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Review article

Comparative Effects of Training Modalities on Countermovement Jump Performance in Soccer Players: A Systematic Review and Network Meta-Analysis

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Abstract
The aim of this study was to provide a comprehensive comparison of training modalities for countermovement jump (CMJ) performance in soccer players using a network meta-analysis (NMA). PubMed, Web of Science, Embase, EBSCO, and the Cochrane Library were searched up to November 2025. Randomized controlled trials (RCTs) involving healthy soccer players, evaluating structured training interventions against comparator training or control conditions, and reporting CMJ height outcomes were included. A random-effects NMA was performed to estimate mean differences (MDs) with 95% confidence intervals (CIs), and interventions were ranked using P-scores, integrating both direct and indirect evidence. Subgroup analyses were conducted according to age, sex, and competitive level. Twenty-nine RCTs (n = 450) were included. The network showed moderate heterogeneity and no evidence of significant inconsistency. Combined training (CBT) was ranked highest in effect estimates in CMJ performance compared with traditional soccer training (TST) (MD = 4.92, 95% CI: 3.02 - 6.83, P-score = 0.98), followed by flywheel resistance training (FT) and plyometric training (PT), whereas other interventions did not demonstrate significant improvements. Subgroup analyses indicated that CBT ranked highest in males, youth, and Tier 2 players; PT ranked highest in females and adults; and FT ranked highest in highly trained players. Given the limited sample sizes, limited statistical power, and the fragmented nature of some subgroup comparisons, these findings should be interpreted cautiously. The network showed moderate heterogeneity (I^2 = 32.4%) and no evidence of significant inconsistency. The certainty of evidence was generally low to moderate according to the CINeMA assessment. Directness of evidence was generally high across comparisons, although several key contrasts (e.g., CBT vs FT and FT vs PT) relied partly on indirect evidence within the network. Although the highest-ranked interventions (CBT, FT, and PT) were supported primarily by direct comparisons with TST, several active–active contrasts relied partly on indirect estimates. The reliability of the intervention rankings depends on similarity in participant characteristics, intervention dose, outcome measurement, and control conditions.

Key words: Soccer, countermovement jump, explosive performance, network meta-analysis, training modalities.

Introduction

Lower-limb explosive power is a key determinant of performance in competitive soccer players, underpinning technical actions and match outcomes, particularly in aerial duels, shooting, and defensive situations (Wisløff et al., 2004). The countermovement jump (CMJ) is widely recognized as a valid and reliable indicator of lower-limb explosive performance and neuromuscular function in soccer players (Gathercole et al., 2015). Importantly, CMJ should be considered a proxy measure of lower-limb explosive capability rather than a direct measure of soccer match performance. CMJ performance is governed by multiple neuromuscular determinants, including maximal strength, rate of force development (RFD), intermuscular coordination, and stretch–shortening cycle (SSC) efficiency (Cormie et al., 2011; Maffiuletti et al., 2016). These factors collectively determine rapid force production, indicating that different training modalities can induce distinct adaptations in CMJ performance (Pardos-Mainer et al., 2021).

Various training approaches have been applied to improve CMJ performance. Traditional strength training (STG) primarily targets maximal force production, which provides the foundation for vertical jump performance (Nuñez et al., 2022). Plyometric training (PT) is designed to improve SSC efficiency and RFD and has consistently shown positive effects on explosive performance in soccer players (Ramirez-Campillo et al., 2020). Combined training (CBT), which integrates resistance and plyometric stimuli, has been proposed to produce complementary adaptations by simultaneously targeting force-generating capacity and rapid force expression (Zghal et al., 2019). Flywheel resistance training (FT), characterized by accentuated eccentric overload, is thought to be associated with SSC utilization and neuromuscular efficiency (Raya-González et al., 2022). In contrast, repeated sprint training (RST) and high-intensity interval training (HIIT) primarily target speed-related and metabolic adaptations and are likely to have less direct transfer to CMJ performance (Gibala et al., 2012; Girard et al., 2011). Although a growing number of studies have investigated these interventions, most previous evidence has been based on pairwise comparisons, limiting the ability to simultaneously compare multiple interventions and establish a hierarchy of effectiveness (Florez et al., 2024).

Furthermore, it remains unclear whether multimodal approaches such as CBT provide greater adaptations than single-modality interventions, whether relative effectiveness differs according to age, sex, and competitive level, and whether specific intervention pairings yield consistent effects across different soccer populations. These uncertainties apply not only to the overall soccer player population but also to important subgroups such as youth, adult, male, female, and highly trained athletes. A recent

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review by Oliver et al. (2024) synthesized evidence regarding training interventions for CMJ performance in soccer players; however, it primarily focused on specific athlete populations and did not comprehensively compare a broad range of training modalities within a network framework. Consequently, the relative effectiveness and ranking of available training strategies remain uncertain.

Network meta-analysis (NMA) addresses these limitations by combining both direct and indirect evidence within a single analytical framework, allowing simultaneous comparisons among multiple interventions, including those not directly compared within individual RCTs (Chaimani et al., 2019; Chaimani and Salanti, 2012). For readers unfamiliar with NMA, direct evidence arises from studies directly comparing two interventions, whereas indirect evidence is estimated through a common comparator; for example, if CBT has been compared with TST and PT has been compared with TST, NMA can estimate the effect of CBT versus PT indirectly through TST. The validity of intervention rankings relies on assumptions of similarity and transitivity across studies, including comparable participant characteristics, intervention doses, outcome measurements, and control conditions. When these assumptions are adequately met, NMA provides a comprehensive evaluation of comparative effectiveness and facilitates evidence-based training prescription (Dias et al., 2018). The intervention nodes used in this network meta-analysis were defined as pragmatic classifications for comparative synthesis rather than strictly mechanistic categories. Interventions incorporating multiple training components were assigned according to the dominant training stimulus and intended adaptation. The plausibility of these assumptions was evaluated through assessment of network geometry, heterogeneity, and consistency within the network.

Therefore, the primary aim of this study was to compare and rank the effects of different training modalities on CMJ performance in soccer players using a network meta-analysis of RCTs. In addition, exploratory subgroup analyses were conducted according to age, sex, and competitive level to investigate potential effect modifiers. Based on prior evidence and theoretical expectations, CBT was anticipated to be most effective in males and youth players, PT in females and adults, and FT in highly trained athletes. Training recommendations derived from subgroup analyses were explicitly conditioned on the certainty and directness of the underlying evidence to ensure practical applicability.

Methods

This study was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Network Meta-Analysis (PRISMA-NMA) guidelines and the PRISMA 2020 statement (Hutton et al., 2015). The PRISMA 2020 checklist is provided in Supplementary Table S1 (https://www.jssm.org/SM/Man9351-2026SupplMaterials.pdf). The protocol was registered in PROSPERO (CRD420251237826).

Search strategy

We searched PubMed, Embase, Web of Science, EBSCO, and the Cochrane Library from inception to 28 November 2025 (search terms in Supplementary Tables S2-S6 see at https://www.jssm.org/SM/Man9351-2026SupplMaterials.pdf). The search strategy was developed based on PICOS elements. In addition, the reference lists of included studies were manually screened to identify potentially relevant articles (Moher et al., 2009). Any disagreements were resolved through discussion between two reviewers (X. Dong and T. Li). Searches of clinical trial registries (e.g., ClinicalTrials.gov and WHO ICTRP) and grey-literature databases were not performed because the review focused on peer-reviewed RCTs. This decision may increase the possibility of publication bias and was considered when interpreting the findings.

Inclusion and exclusion criteria

The inclusion and exclusion criteria were defined according to the PICOS (Population, Intervention, Comparator, Outcomes, and Study design) framework and are presented in Table 1. In brief, eligible studies involved soccer players undergoing structured training interventions, reported CMJ outcomes, and were designed as RCTs. Although the focus was on soccer players, studies were considered eligible when participants were soccer athletes or when the intervention protocols and performance outcomes were specifically designed to reflect soccer performance demands (Chandler et al., 2019).

Table 1 **Study inclusion and exclusion criteria.**

Items	Inclusion criteria	Exclusion criteria
Population (P)	√ Soccer players of any age, sex, and competitive level √ Healthy and able to participate in training √ No major injury or illness	× Athletes from other sports × Injured or rehabilitating players × Studies with outcomes not directly relevant to soccer performance
Intervention (I)	√ Structured training interventions (e.g., CBT, PT, FT, HIIT, RST, SSG, STG, TST) √ Clearly defined training protocol (frequency, duration)	× Non-training interventions (e.g., nutrition, medication, rehabilitation) × Unclear or poorly described intervention
Comparator (C)	√ Other training modalities or control condition √ Traditional soccer training (TST) allowed as control	× No comparator or single-arm studies × Studies without baseline or post-test data
Outcome(O)	√ CMJ performance (e.g., CMJ height) √ Quantitative data (mean and SD available) √ Post-intervention outcomes reported	× No CMJ outcome reported × Invalid or incomplete CMJ data × Outcomes not related to explosive performance
Study design (S)	√ RCTs √ Published in English	× Non-RCT designs (observational, cohort, case-control) × Reviews, meta-analyses, conference abstracts × Non-English articles

RCTs = Randomized controlled trials.

Study selection and data extraction

All retrieved records were independently screened by two reviewers at the title/abstract and full-text levels. Studies that met the eligibility criteria subsequently underwent data extraction. Data extraction was performed independently by two reviewers using a standardized form, and discrepancies were resolved through discussion.

The following information was systematically extracted: (i) study characteristics (authors, year of publication, sample size, and country of origin), (ii) intervention characteristics (type, frequency, duration, and intensity), (iii) participant characteristics (sex, age, and competitive level), and (iv) outcome data, specifically the means and standard deviations for CMJ performance. Information regarding CMJ assessment methods and devices was also extracted when available and is summarized in Supplementary Table S7 (https://www.jssm.org/SM/Man9351-2026SupplMaterials.pdf). Detailed intervention characteristics, including training type, frequency, duration, and intensity, are summarized in Table 2. When data were reported only in graphical form, WebPlot Digitizer was used to extract numerical values. Intervention arms were categorized into eight predefined nodes for the NMA: CBT, PT, FT, HIIT, RST, SSG, STG, and TST. Nodes were defined based on the primary training stimulus, and mixed interventions were classified according to the dominant training component and intended adaptation.

Two reviewers (X. Dong and T. Li) independently classified all intervention arms into the predefined network nodes according to their primary training characteristics. Any disagreements regarding intervention classification were resolved through discussion until consensus was reached. Detailed intervention classification criteria are provided in Supplementary Table S8 (https://www.jssm.org/SM/Man9351-2026SupplMaterials.pdf). The network geometry was described, with node sizes reflecting the number of participants contributing to each intervention and line thickness representing the number of direct comparisons between interventions. Most comparisons were conducted against TST, whereas direct head-to-head comparisons between active interventions were relatively limited, with some estimates relying partly on indirect evidence.

Outcome measures

The primary outcome of this review was CMJ performance, expressed as CMJ height. CMJ is widely recognized as a valid and reliable indicator of lower-limb explosive performance and neuromuscular function in soccer players. When multiple CMJ measurements were reported within a study, the value obtained immediately after the intervention period was extracted. All analyses were restricted to CMJ outcomes (Markovic et al., 2004).

Risk of bias and credibility assessment

Risk of bias was assessed using the Cochrane Risk of Bias 2 (RoB 2) tool (Sterne et al., 2019), which evaluates five domains: (i) bias arising from the randomization process, (ii) bias due to deviations from intended interventions, (iii) bias due to missing outcome data, (iv) bias in outcome measurement, and (v) bias in selection of the reported result. Each domain was rated as "low risk," "some concerns," or "high risk." Studies judged as high risk in any domain were classified as having an overall high risk of bias.

The certainty of evidence was evaluated using the Confidence in NMA (CINeMA) framework (Nikolakopoulou et al., 2020). Two reviewers (X. Dong and T. Li) independently assessed each comparison across six domains: within-study bias, reporting bias, indirectness, imprecision, heterogeneity, and incoherence. Judgments regarding imprecision, heterogeneity, and incoherence followed the predefined criteria implemented within the CINeMA framework (Nikolakopoulou et al., 2020). Any disagreements were resolved through discussion until consensus was reached. CINeMA ratings were considered when interpreting treatment rankings and formulating practical recommendations.

A risk-of-bias exclusion sensitivity analysis was prespecified; however, no study was classified as high risk of bias according to the ROB2 assessment. Therefore, no studies were excluded and all studies were retained in the primary analysis. Potential small-study effects and publication bias were evaluated using funnel plots and Egger's regression test (Egger et al., 1997).

Statistical analysis

A frequentist random-effects NMA was conducted (Rücker and Schwarzer, 2015). All analyses were conducted in R (version 4.4.1) using the netmeta package (version 3.0 - 0). Between-study heterogeneity (τ^2) was estimated using the Paule–Mandel estimator, assuming a common heterogeneity variance across all treatment comparisons. Effect sizes were expressed as mean differences (MDs) with 95% confidence intervals (CIs). Because all included studies reported CMJ height using the same measurement unit (cm), MDs were calculated using post-intervention values. Standardized mean differences (SMDs) were not considered necessary because outcome scales were comparable across studies. Baseline CMJ values were generally comparable between intervention and control groups within individual RCTs; therefore, additional sensitivity analyses using change scores were not performed.

Statistical heterogeneity was assessed using the I^2 statistic and Cochran's Q test (with corresponding degrees of freedom and p-values) (Higgins et al., 2003). Global inconsistency was evaluated using the design-by-treatment interaction model (Higgins et al., 2012), and local inconsistency was examined using node-splitting methods where data permitted (Dias et al., 2018). Relative treatment effects were summarized using league tables, which incorporated both direct and indirect evidence across the treatment network. Forest plots were generated using TST as the reference comparator. Interventions were ranked using P-scores, which reflect the mean extent of certainty that a treatment is better than competing interventions, with higher values indicating greater effectiveness (Rücker and Schwarzer, 2015).

Prespecified subgroup analyses were conducted according to age, sex, and competitive level (athlete tier). Tier classification followed the Participant Classification Framework proposed by McKay et al. (2021). Tier 2 athletes were defined as trained or developmental players who regularly participated in structured training and competition, whereas Tier 3 athletes were classified as highly trained or national-level players with advanced competitive experience. Only Tier 2 - 3 athletes were included in the present review. Youth players were defined as ≤18 years, whereas adult players were defined as >18 years. Tier classification for all included studies was independently checked by two reviewers according to the Participant Classification Framework, and any disagreements were resolved through discussion until consensus was reached.

Results

A total of 2,683 records were identified through database searching and other sources. After duplicate removal, 602 records remained for title and abstract screening. Subsequently, 212 full-text articles were assessed for eligibility, of which 183 were excluded for predefined reasons. Ultimately, 29 RCTs were retained in the final NMA. The study selection process is illustrated in Figure 1.

The network comprised eight intervention categories and incorporated 29 RCTs involving a total of 450 participants contributing analyzable CMJ outcome data. The sample consisted of 226 males (50.2%) and 224 females (49.8%). All studies reported CMJ performance outcomes. The mean participant age across studies was 18 years (range: 12.3 - 26.6 years). Regarding sex distribution, 21 studies enrolled exclusively male soccer players, 7 enrolled exclusively female soccer players, and 1 study included mixed-sex participants. Baseline characteristics and intervention characteristics are summarized in Supplementary Tables S9-S10 (https://www.jssm.org/SM/Man9351-2026SupplMaterials.pdf), whereas detailed study characteristics are presented in Table 2.

Network characteristics and review of assumptions

The network structure is presented in Figure 2. A summary of the network geometry, including the number of studies and participants contributing to each intervention node and the number of direct comparisons between interventions, is provided in Table 3. Detailed participant characteristics and intervention characteristics (including comparator conditions, training duration, and weekly frequency) are summarized in Table 2, whereas CMJ assessment methods and measurement devices are provided in Supplementary Table S7 (https://www.jssm.org/SM/Man9351-2026SupplMaterials.pdf). Moderate heterogeneity was observed across the included studies (I^2 = 32.4%). The observed heterogeneity may be attributed to differences in intervention characteristics (e.g., duration, frequency, and intensity), as well as variability in participant characteristics such as age, sex, and competitive level across included studies. Detailed heterogeneity results are provided in Supplementary Tables S11-S12 (https://www.jssm.org/SM/Man9351-2026SupplMaterials.pdf).

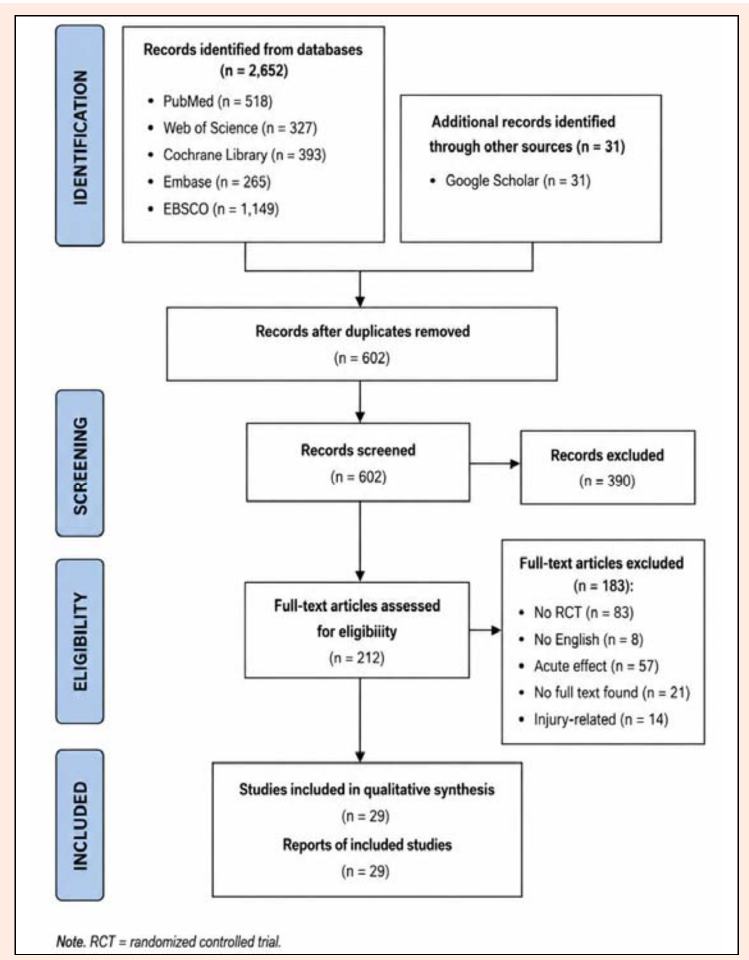

Figure 1. PRISMA flow diagram of the study selection process.

Global consistency was assessed using the design-by-treatment interaction model. Local inconsistency was evaluated using node-splitting analysis, with detailed results reported in Supplementary Table S13 (https://www.jssm.org/SM/Man9351-2026SupplMaterials.pdf). No significant global or local inconsistency was detected.

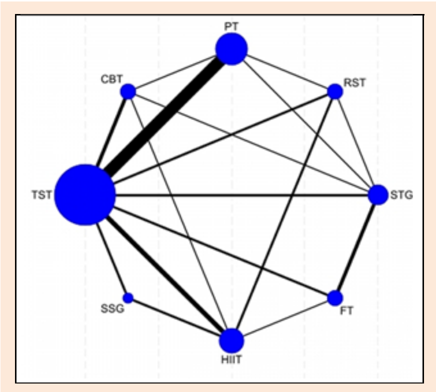

Figure 2. Network plot of comparisons among different training modalities. Node size is proportional to the number of participants contributing to each intervention node, and line thickness represents the number of direct comparisons between interventions. Most direct comparisons involved TST as the comparator, whereas direct head-to-head comparisons between active interventions were relatively limited.

The network included eight training modalities (CBT, PT, FT, HIIT, RST, SSG, STG, and TST). Most comparisons were conducted between active interventions and TST. The distribution of studies across comparisons was uneven, with a higher number of trials comparing active interventions with TST than direct comparisons between active interventions.

Direct comparisons between active interventions were relatively uncommon, with most available evidence derived from comparisons against TST. Consequently, several relative treatment estimates relied partly on indirect evidence within the network.

Active–active comparisons provided additional insight into the relative effectiveness of different training modalities. CBT demonstrated a significant advantage over PT (MD = 2.04 cm, p = 0.047) and STG (MD = 3.32 cm, p = 0.004), whereas the comparison between CBT and FT was not statistically significant (MD = 1.74 cm, p = 0.178). No significant differences were observed between FT and PT (MD = 0.30 cm, p = 0.771), FT and STG (MD = 1.58 cm, p = 0.075), or PT and STG (MD = 1.28 cm, p = 0.152). These findings should be interpreted cautiously because several active–active comparisons were supported primarily by indirect evidence and relatively small numbers of studies. According to the CINeMA assessment, certainty of evidence for these active–active comparisons ranged from low to moderate, with downgrades primarily related to within-study bias and imprecision. Detailed results are provided in Supplementary Table S13 (https://www.jssm.org/SM/Man9351-2026SupplMaterials.pdf).

Table 2. Characteristics of included studies (n = 29). Data extracted from included RCTs.

Study (Year)	n	Age	Sex	Intervention	Tier	Duration	Sessions
Barra-Moura (2024)	21	15.3 ± 1.1	M/F	CBT vs TST	Tier 2	6weeks	3
Dhull (2025)	30	22.9 ± 1.5	M	CBT vs TST	Tier 3	4weeks	2
Gallego-Sendarrubias (2021)	24	25.5 ± 4.2	M	CBT vs STG	Tier 3	2weeks	2
Gómez (2023)	21	21.2 ± 3.0	M	CBT vs HIIT	Tier 3	4weeks	2
Liu (2024)	51	16.3 ± 0.6	M	PT vs CBT	Tier 2	8weeks	4
Nonnato (2022)	16	23.0 ± 4.0	F	PT vs TST	Tier 3	12weeks	4
Quan (2024)	21	17.7 ± 1.7	M	CBT vs TST	Tier 2	4weeks	2
Sagelv (2020)	38	23.2 ± 2.6	M	FT vs STG	Tier 3	6weeks	2
Sammoud (2024)	27	12.3 ± 0.5	M	PT vs TST	Tier 2	8weeks	2
Yang (2025)	45	15.7 ± 0.5	F	PT vs TST	Tier 2	6weeks	2
Zhu (2025)	46	16.5 ± 0.5	M	PT vs TST	Tier 2	6weeks	2
Brahim (2025)	32	19.1 ± 0.7	M	FT vs STG	Tier 3	8weeks	2
Sedano Campo (2009)	20	22.9 ± 2.7	F	PT vs STG	Tier 3	12weeks	3
Fischetti (2019)	28	26.6 ± 6.1	F	PT vs TST	Tier 3	12weeks	3
Maciejczyk (2021)	15	19.6 ± 2.4	F	STG vs TST	Tier 3	4weeks	2
Ozbar (2014)	18	18.2 ± 2.3	F	PT vs TST	Tier 2	8weeks	1~3
Sperlich (2011)	17	13.5 ± 0.4	M	HIIT vs TST	Tier 3	5weeks	3~4
Ferrari Bravo (2008)	26	21.1 ± 5.1	M	HIIT vs TST	Tier 3	7weeks	2
Mujika (2009)	20	18.3 ± 0.6	M	HIIT vs STG	Tier 3	7weeks	1
Tønnessen (2011)	20	16.4 ± 0.9	M	HIIT vs TST	Tier 3	10weeks	1
Pecci (2023)	20	20.5 ± 2.6	F	PT vs TST	Tier 3	6weeks	2
Sanchez-Sanchez (2019)	22	22.5 ± 2.2	M	HIIT vs FT	Tier 2	5weeks	2
Buchheit (2010)	15	14.5 ± 0.5	M	HIIT vs PT	Tier 3	10weeks	1
Los Arcos (2015)	15	15.5 ± 0.6	M	HIIT vs TST	Tier 2	6weeks	2
Hammami (2019)	40	15.9 ± 0.3	M	CBT vs PT	Tier 2	8weeks	4~5
McKinlay (2018)	41	12.5 ± 0.6	M	STG vs PT	Tier 2	8weeks	3
Vera-Assaoka (2020)	76	13.0 ± 1.5	M	PT vs TST	Tier 2	7weeks	2
de Hoyo (2015)	33	17.5 ± 1.0	M	FT vs TST	Tier 3	10weeks	1~2
Coratella (2019)	40	23.0 ± 4.0	M	FT vs STG	Tier 3	8weeks	1

Note: Tier classification followed the Participant Classification Framework Tier 1 = recreationally active, Tier 2 = trained/developmental, Tier 3 = highly trained/national level. Youth players were defined as ≤18 years, whereas adult players were defined as >18 years. TST: Traditional soccer training, FT: Flywheel Resistance Training, STG: Traditional Strength Training, PT, Plyometric Training, CBT, Combined Training, SSG: Small-Sided Games Training, RST: Repeated Sprint Training, HIIT: High-Intensity Interval Training. The intervention column presents the direct comparison evaluated in each study. Duration = intervention period in weeks; Frequency = number of training sessions per week.

Table 3. Network geometry of included studies.

A. Node Characteristics

Node	Studies (k)	Participants (n)
CBT	5	54
PT	11	130
FT	5	78
STG	6	87
HIIT	8	94
RST	5	51
SSG	3	36
TST	20	240

B. Direct Comparisons in the Network

Comparison	Direct Studies (k)
PT vs TST	10
HIIT vs TST	4
CBT vs TST	3
FT vs STG	3
FT vs TST	2
SSG vs TST	2
HIIT vs SSG	2
HIIT vs RST	2
RST vs TST	2
STG vs TST	2
CBT vs STG	1
CBT vs HIIT	1
RST vs STG	1
FT vs HIIT	1
PT vs RST	1
CBT vs PT	1
PT vs STG	1

CBT, combined training; PT, plyometric training; FT, flywheel resistance training; STG, traditional strength training; HIIT, high-intensity interval training; RST, repeated sprint training; SSG, small-sided games; TST, traditional soccer training. k = number of studies; n = total number of participants contributing to each intervention node.

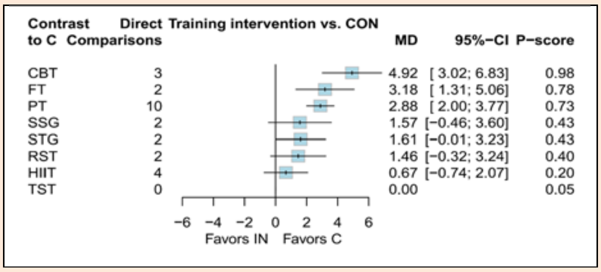

Figure 3. Forest plot of the effects of different training modalities on CMJ performance. Effect sizes are presented as mean differences (MDs) with 95% confidence intervals.

CMJ performance

The effects of different training modalities on CMJ performance are presented in Figure 3. In the primary NMA, CBT showed the largest improvement compared with TST (MD = 4.92, 95% CI: 3.02 - 6.83, P-score = 0.98), followed by FT and PT. In contrast, SSG, STG, RST, and HIIT did not demonstrate significant improvements, as their confidence intervals included the null value. The ranking probabilities of the interventions based on P-scores are presented in Figure 4.

League table results

League tables summarizing relative effects on CMJ performance are reported in Supplementary Table S14 (https://www.jssm.org/SM/Man9351-2026SupplMaterials.pdf). League tables were annotated according to CINeMA certainty ratings (very low, low, moderate). Visual shading was used as a supplementary aid to support interpretation.

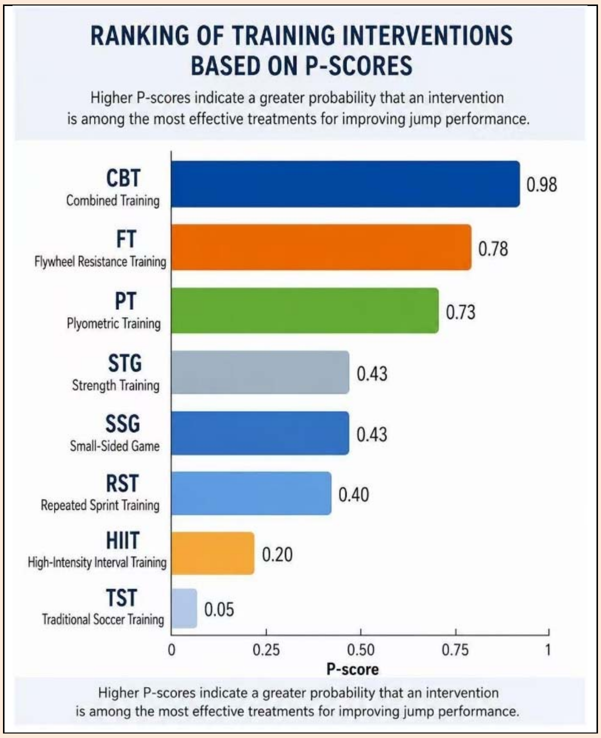

Figure 4. Ranking of training interventions based on P-scores. Higher P-scores indicate a higher ranking for improving CMJ performance. Effect sizes are presented as mean differences (MDs) with 95% confidence intervals.

Subgroup NMA

Subgroup analyses were conducted according to age (≤18 vs. >18 years), sex (male vs. female), and competitive level (Tier 2 - 3). Tier 1 was not analyzed due to insufficient data. In male and youth (≤18 years) subgroups, CBT ranked highest. In female and adult (>18 years) subgroups, PT ranked highest. In Tier 3 athletes, FT ranked highest. Subgroup-specific effect sizes (MDs with 95% CIs) and P-scores are presented in Supplementary Figures S1-S6 (https://www.jssm.org/SM/Man9351-2026SupplMaterials.pdf).

Risk of bias and credibility assessment

The risk of bias assessment is summarized in Figure 5. Among the 29 included studies, 3 (10.3%) were rated as low risk of bias and 26 (89.7%) as having some concerns. No studies were classified as high risk of bias according to the ROB2 assessment; therefore, a risk-of-bias exclusion sensitivity analysis was not performed. Detailed assessments are provided in Supplementary Table S15 (https://www.jssm.org/SM/Man9351-2026SupplMaterials.pdf). Certainty of evidence assessed using the CINeMA framework was predominantly low to moderate, with downgrades mainly due to within-study bias. A summary and network plot of study limitations are shown in Supplementary Figure S7-S8 (https://www.jssm.org/SM/Man9351-2026SupplMaterails.pdf). Detailed CINeMA results for the primary outcome (e.g., CMJ) are reported in Supplementary Table S16 (https://www.jssm.org/SM/Man9351-2026SupplMaterials.pdf).

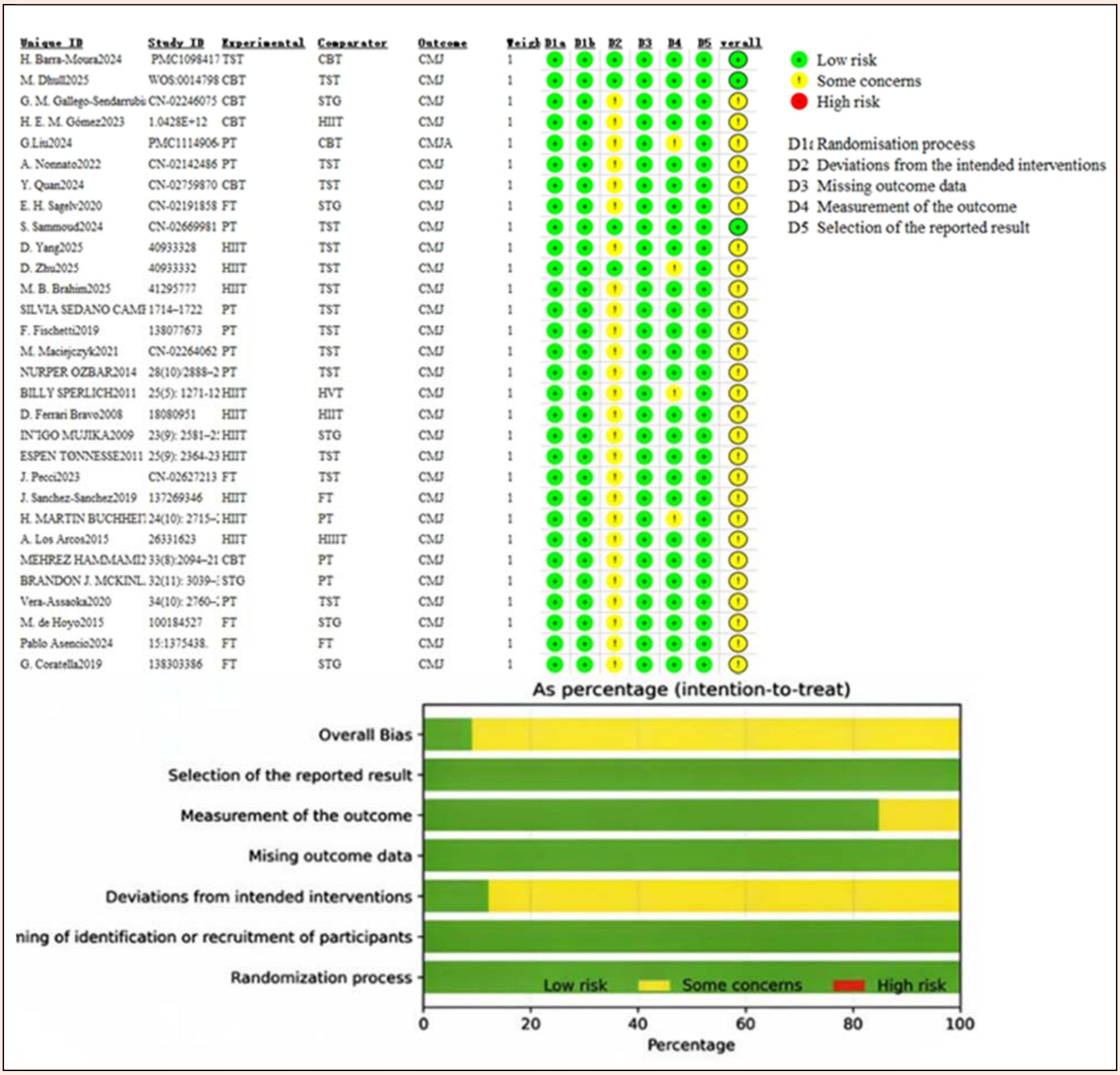

Figure 5. Risk-of-bias assessment of the included studies.

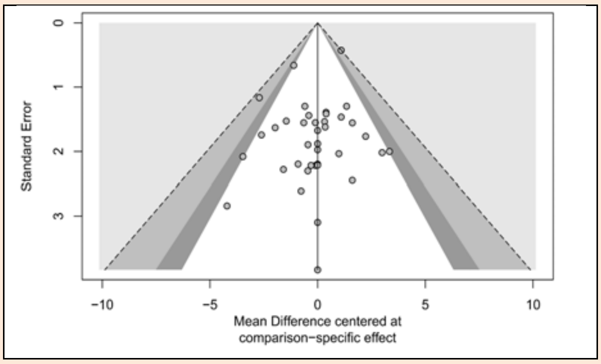

Figure 6. Funnel plot for assessment of publication bias.

Publication bias

Publication bias was assessed using funnel plots and Egger's regression test (Figure 6). The funnel plot showed slight asymmetry, and Egger's regression test suggested potential small-study effects ($t = 3.69$, $p = 0.0007$). These findings indicate that treatment effects may be somewhat overestimated in smaller studies. Therefore, the relatively high rankings of CBT, FT, and PT should be interpreted with caution, although the overall pattern of results remained consistent across the network.

Discussion

This study provides a comparative synthesis of different training modalities for improving CMJ performance in soccer players using a network meta-analysis framework. This NMA extends previous pairwise meta-analyses by integrating both direct and indirect evidence to compare and rank multiple training interventions for CMJ performance in soccer players. The results indicate that CBT, FT, and PT tended to show higher ranking probabilities; however, these findings should be interpreted in light of the predominantly low-to-moderate certainty of evidence and the limited number of direct head-to-head comparisons between active interventions. Consequently, treatment rankings should be viewed as comparative estimates rather than definitive evidence of superiority. Importantly, by applying an NMA approach, this study integrates both direct and indirect evidence, enabling the comparison and ranking of multiple training strategies within a single analytical framework. This approach may represent an advancement over previous pairwise meta-analyses and may provide a clearer understanding of the relative effectiveness of commonly used training modalities in soccer. These findings may provide practical implications for strength and conditioning practice.

Although CBT ranked highest overall, comparisons among active interventions provide additional practical insights. Compared with PT, the superior ranking of CBT may reflect the combined influence of resistance and plyometric components, potentially associated with both force production and rapid force expression. Compared with FT, CBT may offer broader neuromuscular adaptations, whereas FT is characterized by eccentric overload and may provide a greater eccentric stimulus that may be particularly beneficial for highly trained athletes. PT remained an effective intervention but may depend more strongly on the athlete's existing strength capacity and training background. However, because direct head-to-head comparisons between active interventions were limited, these observations should be interpreted with caution.

Effects of training on CMJ performance

Overall, the findings should be interpreted in light of the limited number of studies and the reliance on indirect evidence in some comparisons. CBT appeared to demonstrate the greatest observed improvements in CMJ performance, which may be related to adaptations in maximal strength, RFD, and SSC efficiency reported in literature. (Cormie et al., 2011). The integration of strength-based and plyometric stimuli may likely reflect complementary neuromuscular characteristics that have been reported in previous literature (Suchomel et al., 2016). From a practical perspective, these findings suggest that combining resistance and plyometric training may be an effective strategy for improving lower-limb explosive performance in soccer players.

FT is characterized by eccentric overload characteristics that have been linked to SSC-related performance adaptations in the literature (Raya-González et al., 2022). This type of stimulus may be associated with improvements in neuromuscular efficiency, tendon stiffness, and SSC function, all of which are critical for CMJ performance. These adaptations may be particularly beneficial for athletes with a higher training background, who require greater mechanical loading to further improve performance (Raya-González et al., 2022). PT was associated with moderate improvements in CMJ performance, which is consistent with previous findings suggesting its association with SSC-related performance characteristics and explosive strength qualities reported in the literature. However, its effectiveness may depend on the athlete’s strength level. Individuals with lower maximal strength levels may show attenuated responses to PT, potentially due to limitations in force production capacity reported in literature. Therefore, PT may be more effective when combined with strength-based training or applied in athletes with an adequate strength foundation (Markovic and Mikulic, 2010).

Other interventions, including SSG, RST, HIIT, and STG, showed limited or unclear effects on CMJ performance. The absence of statistically significant effects for STG and similar interventions should not be interpreted as evidence of physiological inefficacy, but rather as limited or heterogeneous statistical evidence within the current network. STG protocols varied across studies, which may further contribute to inconsistent effects. These modalities primarily target metabolic conditioning, sport-specific skills, or general strength rather than the specific neuromuscular qualities required for maximal vertical jump performance (Buchheit and Laursen, 2013, Girard et al., 2011). As a result, the current evidence does not clearly demonstrate consistent observed improvements in CMJ performance following these interventions. Subgroup analyses revealed that the effectiveness of training modalities may vary according to age, sex, and competitive level. For example, FT appeared to be more effective in higher-level athletes, whereas CBT generally ranked highly across several subgroups (Komi, 2000). These findings suggest that training strategies should be tailored to individual athlete characteristics. Subgroup analyses provide further insight into the relative effectiveness of different training modalities across populations. Athletes with greater strength levels may experience greater improvements in RFD following PT.

Age and training experience also appear to modulate training responses (Moran et al., 2017). Soccer players older than 18 years tended to benefit more from PT-dominant training programs, likely due to their relatively well-developed strength base. In contrast, youth players (≤18 years) showed greater responsiveness to CBT. Differences were also observed across competitive levels. In the primary model, FT produced the largest observed improvements in Tier 3 athletes. This may be explained by the fact that FT involves eccentric overload, which requires substantial strength reserves and neuromuscular adaptation. High-level athletes typically possess greater training experience and strength capacity, meaning that conventional training stimuli may be insufficient to induce further adaptation. Because FT generates high mechanical tension and strong neural stimuli, it may help athletes overcome training plateaus and achieve further improvements in strength and explosive power. In contrast, CBT ranked highest among Tier 2 athletes, which may reflect differences in strength reserves and performance ceilings between athletes of different competitive levels.

Although the results suggested that both FT and CBT can improve CMJ performance in soccer players, most effect estimates for CBT and FT were based on indirect evidence and relatively small sample sizes (k = 5), and therefore should be interpreted with caution. CINeMA indicated predominantly low-to-moderate certainty of evidence across comparisons, primarily driven by within-study bias and imprecision, which should be considered when interpreting treatment rankings. Although PT was the most frequently studied training modality (k = 11), its effectiveness varied across athletes of different levels. This may indicate that PT alone may be less effective when athletes lack sufficient strength foundations. Previous research has suggested that athletes should possess a certain level of strength before focusing on explosive power training. For example, a back squat strength of at least 1.5 times body mass has been suggested as a potential threshold (Suchomel et al., 2016). A meta-analysis published in 2012 reported similar findings, showing that athletes with longer training histories and stronger strength foundations experienced greater improvements in power following PT (Markovic and Mikulic, 2010).

Overall, the results indicate that training modality selection should be individualized according to athletes' sex, age, training experience, and competitive level (Suchomel et al., 2016). In addition, subgroup results based on limited sample sizes should be interpreted with caution.

Practical applications

The findings of this NMA provide practical guidance for strength and conditioning coaches working with soccer players. Practical recommendations based on intervention rankings, athlete characteristics, certainty of evidence, and typical implementation parameters are presented in Table 4. These practical recommendations are derived from relative treatment rankings and should be interpreted in light of implementation constraints, including variability in training protocols, limited certainty of evidence, network limitations, and reliance on indirect comparisons for several interventions.

For players with lower training experience or insufficient strength levels, CBT may be used as a foundational strategy. As athletes progress, more specific training modalities such as PT or FT can be implemented according to individual needs. Subgroup analyses suggest that training responses may differ across athlete characteristics. CBT showed the greatest improvements in males, youth, and Tier 2 athletes; PT was most effective in females and adult players; and FT produced the largest observed improvements in highly trained athletes. These findings highlight the importance of tailoring training strategies to individual athlete characteristics, while interpreting results with caution due to limited direct comparisons in some subgroups. Overall, training prescription should be individualized based on age, sex, and competitive level. Coaches are encouraged to select and adjust training modalities according to the specific characteristics and development stage of the players.

Methodological Strengths and Limitations

This study has several strengths. First, only RCTs were included, which improves study design quality relative to non-randomized evidence. Second, the NMA framework enabled the integration of both direct and indirect evidence, allowing a comprehensive comparison and ranking of multiple training modalities within a single analytical framework. Third, the use of a single outcome measure (CMJ performance) improved comparability across studies, although differences in testing protocols may still have contributed to outcome variability. Finally, detailed subgroup analyses based on age, sex, and competitive level provided more nuanced and practically relevant insights. The credibility of the findings was further supported by the ROB2 assessment, which identified no studies at high risk of bias, and by the CINeMA evaluation, which indicated predominantly low-to-moderate certainty of evidence across comparisons. The downgrading in CINeMA was mainly driven by within-study bias and imprecision in several comparisons. However, despite the restriction to RCTs, the presence of some concerns in RoB2 assessments and the relatively sparse NMA structure may still limit internal validity and reduce confidence in treatment ranking estimates. Several limitations should also be acknowledged. Moderate heterogeneity was observed in

Table 4 **Practical recommendations for improving CMJ performance in soccer players based on the network meta-analysis.**

Training modality	Player group	Duration	Frequency	Certainty (CINeMA)	Practical considerations (HOW/CONTEXT)	Cautions (LIMITATIONS)	Recommendation (WHAT works)
CBT (Combined training)	Youth (≤ 18), Tier 2, male	4 - 8 weeks	2 - 5 sessions/ week	Moderate	Combines resistance and plyometric stimuli and may be associated with complementary neuromuscular adaptations.	Some concerns in RoB2; moderate heterogeneity; limited head-to-head comparisons	Most effective modality for CMJ improvement
PT (Plyometric training)	Adult (> 18 years), female, general athletes	6 - 12 weeks	2 - 4 sessions/ week	Moderate	Particularly beneficial when athletes have an adequate strength foundation	Small number of studies; reliance on indirect comparisons; moderate heterogeneity	Effective for improving explosive performance
FT (Flywheel resistance training)	Tier 3 / highly trained	6 - 10 weeks	1 - 2 sessions/ week	Low-Moderate	May enhance neuromuscular adaptations under high mechanical load conditions	Small sample size; heterogeneous protocols; reliance on indirect evidence	Provides eccentric overload stimulus for CMJ improvement
STG (Traditional strength training)	Strength-focused athletes	4 - 8 weeks	2 - 3 sessions/ week	Low	Primarily develops general strength qualities rather than CMJ-specific adaptations	Heterogeneous training protocols; inconsistent effects; limited direct comparisons	Limited effectiveness for CMJ improvement
HIIT/RST/ SSG	Conditioning-focused soccer contexts	5 - 10 weeks	1 - 3 sessions/ week	Low	More suitable for conditioning and match fitness development	Indirect evidence base; small sample sizes; limited CMJ-specific adaptations	Limited direct transfer to CMJ performance

Note: Recommendations are based on NMA ranking probabilities. Certainty of evidence was assessed using CINeMA. Interpretation should consider indirect comparisons, study-level limitations, and variability in training protocols across studies.

the primary network ($I^2 = 32.4\%$), and higher heterogeneity was present in some subgroups (e.g., Tier 2), which may affect the precision of certain estimates. In addition, subgroup analyses were based on relatively small numbers of studies, reducing statistical power and increasing uncertainty, and several highly ranked interventions, such as CBT and FT, were supported by a limited number of studies. This may restrict the generalizability of the findings. In some cases, comparisons relied primarily on indirect evidence, and direct head-to-head comparisons between active interventions were relatively limited, which may reduce confidence in certain relative treatment estimates despite the advantages of the network meta-analytic framework. Additionally, key details of training interventions, such as intensity, volume, and progression, were not consistently reported across studies, limiting the ability to fully interpret and compare the effectiveness of different modalities. In particular, STG protocols were heterogeneous across studies and lacked standardized training prescriptions, which may limit node-level interpretability and contribute to variability in effect estimates. Consequently, the findings—especially those derived from subgroup analyses—should be interpreted with caution. In addition, clinical trial registries and grey-literature sources were not systematically searched. Subsequently, unpublished or ongoing studies may have been missed, which could contribute to publication bias and potentially inflate the estimated effects and treatment rankings within the network.

Future research should prioritize high-quality RCTs with explicit head-to-head comparisons between various training modalities to strengthen the evidence base. Standardized reporting of training protocols, including intensity, volume, and progression, is also needed to improve reproducibility and interpretation. Moreover, future studies should further explore subgroup-specific responses, which are likely to be exploratory and underpowered, particularly in underrepresented populations such as female and highly trained athletes, with prespecified recruitment targets for these populations in future trial design. Finally, future studies should prioritize direct comparisons between commonly used active interventions, particularly CBT versus FT, CBT versus PT, and FT versus PT, to strengthen the evidence base for relative treatment effectiveness. Integrating long-term follow-up and multiple performance outcomes may deliver a more comprehensive understanding of training adaptations in soccer players.

Conclusion

CBT ranked highest in effect estimates and appeared to be associated with the most favorable effects on CMJ performance in soccer players, followed by FT and PT. These findings suggest that combining strength and plyometric training stimuli may be beneficial for enhancing lower-limb explosive performance. However, the results should be interpreted in light of the predominantly low-to-moderate certainty of evidence and the limited number of direct head-to-head comparisons between active interventions and the relatively sparse structure of the intervention network. Training responses appeared to vary according to athlete characteristics, highlighting the potential value of individualized training strategies based on age, sex, and competitive level. Future high-quality RCTs directly comparing CBT, FT, and PT (i.e., CBT vs FT, CBT vs PT, and FT vs PT) are warranted to strengthen the evidence base, particularly through prespecified recruitment targets for female and highly trained (Tier 3) athletes, and to improve confidence in treatment rankings. The use of standardized training intervention reporting frameworks is also recommended to improve reproducibility and comparability across studies.

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Key points

- This network meta-analysis synthesized 29 RCTs involving 450 soccer players and compared eight training modalities for improving countermovement jump performance.
- Combined training ranked highest overall compared with traditional soccer training, followed by flywheel resistance training and plyometric training.
- Exploratory subgroup analyses indicated that combined training ranked highest in males, youth, and Tier 2 players; plyometric training in females and adults; and flywheel resistance training in Tier 3 players.
- The certainty of evidence was generally low to moderate, and the limited number of direct head-to-head comparisons between active interventions warrants cautious interpretation of treatment rankings.

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