshi college of Physiotherapy, Meenakshi Academy of Higher Education and Research, Chennai, Tamil Nadu, India. Email: hari@maherfpt.ac.in

²Meenakshi college of Physiotherapy, Meenakshi Academy of Higher Education and Research, Chennai, Tamil Nadu, India. Email: principal@maherfpt.ac.in

³Meenakshi college of Physiotherapy, Meenakshi Academy of Higher Education and Research, Chennai, Tamil Nadu, India. Email: mahesh@maherfpt.ac.in

⁴Saveetha College of Physiotherapy, Saveetha Institute of Medical and Technical Sciences, Chennai, Tamil Nadu, india. Email: kamal1712@gmail.com

ABSTRACT

Background: This study conducts a network meta-analysis to evaluate the effectiveness of lower body plyometric and hip strengthening exercises in improving ankle instability among athletes.

Methodology: A systematic search followed PRISMA guidelines across databases including PEDro, ScienceDirect, PUBMED, Cochrane Central, Web of Science, Google Scholar, and MEDLINE in November 2023. Studies published between 2013 and 2024 were included. Primary outcome measures were the Cumberland Ankle Instability Tool (CAIT), Ankle Instability Instrument (AII), Foot and Ankle Ability Measure (FAAM), and Vertical Jump Test. Secondary measures included the Ankle Joint Functional Assessment Tool (AJFAT) and Foot and Ankle Disability Index (ADI). After removing duplicates and screening, nine studies were selected. The PEDro scale assessed study quality. Bayesian NMA was conducted to compare intervention effectiveness and rank them.

Results: The systematic review included nine randomized controlled trials (RCTs) on ankle instability. However, only two RCTs evaluating vertical jump improvement were included in the network meta-analysis due to outcome measure heterogeneity in the other seven studies.

Conclusion: The meta-analysis suggests that fastened ankle multidirectional jumping and multidirectional jumping exercises are the most effective interventions for improving vertical jump in individuals with ankle instability.

KEYWORDS: Ankle instability, plyometrics, Fastened ankle multidirectional jumping exercises, Vertical jump test.

INTRODUCTION

Ankle sprains are common among athletes, with annual incidence ranging from 15% to 45% [1,4]. The reasons for the association between recurrence and altered biomechanics, proprioceptive deficits, ligament damage, neuromuscular dysfunction and muscular imbalance are discussed in the below. The reasons for the association between recurrence and altered biomechanics, proprioceptive deficits, ligament damage, neuromuscular dysfunction and muscular imbalance are discussed below. The risk factors are age, body mass index, muscle strength, landing performance and previous injuries [4,5]. If not treated properly, chronic ankle instability (CAI) [6] may result.

The CAI consists of recurrent dysfunction, laxity of the ligaments and mechanical or functional instability [5]. Mechanical instability is a measure of ligament laxity and functional ankle instability (FAI) is a condition characterised by recurrent episodes of giving way. Post ankle sprain, 32-47% of people develop FAI, which negatively impacts on their mobility, strength and proprioception and their quality of life [6-9]. It often occurs in athletes who play basketball, volleyball, and soccer [10]. Landing mechanics defects, fatigue, and limited mobility increases the risk for injury, joint degeneration, and abnormal compensatory movements [8,11-14].

Plyometric training involves a rapid stretch shorten cycle (SSC) of eccentric/concentric muscle contraction [15-20]. Strength, power, agility, balance and athletic performance are enhanced through exercises like hopping, jumping, and bounding [15,20-23]. Elastic energy storage and stretch reflexes and interactions between the muscle and tendon are important for the effectiveness of the SSC [22-24]. Slow and fast SSC are different in terms of the length of time that they have ground contact and the range of movement that occurs in the joints [25]. Progressive training involves eccentric, amortization, and concentric phases that enhances muscle adaptations and functional performance [16,26-30].

The hip abductors, extensors and external rotators give stability to the pelvis, gait mechanics and postural control [31-35]. Proximal neuromuscular control deficits are associated with CAI, and strengthening of the hip is associated with increased hip stability and decreased recurrence of symptoms [32,33,36,37].

Assessment instruments that have been validated are the Cumberland Ankle Instability Tool (CAIT) [38,39], Ankle Instability Instrument (AII) [40], Foot and Ankle Ability Measure (FAAM) [41] and Foot and Ankle Disability Index sports module (FADI-Sports) [42]. Strengthening and proprioceptive training can be combined to enhance rehabilitation [43]. Thus, the aim of this Bayesian network meta-analysis was to compare lower body plyometric and hip strengthening interventions for enhancing ankle instability in athletes.

Searching The Databases

A systematic search was conducted in November 2023 across PEDro, ScienceDirect, PubMed, Cochrane CENTRAL, Web of Science, Google Scholar, and MEDLINE for English-language studies published during 2013–2024. Expert consultation, literature reviews, and MeSH informed search terms. Boolean operators “AND” and “OR” combined population (athletes, ankle instability), intervention (plyometrics, hip strengthening, hopping), and comparison terms. Outcomes included CAIT, AII, FAAM, AJFAT, and FADI. Additional Google Scholar searches and reference screening identified relevant studies. Eligibility criteria guided selection. The review followed PRISMA guidelines (Figure 1) [60], with methodological quality assessed using the PEDro scale.

Selection Criteria

To be included in the network meta-analysis, original studies needed to fulfil the following inclusion criteria:

- **Participants:** Athletics participants of both sexes aged 18 to 35 for functional ankle instability or chronic ankle instability.
- **Intervention:** Plyometrics and Hip Strengthening Exercises
- **Outcomes:** Primary Outcome Measure: CAIT, AII, FAAM. Secondary Outcome Measure: FADI-sports module
- **Language:** available English full-text studies
- **Study design:** Full-text Randomized controlled trials, Randomized control laboratory study design, Single blinded randomized control trial.

Criteria For Exclusion

- Studies that were not written in English, did not include a review article, or were not available in full text were excluded.
- Athletes under 18 and over 30 were excluded.
- Studies with non-athletic patients, ankle surgery, or a 6-month fracture were excluded.
- Exercise interventions that did not include plyometric (types of plyometrics exercises) or hip strengthening exercises were excluded
- Athletes with mechanical ankle instability and lateral ankle instability were excluded.
- Research outcomes not relevant to our field of study
- Duplicate publications and Data are not included

Study Selection:

The search engines yielded a total of 2,693 published articles, eligible for the title and abstract screening. After removing duplicate articles, a total of 2,283 articles were selected. After the screening of the title and abstract a total of 876 articles were selected, finally 102 articles were excluded with reasons and a total of 10 studies were selected for the review. The PRISMA flow chart is shown in (figure.1).

Data Extraction

The Data extraction sheets were used to extract the following details; The collected data included; 1. study design and setting, 2. Demographic data including Participants “age, gender, sample size and grouping”, 3. Description of Intervention, 4. Treatment Duration, 5. Outcome measures.

Risk Of Bias Assessment

The PEDro scale assessed methodological quality and risk of bias in randomized and quasi-randomized physiotherapy trials [60]. Criteria included randomization, allocation concealment, baseline comparability, participant, therapist and assessor blinding, incomplete outcome data, and intention-to-treat analysis. Two independent reviewers scored items as present (1) or absent (0), resolving disagreements through a third reviewer. Scores ranged from 0–10, classified as excellent (9–10), good (6–8), fair (4–5), or poor (3) [61]. Risk-of-bias assessment examined random sequence generation, allocation concealment, blinding, incomplete data, selective reporting, and other biases, which may overestimate or underestimate intervention effects to varying, often unquantifiable degrees.

Quantitative Synthesis Method

Quantitative synthesis employed STATA 17 (mvmeta, network suite, network graphs) and R (gemtc package). Bayesian network meta-analysis used Markov Chain Monte Carlo methods. Network and contribution plots illustrated comparisons and evidence contributions. Loop-specific inconsistency and node-splitting assessed consistency ($p < 0.05$), while deviance plots compare consistency and unrelated mean effect models. Leverage plots identified outliers, and league tables summarized treatment comparisons. SUCRA, Litmus-o-Rankograms, and radial SUCRA plots ranked interventions by vertical jump improvement. Comparison-adjusted funnel plots assessed publication bias. CINeMA evaluated confidence in mixed and indirect evidence across six domains: within-study bias, reporting bias, indirectness, imprecision, heterogeneity, and incoherence.

Cerativity Assessment (Cinema Tool)

The CINeMA (Confidence in Network Meta-analysis) framework was used for assessing the confidence in treatment effect estimates from this network meta-analysis, covering the 6 domains namely within-study bias, reporting bias, indirectness, imprecision, heterogeneity and incoherence. Confidence rating was computed for all mixed and indirect comparisons based on the judgement provided in the individual domains.

Results Of Study Selection

Database searches identified 2,693 articles: CENTRAL (276), PEDro (130), PubMed (877), and Google Scholar (1,410). Following duplicate removal, 2,283 records underwent title and abstract screening. Of 235 full-text articles assessed, 102 were excluded based on eligibility criteria or missing outcomes, leaving nine included studies (Figure 1). Control-group characteristics and methodological quality are presented in Tables 1 and 2.

Participant characteristics: Functional ankle instability, Athletes with recurrent ankle sprains or ankle “giving way” or feeling of instability, membership in a sport team (eg, basketball, Hopping, soccer, Football, volleyball), (CAIT) < 27 [1,2,42,45,49,54,57,58,59].

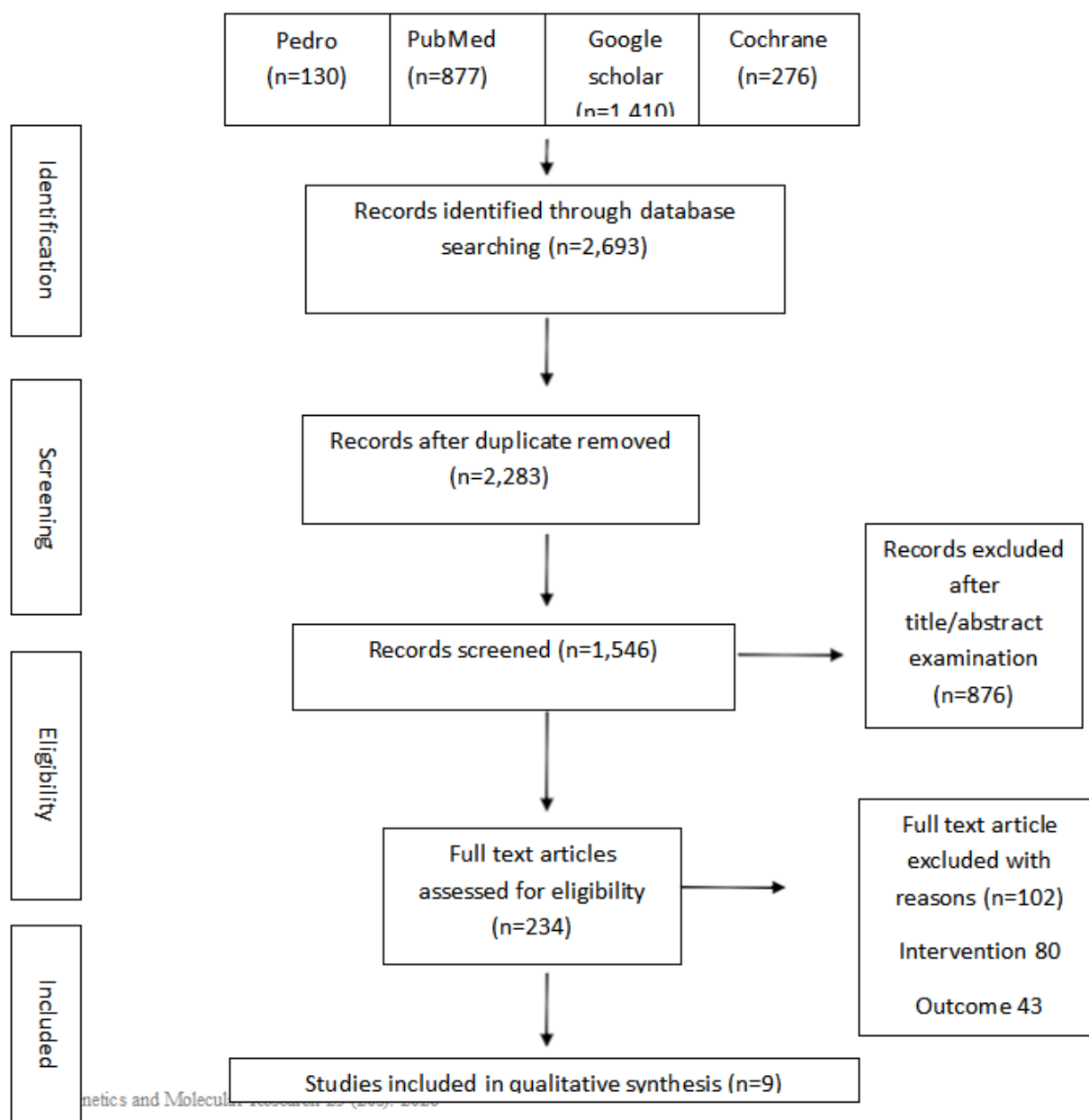
Intervention: All studies investigated the efficacy of plyometrics and hip strengthening exercises in athletes with functional ankle instability. [1,2,42,45,49,54,57,58,59]

Types of outcomes measured: CAIT, AII, FAAM, AJFAT, ADI [1,2,42,45,49,54,57,58,59]

Measurements of outcome

The above-mentioned outcome was used in all studies to measure Functional ankle instability using the CAIT, AII, FAAM, AJFAT, ADI [1,2,42,45,49,54,57,58,59].

Figure 1 PRISMA (Preferred Reporting items for Systematic Reviews and Meta- Analyses)



Charateristics Of Included Studies

Nine studies included seven randomized controlled trials [2,45,49,54,57,58,59], one laboratory trial [1], and one single-blinded trial [42], conducted in India, Iran, Pakistan, and China. Six examined chronic [2,42,45,49,57,58] and three functional ankle instability [1,54,59]. Interventions included plyometrics [1,2,59], hip strengthening [49], hopping [45,49,54,57,58], and multidirectional jumping [42]. Outcomes included CAIT [1,2,49,57,58,59], FAAM [45,49,57,58], AII [57,58], vertical jumping [42], and FADI-Sports [42,49,57].

DURATION	OUTCOME MEASURES	RESULTS
Each training program lasted for 6 weeks with 3 individual sessions per week. Everyone was requested to participate in at least two-thirds of the sessions (i.e., 12 of the 18 sessions).	CAIT questionnaire; Integrated electromyography (EMG); Single leg drop landing tasks; Joint position sense test	Significant
6 weeks	CAIT Questionnaire; Visual Analogue Scale	Significant

STUDY	PARTICIPANTS	INTERVENTIONS
Pi-Yin Huang et al. [59]	A randomized controlled laboratory study involving 45 collegiate recreational athletes aged 18–30 years with FAI; 13 athletes were excluded.	Randomly assigned into three groups: isolated plyometric (P, 9 males and 2 females), integrated balance + plyometric (BP, 9 males and 2 females), and control (C, 7 males and 3 females).
Muralisankar K.S.I et al. [2]	Randomized controlled trial involving 64 football players with ankle instability, randomly recruited into two groups (n = 32 each; Groups A and B).	Group A: Received a plyometric training program. Group B: Received conventional treatments, including cryotherapy and crepe bandages, with active exercises (dorsiflexion, plantar flexion, inversion, and eversion).

Table1: participants, diagnosis, intervention, duration, outcome measures and results

DURATION	OUTCOME MEASURES	RESULTS
Four days per week for five consecutive weeks.	Numerical Pain Rating Scale (NPRS); Vertical jump test; Foot and Ankle Disability Index (FADI-Sports module)	Significant
A 6-week plyometric training program versus a 6-week integrated training program.	CAIT questionnaire; Single-Legged Drop Landing; Single-Legged Standing Balance	Significant

STUDY	PARTICIPANTS	INTERVENTIONS
Fiza Raza Rizvi et al. [42]	Single-blinded randomized controlled trial involving 45 subjects aged 16–25 years. Fifteen subjects were excluded for not meeting the inclusion criteria, leaving 30 participants divided into three groups of 10 each.	Group 1: Ankle active range-of-motion exercises. Group 2: Multidirectional jumping exercises. Group 3: Multidirectional jumping exercise program.
Pi-Yin Huang et al. [59]	Randomized controlled clinical trial involving 30 collegiate athletes with functional ankle instability, aged 18–30 years (10 participants per group). The study aimed to reduce postural sway during single-legged stance and COM–COP deviation during drop-landing tasks.	Plyometric group: 8 men and 2 women; age 23.20 ± 2.82 years; 10 unstable ankles. Plyometric balance (integrated) training group: 8 men and 2 women; age 23.80 ± 4.13 years; 10 unstable ankles. Control group: 7 men and 3 women; age 23.50 ± 3.00 years; 10 unstable ankles.

DURATION	OUTCOME MEASURES	RESULTS
8 weeks	CAIT; Anterior drawer test of ankle; FAAM and FAAM-Sport disability questionnaires; Dynamometer; Y-Balance Test	Significant
6 weeks	AJFAT	Significant

STUDY	PARTICIPANTS	INTERVENTIONS
Hadi Mohammadi Nia Samakos h et al. [49]	Randomized controlled study involving 36 male professional soccer players with chronic ankle instability (CAI), randomly allocated into three groups.	Control group (CG): n = 12; Hopping group (HG): n = 12; Balance plus strength group (BSG): n = 12. Functional tests included Triple Hop, Figure 8 Hop, and vertical jump. Isometric assessments included hip abductor/adductor strength and ankle plantarflexion, dorsiflexion, inversion, and eversion strength.

Sasan Arjang et al. [54]	Randomized clinical trial involving 24 male athletes aged 18–25 years with functional ankle instability, divided into a control group (n = 12) and a training group (n = 12).	Experimental group: Hopping exercises for 6 weeks, 3 sessions per week. Control group: Continued routine exercises, 3 sessions per week.
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Table 1 (continued)

DURATION	OUTCOME MEASURES	RESULTS
6 weeks	Star Excursion Balance Test; Functional Ankle Disability Index; Functional Ankle Ability Measure questionnaire; Multiple Single Leg Hop Stabilization Test (MSLHST)	Insignificant
6 weeks	CAIT; FAAM; FAAM-Sport (FAAM-S); Foot and Ankle Outcome Score (FAOS); AII	Significant

STUDY	PARTICIPANTS	INTERVENTIONS
Rafia Mukhtar et al. [45]	Randomized controlled trial involving young basketball players with chronic ankle instability (CAI), aged 25–35 years, randomly allocated into two groups (Group A and Group B).	Group A: Received 6 weeks of hop stabilization training alongside general training. Group B: Received 6 weeks of balance training alongside general training.
Hooman Minoonejad et al. [58]	Randomized controlled trial involving 28 college basketball players with CAI. Experimental group: Age 22.78 ± 3.09 years; weight 82.59 ± 9.51 kg; height 187.96 ± 7.93 cm. Control group: Age 22.57 ± 2.76 years; weight 78.35 ± 7.02 kg; height 185.69 ± 7.28 cm.	Experimental group (n = 14): Supervised hop stabilization exercises, 3 sessions per week for 6 weeks. Control group (n = 14): Received no intervention.

Table 1 (continued)

DURATION	OUTCOME MEASURES	RESULTS
6 weeks	AII; FAAM; FAAM-Sport (FAAM-S); CAIT; Foot and Ankle Outcome Score (FAOS)	Significant

STUDY	PARTICIPANTS	INTERVENTIONS
Mohammad Karimizadeh Ardakani et al. [58]	Randomized controlled clinical trial involving 28 male collegiate basketball players with chronic ankle instability (CAI), divided into two groups: hop-training group and control group.	Hop-training group: n = 14. Control group: n = 14.

TABLE 1 (CONTINUED)

Pi-Yin Huang et al. [59]	YES	YES	NO	YES	NO	NO	NO	YES	YES	YES	YES	6
Hooman Minoonejad et al. [58]	YES	YES	NO	YES	NO	YES	NO	YES	YES	YES	YES	7
Mohammad Karimizadeh Ardakani et al. [58]	YES	YES	NO	YES	NO	NO	NO	YES	NO	YES	YES	5

PEDRO SCALE	Muralisa nkar K.S.I et al [2]	Fiza Rizvi et al [42]	Raza Mukhtar et al [45]	Hadi Mohammadi Nia Samakosh ET et al [49]	Pi-Yin Huang et al [59]	Sasan Arjang et al [54]
Eligibility criteria	YES	YES	NO	YES	YES	YES
randomly allocated	YES	YES	YES	YES	YES	NO
Concealed allocation	NO	YES	NO	YES	YES	NO
Similar Baseline	YES	YES	NO	YES	YES	YES
subject blinding	NO	NO	YES	NO	YES	NO
Therapist blinding	NO	NO	NO	YES	NO	NO
assessors blinding	NO	NO	NO	NO	NO	NO
Dropouts less than 15 %	YES	YES	NO	YES	YES	YES
intention to treat analysis	YES	NO	NO	YES	YES	YES
between-group statistical comparisons	YES	YES	NO	YES	YES	YES
point measures and variability data	YES	YES	NO	YES	YES	NO
SCORE	6	6	2	8	8	4

Table 2: PEDro score

RISK OF BIAS ASSESSMENT IN INCLUDED STUDIES

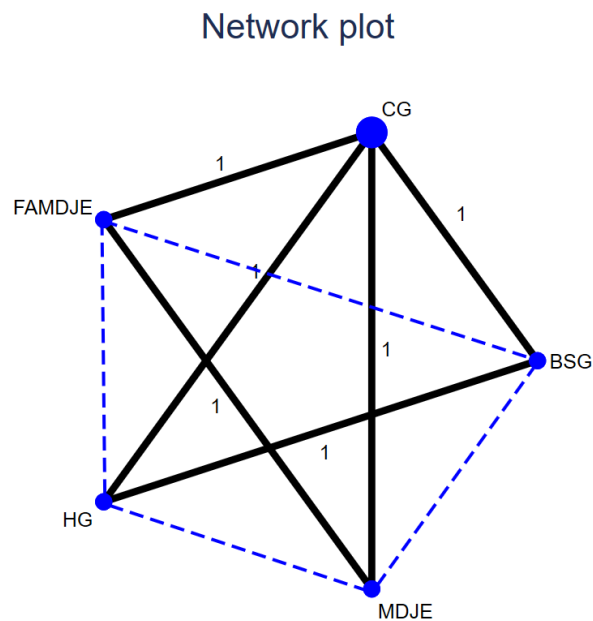


Figure 2: Network plot

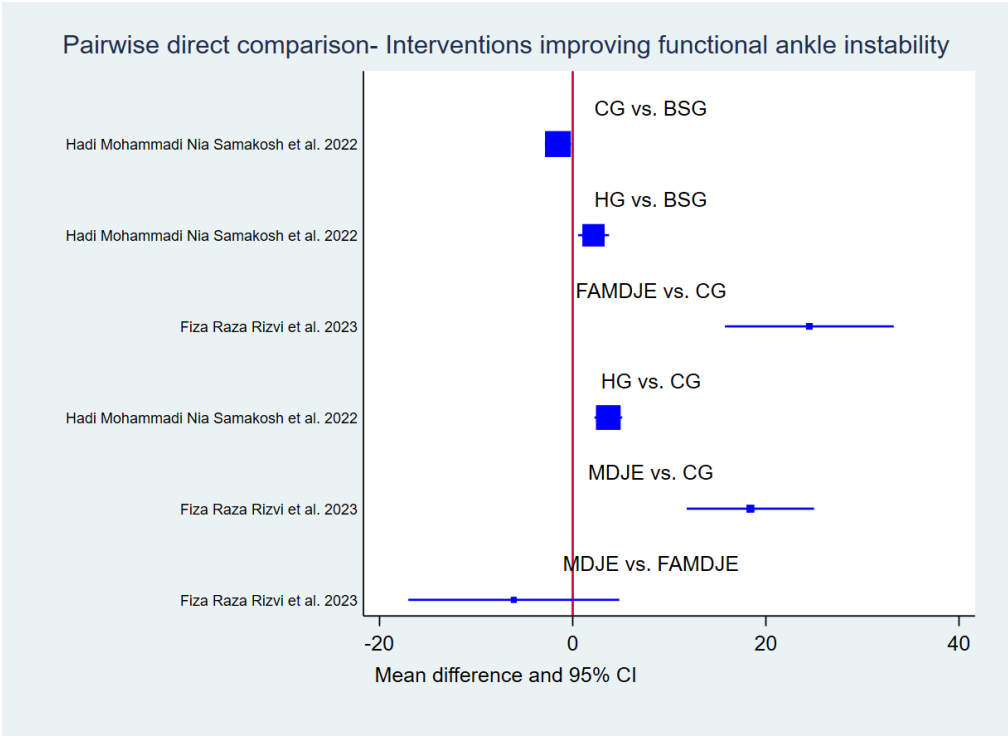


Figure 3: Pairwise direct comparison

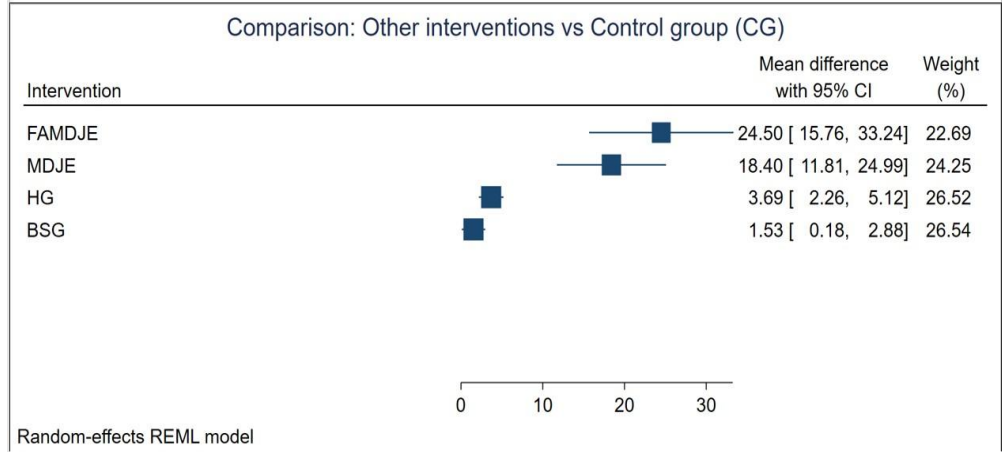


Figure 4: Network meta-analysis estimates comparison with CG

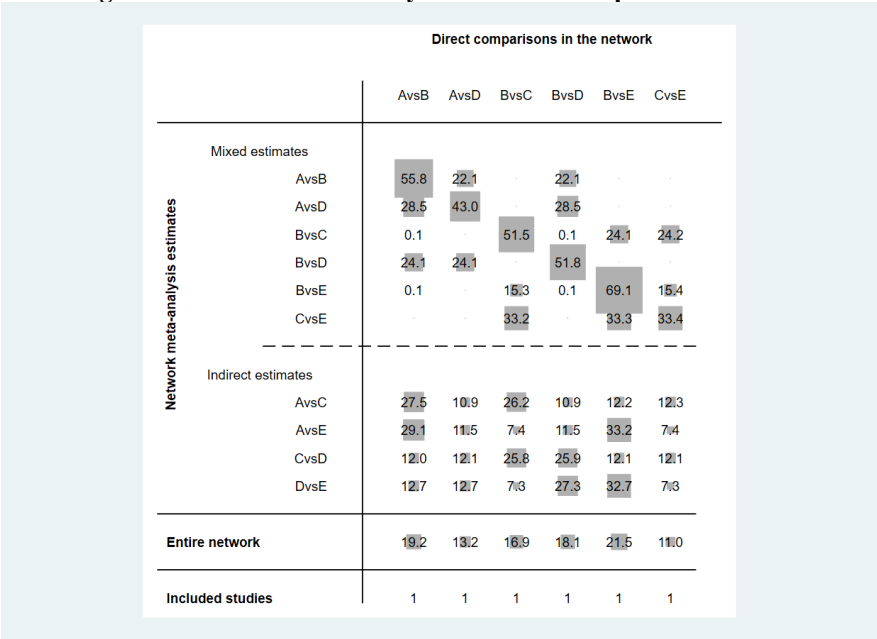


Figure 5: Contribution plot

Table 1: Assessment of inconsistency for all studies

Comparison	No. of studies	NMA	Direct	Indirect	Difference	Diff_95C I_lower	Diff_95C I_upper	p value
BSG:CG	1	1.53	1.53	NA	NA	NA	NA	NA
BSG:FAM DJE	0	-22.97	NA	-22.97	NA	NA	NA	NA
BSG:HG	1	-2.16	-2.16	NA	NA	NA	NA	NA
BSG:MD JE	0	-16.87	NA	-16.87	NA	NA	NA	NA
FAM DJE :CG	1	24.50	24.50	NA	NA	NA	NA	NA
HG:CG	1	3.69	3.69	NA	NA	NA	NA	NA
MDJE:CG	1	18.40	18.40	NA	NA	NA	NA	NA
FAM DJE :HG	0	20.81	NA	20.81	NA	NA	NA	NA
FAM DJE :MDJE	1	6.10	6.10	NA	NA	NA	NA	NA
HG:MDJE	0	-14.71	NA	-14.71	NA	NA	NA	NA

Table 2: Loop specific inconsistency

Loop	IF	Loop_Heterog_tau2
CG-BSG-FAM DJE	0 %	0
CG-HG-MDJE	0%	0

Table 3: Network league table

FAM DJE	6.10[-4.83;17.03]	-	-	24.50 [15.76;33.24]
6.10[-4.83;17.03]	MDJE	-	-	18.40 [11.81; 24.99]
20.81[11.95;29.67]	14.71[7.96;21.46]	HG	2.16[0.55; 3.77]	3.69 [2.26;5.12]
22.97 [14.13;31.81]	16.87 [10.14;23.60]	2.16[0.55; 3.77]	BSG	1.53 [0.18;2.88]
24.50 [15.76;33.24]	18.40 [11.81; 24.99]	3.69 [2.26;5.12]	1.53 [0.18;2.88]	CG

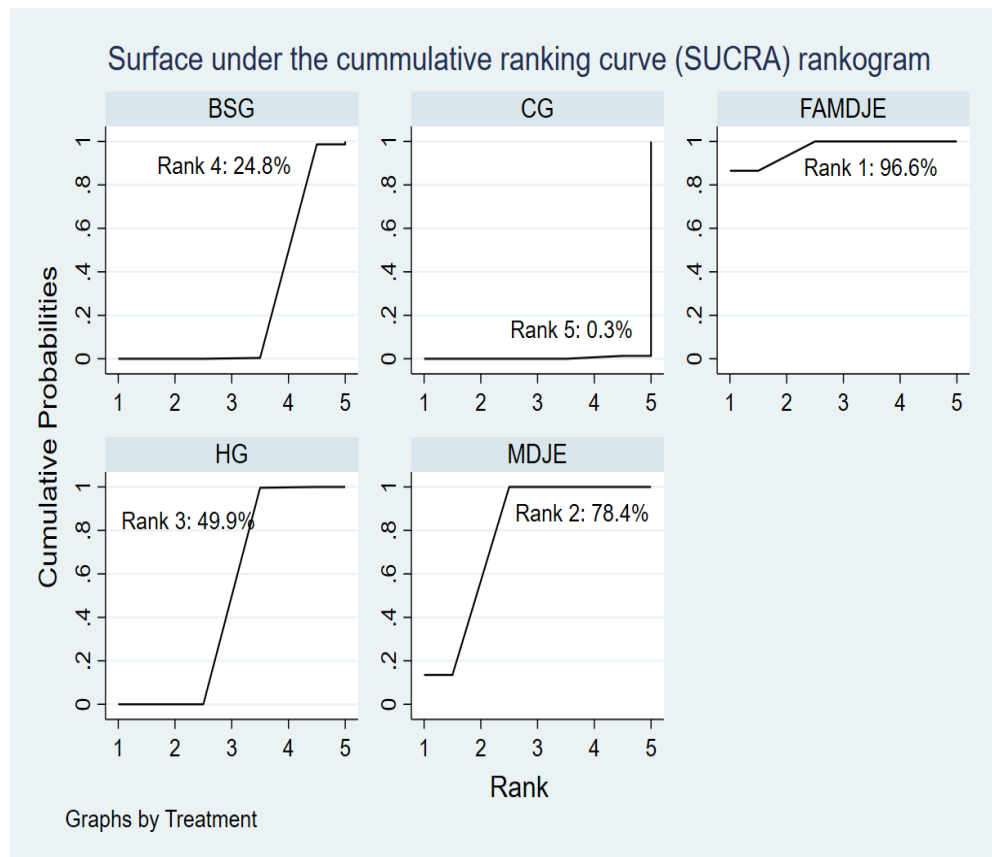


Figure 6: SUCRA RANKOGRAM

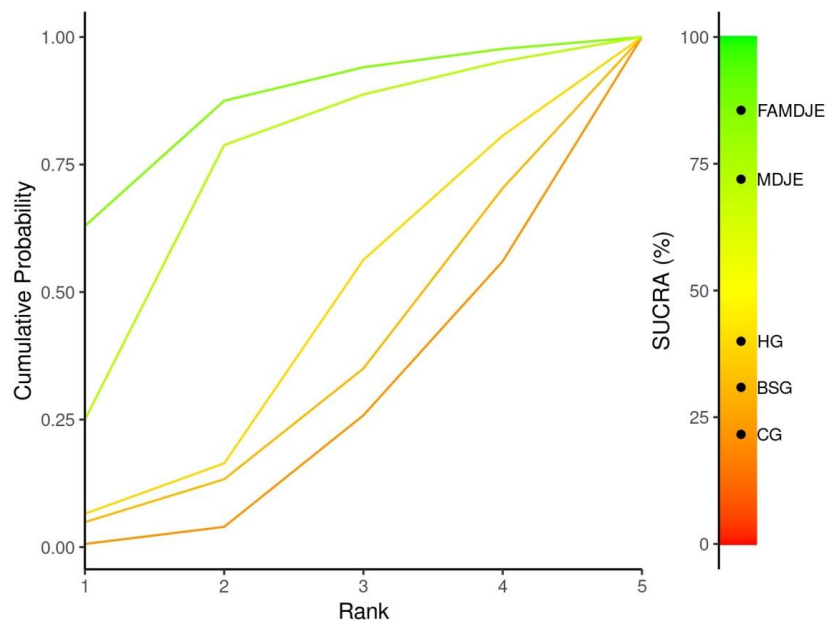


Figure 7: Litmus-O- Rankogram

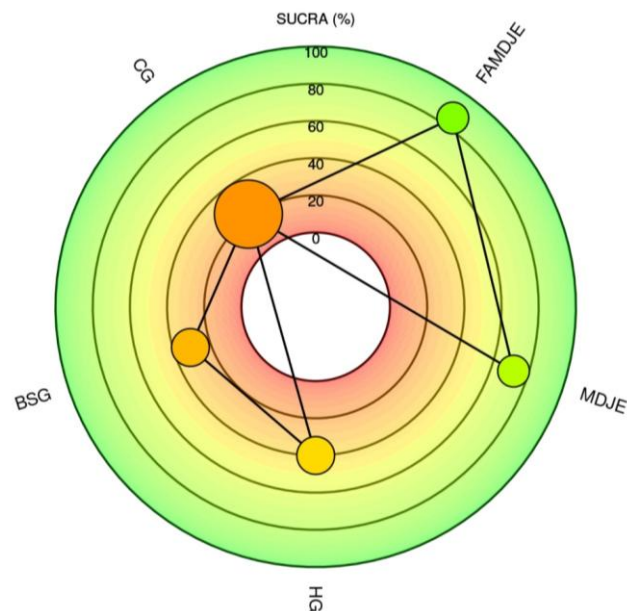


Figure 8: Radial SUCRA

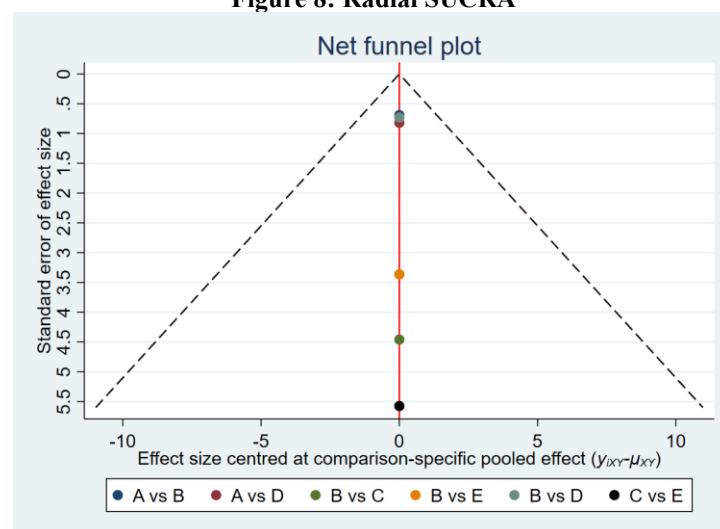


Figure 9: Net funnel plot

Table 4: SUCRA ranking table

Intervention	Rank	Probability for that particular rank
FAMDJE	1	86.3
MDJE	2	86.3
HG	3	99.6
BSG	4	98.3
CG	5	98.7

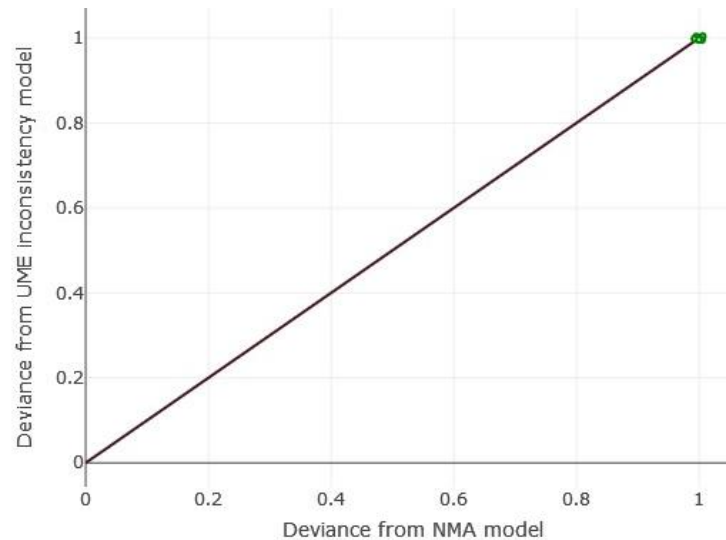


Figure 10: Deviance plot
Leverage versus residual deviance

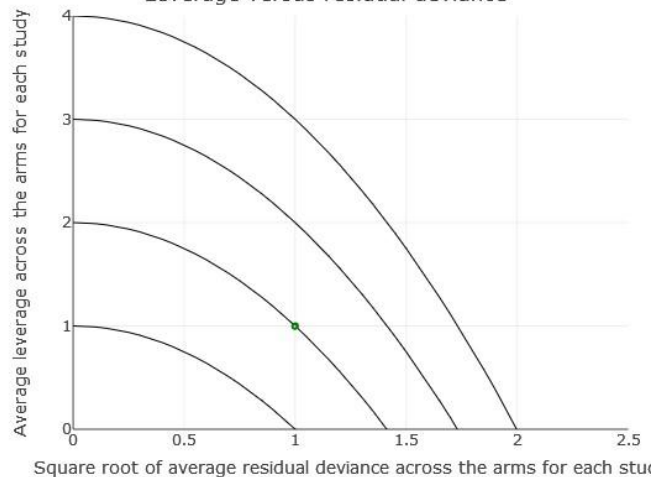


Figure 11: Leverage plot

Foot notes for the figures

FAMDJE - Fastened ankle multidirectional jumping exercise (E)

MDJE- Multidirectional jumping exercise (D)

HG- Hopping training group (C)

BSG- Combined balance strengthening group (B)

CG- Control group (A)

Results Of The Network Meta-Analysis

Quantitative (Meta) Analysis – Effects on the Outcomes

Network Plot Diagram

Figure 2 illustrates intervention comparisons for vertical jump improvement (cm), including fastened-ankle multidirectional jumping, multidirectional jumping, hopping, combined balance strengthening, and control. Node size represents study frequency; edge width indicates direct comparisons.

Forest plots

Pairwise comparisons (Figure 3) and random-effects forest plots (Figure 4) assumed common between-study variance. Vertical jump improvements versus control were 24.50 (15.76–33.24), 18.40 (11.81–24.99), 3.69 (2.26–5.12), and 1.53 (0.18–2.88), respectively.

Contribution plot

The contribution plot (Figure 5) showed equal mixed and indirect contributions, highest for combined balance strengthening versus fastened-ankle multidirectional jumping (21.5%) and lowest for hopping versus fastened-ankle multidirectional jumping (11%).

Assessment of inconsistency across the included studies

Node splitting analysis was used to check the inconsistency across the individual comparison arms. It revealed that there was no inconsistency between direct and indirect estimated from the network meta-analysis (Table 1).

Loop specific inconsistency

Two triangular loops were identified: control–combined balance strengthening–fastened-ankle multidirectional jumping and control–hopping–multidirectional jumping. Both showed 0% inconsistency, indicating no loop-specific inconsistency (Table 2).

Network League Table

The network league table (Table 3) presents indirect estimates above and direct estimates below the diagonal, ranking interventions: fastened-ankle multidirectional jumping, multidirectional jumping, hopping, combined balance strengthening, and control.

Ranking probability of the intervention

SUCRA rankings favored fastened-ankle multidirectional jumping (96.6%), followed by multidirectional jumping (78.4%), hopping (49.9%), combined balance strengthening (24.8%), and control (0.3%) (Figure 6). Respective rank probabilities were 86.3% (Rank 1), 86.3% (Rank 2), 99.6% (Rank 3), 98.3% (Rank 4), and 98.7% (Rank 5) (Table 4). The Litmus-o-Rankogram positioned both multidirectional jumping interventions near the green region, indicating greater effectiveness, whereas other interventions appeared near the red region, suggesting limited effectiveness (Figure 7). Radial SUCRA plots positioned fastened-ankle multidirectional jumping nearest the outer ring, followed by multidirectional jumping, indicating superior improvement in functional ankle instability (Figure 8).

Publication bias

Visual inspection of comparison adjusted funnel plot showed it to be symmetrical, indicating the absence of any publication bias (Figure 9).

Deviance plot

Deviance plot showed that the points were lying on the line of equality indicating absence of inconsistency in the network of interventions (Figure 10).

Leverage plot

The leverage plot was used to check for any outlier studies contributing to the network of intervention. Studies showing leverage of three and square roots of average residual deviance across the treatment arm greater than 1.5 were considered as outliers (Figure 11). It was evident from the leverage plot that there were no potential outliers.

Grading of the evidence – CINeMA framework

The confidence rating was moderate for both mixed and indirect evidence (Table 5). The most common reason for downgrading confidence ratings in both indirect and mixed evidence was due to some concerns for “within study bias” domain. Moderate concerns of imprecision were observed for the treatment comparison fastened ankle multidirectional jumping exercise group vs multidirectional jumping exercise group. Although, the prediction intervals for fastened ankle multidirectional jumping exercise group vs multidirectional jumping exercise group crossed the line of no difference, it was rated to have moderate concerns for imprecision due to majority of the prediction interval lying to the left of line of no difference (Figure 3) (Table 5).

Certainty Of Evidence (Cinema Tool)

Table 5: CINeMA plot (Confidence in Network Meta-Analysis)

Comparison	No. of studies	Within-study bias	Reporting bias	Indirectness	Imprecision	Heterogeneity	Incoherence	Confidence rating	Reason(s) for downgrading
MIXED EVIDENCE									
BSG vs CG	1	Some concerns	Low risk	No concerns	No concerns	No concerns	No concerns	Moderate	Some concerns for “within study bias”
BSG vs HG	1	Some concerns	Low risk	No concerns	No concerns	No concerns	No concerns	Moderate	Some concerns for “within study bias”
CG vs FAMDJJE	1	Some concerns	Low risk	No concerns	No concerns	No concerns	No concerns	Moderate	Some concerns for “within study bias”

CG vs HG	1	Some concerns	Low risk	No concerns	No concerns	No concerns	No concern	Moderate	Some concerns for “within study bias”
CG vs MDJE	1	Some concerns	Low risk	No concerns	No concerns	No concerns	No concerns	Moderate	Some concerns for “within study bias”
FAMDJE vs MDJE	1	Some concerns	Low risk	No concerns	Moderate concerns	No concerns	No concerns	Moderate	Some concerns for “within study bias” and “imprecision”
INDIRECT EVIDENCE									
BSG vs FAMDJE	-	Some concerns	Low risk	No concerns	No concerns	No concerns	No concerns	Moderate	Some concerns for “within study bias”
BSG vs MDJE	-	Some concerns	Low risk	No concerns	No concerns	No concerns	No concerns	Moderate	Some concerns for “within study bias”
FAMDJE vs HG	-	Some concerns	Low risk	No concerns	No concerns	No concerns	No concerns	Moderate	Some concerns for “within study bias”
HG vs MDJE	-	Some concerns	Low risk	No concerns	No concerns	No concerns	No concerns	Moderate	Some concerns for “within study bias”

Foot notes for the tables

FAMDJE - Fastened ankle multidirectional jumping exercise

MDJE- Multidirectional jumping exercise

HG- Hopping training group

BSG- Combined balance strengthening group

CG- Control group

- This systematic review and Bayesian network meta-analysis evaluated lower-body plyometric and hip-strengthening interventions for ankle instability among athletes. Nine randomized trials were reviewed, although only two contributed to the network meta-analysis because of outcome heterogeneity. Five interventions were compared based on vertical jump improvement.

- Fastened-ankle multidirectional jumping demonstrated the greatest improvement (MD: 24.50 cm), followed by multidirectional jumping (MD: 18.40 cm). SUCRA values were 96.6%, 78.4%, 49.9%, 24.8%, and 0.3% for fastened-ankle multidirectional jumping, multidirectional jumping, hopping, combined balance strengthening, and control, respectively. Consistency assessments revealed no significant disagreement between direct and indirect comparisons.

- Superior multidirectional jumping outcomes may reflect enhanced proprioception, neuromuscular coordination, dynamic stability, and multiplanar movement control. Combined balance strengthening is progressive plyometric stimulation while combined balance strengthening targets proximal hip and distal ankle stability. The results suggest that personalized rehabilitation combining hip strengthening with progressive plyometrics are beneficial.

- Comprehensive intervention comparisons were supported by methodological quality assessment and CINeMA evaluation which were supported by Bayesian methods. There are, however, a few limitations in generalizability because of the limited trials, protocols, participant characteristics, and mostly short-term outcomes. Randomized studies are needed in the future to test the long-term effectiveness, underlying mechanisms and the effect of chronicity of instability, activity level and age. More research is necessary to provide evidence-based recommendations for comparing treatments among athletes with functional ankle instability.

CONCLUSION

This Bayesian network meta-analysis highlighted the superiority of fastened-ankle multidirectional jumping and multidirectional jumping exercises for improving vertical jumping ability in functional ankle instability patients. Multidirectional jumping and hopping training produced high confidence ratings for its effectiveness, highlighting a dynamic rehabilitation method based on sports-specific exercises. However, there is less confidence in combined balance and strengthening interventions, suggesting some uncertainty about the comparative effectiveness of these interventions. The findings offer clinical guidance to maximize the rehabilitation strategies between athletes. To establish effective treatment and provide reliable rehabilitation recommendations, additional high quality studies with larger samples and longer follow-up periods are needed and comparisons of direct treatments are required.

LIMITATIONS AND RECOMMENDATIONS

- This network meta-analysis will integrate direct evidence with indirect evidence from multiple treatment comparisons to estimate the interrelations across all treatments.
- The strengths of this review are its comprehensive search strategy, restriction of studies to randomised controlled trials, duplicate assessment of data abstraction and risk of bias, to evaluate the quality of evidence.

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