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Hansi Xu, Tao Li, Weihuan Xing, Jiakang Zhu, Zirui Zhang & Zezhao Chen

Comparative Effectiveness of Training Interventions on VO_{2max} in Male Soccer Players: A Systematic Review and Network Meta-analysis

Hansi Xu,[1] Tao Li,[2] Weihuan Xing,[1] Jiakang Zhu,[2] Zirui Zhang,[3] Zezhao Chen[1,4*]

[1] School of Strength and Conditioning Training, Beijing Sport University, Beijing 100084, China.

[2] School of Chinese Basketball, Beijing Sport University, Beijing 100084, China.

[3] Department of Applied Physiology & Kinesiology, College of Health & Human Performance, University of Florida 1864 Stadium Road, Gainesville, FL 32611, USA.

[4] Key Laboratory for Performance Training and Recovery of General Administration of Sport, Beijing Sport University, Beijing, China.

*Corresponding author

Dr. Zezhao Chen[1,4*]

Assistant Professor

School of Strength and Conditioning Training

Beijing Sport University, Xinxi Road, Haidian District, Beijing, China

Email: chenzezhao2022@bsu.edu.cn

Phone:86-15759815717

https://orcid.org/0000-0003-0002-6748

Abstract

Objective: To systematically evaluate the effectiveness of various training interventions on maximal oxygen uptake (VO_{2max}) in male soccer players and to compare their relative effects using network meta-analysis.

Methods: PubMed, SPORTDiscus, Web of Science, and the Cochrane Library were searched from inception to February 1, 2026, using terms related to exercise, VO_{2max}, male athletes, soccer or football, inspiratory muscle training, strength training, change of direction training, and sprint training. Eligible studies included healthy male soccer players receiving additional training on top of regular soccer practice, with VO_{2max} reported as an outcome. A frequentist random-effects network meta-analysis was conducted, and interventions were ranked using P-scores. Subgroup analyses were performed according to age and competitive level.

Results: 29 studies involving 761 participants were included. Compared with soccer training only, high-intensity interval training (HIIT), small-sided games (SSG), and sprint training with change of direction (CODT) showed favorable effects on VO_{2max}. HIIT had the highest P-score (SMD = 0.97, 95% CI: 0.65 to 1.30; P-score = 0.85), followed by SSG (SMD = 0.91, 95% CI: 0.38 to 1.43; P-score = 0.77) and CODT (SMD = 0.71, 95% CI: 0.04 to 1.37; P-score = 0.60). Heterogeneity in the network was moderate (I^2 = 56.9%; τ^2 = 0.2643). Subgroup analyses suggested that inspiratory muscle training had the highest P-score in players aged <18 years, SSG had the top P-score in players aged ≥18 years and in lower-level players, whereas Strength and power training showed the most favorable P-score in higher-level players.

Conclusion: HIIT appeared to be a promising intervention for improving VO_{2max} in male soccer players and had the highest P-score in the primary analysis, while SSG and CODT also showed favorable effects. The relative effectiveness of training interventions may vary according to age and competitive level, supporting the importance of individualized training prescription.

Keywords: high-intensity interval training; aerobic capacity; endurance performance; physical conditioning.

Introduction

Modern competitive soccer requires players to sprint frequently for 90 minutes or longer and to switch rapidly between high-intensity effort and recovery [1]. Soccer players typically cover 8–13 km during a match, including approximately 0.7–1.0 km of high-intensity running and 0.2–0.3 km of sprinting activities, depending on playing position [2]. Consequently, these demands place substantial stress on both the aerobic energy system, which supports prolonged running and recovery, and the anaerobic energy system responsible for sprinting and explosive actions [3, 4]. Maximal oxygen uptake (VO_{2max}) is a key physiological indicator of cardiorespiratory fitness and endurance capacity, widely used to assess the athletic performance and recovery efficiency of soccer players [5, 6]. Athletes with higher VO_{2max} can run farther, complete more high-intensity training, and recover faster between training sessions, enabling them to maintain performance more effectively during competition, which makes endurance a key factor in soccer performance [7, 8]. In addition, a recent network meta-analysis (NMA) reported that higher-level soccer players exhibited greater VO_{2max} values than lower-level players, while midfielders and defenders generally demonstrated superior aerobic capacity compared with goalkeepers. The study also showed that VO_{2max} increased significantly with age [9]. The findings showed that VO_{2max} effectively distinguished athletic capacity and emphasized the importance of individual characteristics in training adaptation [10]. Similarly, previous studies have shown that maximal aerobic speed (MAS) progressively increases across youth soccer age groups, from 4.08 ± 0.29 m·s^{-1} in U13 players to 4.14 ± 0.26 m·s^{-1} in U14 players, 4.38 ± 0.26 m·s^{-1} in U15 players, and 4.61 ± 0.23 m·s^{-1} in U16 players [11]. Consequently, researchers have explored various training strategies to improve VO_{2max} and better meet the physiological demands of soccer. A body of research has shown that high-intensity interval training (HIIT) [12, 13] can effectively stimulate adaptive changes in the cardiovascular and skeletal muscle oxidative systems, thereby significantly improving VO_{2max} [14, 15]. Other training types, such as sprint training combined with change-of-direction training (CODT), have also shown positive effects on aerobic capacity. These improvements may be related to enhanced locomotor function and repeated sprint performance, which are associated with aerobic fitness in team-sport athletes [16] Similar findings have been reported for Strength and power training (SPT) and inspiratory muscle training (IMT) [17, 18]. Recently, increasing attention has been paid to combined training methods. For example, Arslanoglu et al. found that combining HIIT with small-sided games (SSG) [19] improved VO_{2max} and endurance performance more than HIIT alone. These findings suggest that adding tactical elements to high-intensity training may improve training effectiveness [20]. Other studies have shown that combining HIIT with CODT can improve explosive performance, agility, countermovement jump performance, and VO_{2max} in young soccer players [21].

Although some studies have explored the effects of various training interventions on soccer-specific VO_{2max}, few meta-analytic studies have compared multiple training methods simultaneously. For example, a meta-analysis by Yunus et al. (2023) confirmed the significant positive effect of HIIT on VO_{2max} in soccer players [22], another study reported similar improvements in endurance and VO_{2max} between HIIT and small-sided games (SSG) [23]. However, previous meta-analyses mainly focused on individual or limited training modalities and did not simultaneously compare the relative effectiveness of multiple interventions for improving VO_{2max} in soccer players. Therefore, this study aimed to systematically evaluate and compare the relative effectiveness of distinct training interventions for improving VO_{2max} in male soccer players.

Methods

Search strategy

This systematic review and NMA was registered in the International Prospective Register of Systematic Reviews (CRD 42025630939) and was reported in accordance with the PRISMA checklist [24] **(Supplementary File 1)**. Two authors (J.K.Z and H.S.X) conducted a comprehensive literature search in PubMed, SPORTDiscus, Web of Science, and the Cochrane Library through February 1, 2026. The search strategy used a combination of Medical Subject Headings (MeSH) terms and synonyms related to exercise, VO_{2max}, male athletes, soccer or football, inspiratory muscle training, strength training, change-of-direction training, and sprint training. The detailed search strategies, including the specific terms and methods used, are provided in **Supplementary File 2**.

Study selection

First, all retrieved records were imported into EndNote 21 reference management software, and duplicate records were removed. Secondly, conference abstracts, guidelines, reports, experimental protocols, and non-English literature were excluded, along with studies that did not involve regular soccer training. Finally, reviews and meta-analyses were excluded through a careful screening process. Title/abstract and full-text screenings were carried out independently and in duplicate by two reviewers (H.S.X and T.L), with any disagreements resolved through discussion, and a third reviewer (W.H.X) consulted when necessary.

Eligibility criteria

Participants were required to be healthy male soccer players, with no restrictions on age or competitive level. Female players were not included because sex-related physiological differences may influence aerobic capacity and training adaptations, and the currently available evidence involving female soccer players remains limited, which may increase heterogeneity across studies. During the intervention period, all participants were required to continue regular soccer training sessions. Focusing on the effects of additional training on top of routine soccer practice, this study included both intervention and control groups that engaged in some form of training intervention. A comprehensive definition of the exercise interventions is provided in **Supplementary File 3**. Only trials that reported VO_{2max} as a primary or secondary outcome were considered eligible for inclusion. In order to more comprehensively assess the effects of training interventions on VO_{2max} in soccer players, this review included both randomized controlled trials (RCTs) and non-randomized controlled trials (non-RCTs), while still applying strict criteria for study quality and methodological transparency.

Data extraction

The data from studies that met the inclusion criteria (H.S.X and T.L) were extracted independently by two authors and disagreements were resolved by consensus among the third authors (W.H.X). For each included study, pertinent data were extracted and entered into an Excel spreadsheet, including author information, publication year, country, study design, participant characteristics, baseline VO_{2max}, exercise type, training frequency, intervention duration, and intervention details **(Supplementary File 4)**. The formulas used to calculate mean change and standard deviation (SD) values were as follows:

$$\text{Meanchange} = \text{Meanpost} - \text{Meanpre}$$

$$\text{SDchange} = \sqrt{[(\text{SDpre}^2 + \text{SDpost}^2) - (2 \times R \times \text{SDpre} \times \text{SDpost})]}$$

According to the Cochrane Handbook, the correlation coefficient (R) was set at 0.5 [25]. To assess the robustness of this assumption, sensitivity analyses were additionally performed using alternative correlation coefficients of R = 0.3 and R = 0.7. This approach has been used in previous exercise-intervention meta-analyses and is supported by methodological guidance [26, 27].

Data setting

The exercises were divided into seven types according to their content: “Soccer training only” (CON), “High-intensity interval training” (HIIT), “Sprint with change of direction” (CODT), “Small-sided games” (SSG), “Strength and power training” (SPT), “Inspiratory muscle training” (IMT), In addition, Training methods that incorporated two or more of the above training modalities were defined as “HIIT-based combined training” (HICT). Exercise types were classified according to the group labels reported by the original study authors and the definitions provided in **Supplementary File 3**.

Data synthesis

The transitivity assumption was assessed by visually inspecting the distribution of study and intervention characteristics across treatment comparisons. These characteristics included study design, mean age, baseline VO_{2max}, exercise type, training frequency, intervention duration, session duration, and intervention details. These variables were selected because they were extracted from the included studies and may be related to training-induced changes in VO_{2max}. All data analyses were performed in R version 4.0.3 [28], primarily using the "netmeta" package. A frequentist random-effects model was applied for all outcomes. Specifically, soccer training only was selected as the control group for all NMA models. Firstly, Heterogeneity was assessed using within-design Q statistics, I^2, and τ^2 values. A p-value below 0.05 in the Q test was considered to indicate statistically significant heterogeneity. The detailed heterogeneity results are presented in **Supplementary File 5**. To assess the potential for publication bias and small-study effects, funnel plots were generated for each primary outcome and their symmetry was visually inspected, supplemented by Egger's regression test. A p-value below 0.05 indicated possible publication bias. Because VO_{2max} was assessed using different testing protocols across studies, standardized mean differences (SMDs) with 95% confidence intervals were used to improve comparability across trials. Second, network inconsistency was assessed using two approaches: the design-by-treatment interaction model to evaluate global inconsistency [29], and the separate indirect from direct evidence (SIDE) test to assess agreement between direct and indirect comparisons [30]. A network plot was constructed to assess the connectivity of the included interventions. See **Supplementary File 5** for detailed results.

Third, league tables were generated to display the estimated relative effects of all interventions. For interpretation, a positive value in each cell favors the row-defining intervention over the column-defining intervention, indicating greater improvement in VO_{2max}. Values are SMDs with 95% confidence intervals. The upper half shows the results of direct comparisons, whereas the lower half shows the results of mixed comparisons.

Finally, forest plots were constructed using “soccer training only” as the reference comparator to visualize the comparative effectiveness of the interventions. Furthermore, P-scores were used to rank the interventions according to their probability of being among the most effective.

Subgroup analysis

Subgroup analyses were conducted based on age group and competitive level. Based on the available study-level data, subgroup analyses were performed according to the reported mean age of participants (<18 years vs. ≥18 years). This threshold has been commonly used to distinguish youth and adult athletic populations in previous sports-related meta-analyses [31]. A second subgroup analysis was performed according to competitive level, which was classified based on the Participant Classification Framework proposed by McKay et al., (2022) [32]. According to this framework, Tier 1–2 participants represent recreationally active or trained/developmental athletes, whereas Tier 3 participants represent highly trained or national-level athletes. Therefore, for subgroup comparison, Tiers 1–2 were combined into a lower competitive level group, whereas Tier 3 was treated as a higher competitive level group. For each subgroup, treatment effects were re-estimated using the same frequentist random-effects model, and intervention rankings were generated using P-scores.

Risk of bias and quality of evidence

Risk of bias was assessed using the Cochrane Risk of Bias 2.0 (RoB2) tool [33-35]. Two reviewers (T.L. and W.H.X.) independently assessed five categories of risk of bias, including randomized sequence generation, bias due to deviations from the intended intervention, incomplete outcome data, measurement bias, and selective reporting bias. Disagreements were resolved by a fourth author (J.K.Z) **(Supplementary File 6)**. Additionally, sensitivity analyses were conducted to assess the robustness of the findings.

Results

Description of included studies

A total of 3,698 potentially eligible studies were searched. After removing literature that did not fit the criterion by title, abstract, After screening titles and abstracts, 138 studies were considered potentially eligible for inclusion and full-text articles were retrieved. After deleting duplicates and applying the inclusion criteria, 29 studies [14, 15, 17, 18, 20, 21, 36-58] published up to February 2026 were included in the analysis **(Figure 1).** A total of 761 participants were included, with sample sizes ranging from 7 to 28 each, mean ages from 13 to 25 years, and training interventions lasted 4 to 22 weeks with a frequency of 2 to 6 sessions per week. The exercise interventions in the 21 studies had HIIT [14, 15, 20, 21, 36, 39-43, 45-52, 56-58], 19 studies had Soccer Training Only [14, 17, 18, 20, 21, 36-38, 40-46, 48, 49, 53, 55], 9 studies had SSG [15, 37, 50-52, 54, 56-58], 4 studies had

CODT [21, 38, 39, 47] and SPT [17, 44, 45, 53], 3 studies had HICT [20, 21, 54], 2 studies had IMT [18, 55]. The grouping of exercise interventions is detailed in **Supplementary File 3**, and the characteristics of the included studies are provided in **Supplementary File 4**. Overall, the included studies were considered broadly comparable because all participants were healthy male soccer players, the interventions were generally implemented in the context of regular soccer training, and VO_{2max} was used as the common outcome. However, some clinical heterogeneity was observed across studies, particularly in mean age, baseline VO_{2max} , training frequency, intervention duration, session duration, and intervention details. Therefore, the transitivity assumption was considered generally plausible, although residual clinical heterogeneity could not be completely excluded.

Network connectivity and Heterogeneity assessment

NMA relies on sufficient connectivity between interventions. In the present analysis, the network plot showed no major connectivity issues, supporting the validity of the results **(Figure 2)**. The network showed moderate statistical heterogeneity, with I^2 = 56.9% (95% CI: 36.1% to 71.0%), τ^2 = 0.2643, and τ = 0.5141. Based on the within-design Q test, heterogeneity was mainly observed in the comparisons of CON vs HIIT (Q = 35.52, df = 12, p = 0.0004) and CON vs SPT (Q = 7.19, df = 2, p = 0.0275). In contrast, no significant heterogeneity was observed for HIIT vs SSG, CON vs IMT, or CODT vs HIIT. The overall within-design Q statistic was significant (Q = 53.58, df = 22, p = 0.0002), suggesting the presence of statistical heterogeneity in the network **(Supplementary Table 8)**.

Forest plot and league table

Compared to “CON”, three out of six exercise interventions (50%)—HIIT (P-score: 0.85), SSG (P-score: 0.77), and CODT (P-score: 0.60) showed significant effects on VO_{2max} **(Figure 3)**. However, the NMA results showed that no single intervention demonstrated superiority over more than two other exercise types **(Table 1)**. For example, HIIT showed a significant effect on VO_{2max} compared with CON (SMD = 1.05, 95% CI: 0.70 to 1.39). SSG (SMD = 0.91, 95% CI: 0.38 to 1.43) and CODT (SMD = 0.71, 95% CI: 0.04 to 1.37) also showed statistically significant benefits compared with CON. The remaining interventions showed either small effects or high uncertainty. Based on the Confidence in Network Meta-Analysis (CINeMA) ranking, HIIT had the highest probability of being among the more favorable interventions (SMD = 0.97, 95% CI: 0.65 to 1.30; P-score = 0.85). However, this ranking should be interpreted cautiously because P-scores reflect relative ranking probabilities and do not by themselves establish definitive superiority. Overall, HIIT, SSG, and CODT showed favorable effects compared with CON, whereas clear superiority among active interventions remained uncertain.

Age-based subgroup analysis

In players aged <18 years, IMT had the highest P-score (SMD = 0.54, 95% CI: -0.62 to 1.70; P-score = 0.75), followed by HIIT (SMD = 0.27, 95% CI: -0.46 to 0.99; P-score = 0.64) and CODT (SMD = 0.26, 95% CI: -0.61 to 1.12; P-score = 0.62). However, all confidence intervals in this subgroup crossed zero, indicating considerable uncertainty in these ranking results. In players aged ≥18 years, SSG ranked first (SMD = 1.54, 95% CI: 0.55 to 2.53; P-score = 0.92), followed by HIIT (SMD = 1.03, 95% CI: 0.68 to 1.38; P-score = 0.71) and HICT (SMD = 0.93, 95% CI: 0.08 to 1.79; P-score = 0.62) **(Figure 4)**.

Competitive level–based subgroup analysis

Among level 1–2 players, SSG had the highest P-score (SMD = 1.13, 95% CI: 0.27 to 2.00; P-score = 0.81), followed closely by HIIT (SMD = 1.05, 95% CI: 0.47 to 1.63; P-score = 0.78), while CODT showed a relatively high P-score but with a confidence interval crossing zero (SMD = 0.82, 95% CI: -0.18 to 1.82; P-score = 0.63). In level 3 players, SPT had the highest P-score (SMD = 0.96, 95% CI: 0.34 to 1.58; P-score = 0.87), followed by HIIT (SMD = 0.76, 95% CI: 0.46 to 1.06; P-score = 0.75). CODT showed a positive but statistically uncertain estimate in this subgroup (SMD = 0.51, 95% CI: -0.33 to 1.35; P-score = 0.51) **(Figure 5)**.

Risk of bias and certainty of evidence

Eighteen studies had a low risk of bias, eight studies had a moderate risk of bias, and three studies had a high risk of bias **(Figure 6)**. The risk of bias assessments for the individual included studies are presented in **Supplementary Table 10**. Sensitivity analyses excluding studies with a high risk of bias and analyses restricted to RCTs only showed consistent primary results, with HIIT remaining the highest-ranked intervention. Notably, before non-RCTs were excluded, SPT had the lowest ranking, whereas it ranked second in the RCT-only analysis. Additional sensitivity analyses using alternative assumed pre–post correlation coefficients of 0.3 and 0.7 for estimating change-score SDs also produced results consistent with the primary analysis using R = 0.5 **(Supplementary 8)**. According to the CINeMA assessment, three comparisons were rated as having high certainty of evidence, two comparisons as moderate certainty, twelve comparisons as low certainty, and four comparison as very low certainty. Overall, the quality of the evidence was low according to CINeMA **(Supplementary 7)** [59].

Publication bias

The funnel plot appeared symmetric with a uniform distribution of studies around the vertical axis. Egger's test yielded a non-significant result ($p = 0.2429$), indicating no evidence of small-study effects for the primary outcome **(Supplementary 9)**.

Discussion

This study is the first NMA to compare the effects of different training interventions on VO_{2max} in male soccer players. Overall, HIIT, SSG, and CODT were associated with favorable improvements in VO_{2max} compared with soccer training only, which is generally consistent with previous studies and meta-analyses in soccer players [22, 23]. Therefore, the added value of the present study should be regarded as an incremental contribution to the existing evidence rather than a breakthrough discovery, as it provides a comparative ranking of several commonly used training interventions within a single network meta-analytic framework. Among these interventions, HIIT appeared to be a promising intervention and had the highest P-score in the primary analysis, although this ranking should be interpreted cautiously because of the low certainty of evidence and overlapping confidence intervals among active interventions. Therefore, the main finding of this study is not that one intervention is definitively superior, but that several training modalities may be useful for improving VO_{2max}, while the superiority of one active intervention over another remains uncertain.

Among all included interventions, HIIT showed a relatively favorable effect estimate and the highest P-score in the primary analysis. Among the included studies, HIIT protocols varied in exercise format, intensity prescription, and work–recovery structure. Most HIIT interventions were running-based and could be broadly categorized into long-interval running, short-interval running, and sprint-interval/repeated-sprint formats. Long-interval HIIT commonly involved 3–4 min running bouts performed at approximately 70–95% or 90–95% HRmax, usually interspersed with active recovery periods. Short-interval HIIT typically consisted of repeated 15–30 s high-intensity running bouts, prescribed using HRmax, maximal aerobic velocity, or VIFT. Sprint-interval protocols included very short maximal or near-maximal sprint bouts, ranging from approximately 5 to 60 s, with incomplete recovery between repetitions or sets. Therefore, the included HIIT interventions were not identical in duration or intensity, but they shared the common feature of repeated high-intensity exercise bouts interspersed with recovery periods, which is consistent with the conceptual framework proposed by Coates et al. [60]. Previous studies have shown that HIIT can significantly improve VO_{2max}

and endurance performance in soccer players [36, 40, 41], and earlier meta-analyses have likewise confirmed its positive effect on VO_{2max} in this population [23]. One possible explanation is that enhancements in VO_{2max} are generally mediated by both central adaptations related to oxygen delivery and peripheral adaptations related to oxygen extraction and utilization [61]. From a central perspective, repeated training sessions performed at near-maximal intensity may increase stroke volume and cardiac output [62]. From a peripheral perspective, HIIT may induce mitochondrial biogenesis, increase capillary density, and enhance oxidative enzyme activity, thereby improving skeletal muscle oxygen uptake and utilization [63]. Laursen and Jenkins also noted that HIIT can concurrently improve oxygen delivery and oxygen utilization [64], which may partly explain its relative advantage in the present study. More importantly, soccer is inherently an intermittent sport characterized by repeated high-intensity efforts interspersed with short recovery periods, and the training structure of HIIT closely matches these sport-specific demands [3]. During match play, Mohr et al. reported that top-class players covered 2.43 ± 0.14 km of high-intensity running and 0.65 ± 0.06 km of sprinting, whereas moderate-level players covered 1.90 ± 0.12 km and 0.41 ± 0.03 km, respectively [65]. These match-load characteristics may explain why the training structure of HIIT closely matches the sport-specific demands of soccer.

In addition to HIIT, SSG and CODT also showed relatively favorable effect estimates compared with CON. However, the intervention categories in this

NMA should be interpreted as broad training modalities rather than fully standardized protocols, and this within-category variability limits the extent to which specific physiological mechanisms can be inferred. Previous studies have suggested that SSG can not only improve aerobic capacity, but also integrate technical performance, tactical awareness, and decision-making within the training process, thereby facilitating the transfer of training adaptations to actual match performance [66]. Similarly, CODT involves repeated accelerations, decelerations, and multidirectional movements, which provide a substantial sport-specific physiological stimulus and may contribute to improvements in neuromuscular control and lower-limb force production. Harper et al. emphasized the importance of acceleration and deceleration actions in multidirectional sports [67], while Chaouachi et al. suggested that change-of-direction ability is closely related to strength-related qualities in soccer players [68]. In addition, Ortiz et al. reported that supramaximal intermittent shuttle-run training prescribed at 115% of PST-CAR produced greater improvements in aerobic performance-related indices, including LMS, PST-CAR, and VO_{2max}, than regular preseason soccer training alone in junior male soccer players [38]. However, compared with HIIT, the training load of SSG is more likely to be influenced by factors such as pitch size, number of players, and rule constraints, which may reduce load standardization [69]. In the included studies, SSG protocols varied considerably in player format, bout duration, recovery structure, and intensity prescription. For example, some studies used shorter SSG formats, such as 4 sets of 3–4 min or 7 sets of 3 min with approximately 90 s to 3 min of recovery [52, 56], whereas others used longer formats, such as 2–6 sets of 9–13 min or 2–4 sets of 6–10 min [51, 54]. The prescribed intensity also differed across studies, ranging from approximately 60–70% HRmax to >85% HRmax or 70–95% HRmax [50, 56]. These variations in SSG design may partly explain the variability in the estimated effects of SSG across studies. These variations in SSG design may partly explain the variability in the estimated effects of SSG across studies. Although both SSG and CODT showed favorable effects compared with CON, SSG showed a more favorable effect estimate and P-score than CODT in the present NMA. However, both interventions remained below HIIT in the overall ranking. This finding is partly supported by included SSG studies reporting improvements in aerobic capacity following small-sided game interventions [50-52, 54, 56]. Likewise, CODT protocols in the included studies also differed in training design and intensity prescription. Specifically, these protocols included maximal-effort change-of-direction sprinting over 10–30 m [21], supramaximal shuttle running at 115% of PST-CAR [38], repeated change-of-direction sprints at 100% speed [39], and 180° shuttle runs performed at approximately 90% HRmax [47]. These included CODT studies also supported the potential positive role of change-of-direction sprint or shuttle-running protocols in improving aerobic-related outcomes. However, the available evidence did not establish a clear direct superiority of SSG over CODT, because this comparison was mainly based on network estimates rather than direct head-to-head trials. Therefore, although

SSG appeared to show a more favorable ranking than CODT, the comparative advantage between these active interventions should still be interpreted cautiously. Similarly, the HICT node should be interpreted cautiously because it was based on only three studies and represented heterogeneous combined interventions, including HIIT + CODT, HIIT + SSG, and HIIT + aerobic-based training. Therefore, the physiological explanations discussed here should be regarded as plausible interpretations based on previous literature rather than mechanisms directly tested in the present NMA.

The subgroup analyses of the present study suggested that the relative effects of different training interventions on VO_{2max} may vary according to age and competitive level, thereby providing preliminary insight into the potential need for individualized training prescription in soccer training. In younger players, IMT had the highest P-score; however, the corresponding confidence interval crossed zero and was relatively wide, indicating substantial uncertainty. Therefore, this finding should be interpreted only as an exploratory ranking signal rather than evidence of a clear advantage of IMT in players aged <18 years. Although previous studies in young soccer players have shown that inspiratory muscle training can improve pulmonary function, ventilation, and aerobic performance [18], the present subgroup result is insufficient to confirm a consistent benefit of IMT in this population. In older players, SSG and HIIT showed higher P-scores and more favorable effect estimates, which may indicate that sport-specific or structured high-intensity stimuli could be relevant for improving VO_{2max} in this subgroup.

However, these age-based subgroup findings should be interpreted cautiously because chronological age does not necessarily reflect biological maturation. Late-adolescent players may present physiological and training-response characteristics closer to adult players than to younger adolescents, while players of the same chronological age may differ substantially in biological maturity status [70]. Bejm and Klimek investigated the longitudinal changes in aerobic capacity among 7–12-year-old soccer players. They reported that although VO_{2max} and maximal aerobic speed changed across the early training years, training load was not strongly associated with VO_{2max} changes. The observed differences in aerobic capacity appeared to be more related to individual developmental trajectories and biological variability than to training load alone [71]. Therefore, when interpreting age-based subgroup findings, chronological age should not be regarded as a complete indicator of training response or biological maturation. In the subgroup analysis by competitive level, SSG had the highest P-score among lower-level players, which may suggest a possible greater responsiveness to game-based, high-intensity aerobic stimuli in this population. By contrast, SPT had the highest P-score among higher-level players, which may suggest that neuromuscular adaptations, movement economy, force-production capacity, and tolerance to repeated high-intensity efforts could also contribute to aerobic-related performance in well-trained athletes [72, 73]. This interpretation is partly supported by previous studies showing that resistance-based or combined strength-power training can improve aerobic-related performance through enhanced neuromuscular function, reduced running cost, and improved mechanical efficiency, even when changes in VO_{2max} itself are modest or inconsistent [17, 45, 53]. This interpretation is also relevant to the sensitivity analysis restricted to RCTs. After non-randomized studies were excluded, SPT ranked second in the RCT-only analysis, whereas it had the lowest ranking in the primary analysis. This change may be partly explained by the influence of the excluded non-randomized studies. For example, in one non-randomized SPT study, the experimental group had a higher baseline VO_{2max} than the control group at pretest. However, VO_{2max} decreased in the experimental group after the intervention (from 59.64 ± 4.22 to 57.96 ± 8.00), whereas the control group showed an increase from baseline to post-test (from 51.11 ± 5.54 to 52.88 ± 7.15) [44]. This opposite direction of change may have reduced the estimated effect of SPT in the primary analysis. However, although SPT ranked higher in the RCT-only analysis, its confidence interval was relatively wide, suggesting imprecision and limited stability of the estimate. In contrast, HIIT remained consistently high-ranked across analyses with a relatively narrow confidence interval. Therefore, the effect of SPT on VO_{2max} should still be interpreted cautiously, and more high-quality RCTs are needed to further clarify its effectiveness in male soccer players. Nevertheless, given the limited number of studies included in some subgroups and the relatively wide confidence intervals of several effect estimates, the subgroup findings should still be interpreted with caution.

This study also has several strengths. It provides a more comprehensive overview of the relative effectiveness of available training strategies than traditional pairwise comparisons by integrating both direct and indirect evidence across multiple exercise modalities. Importantly, all included studies were conducted on top of regular soccer training, which enhances the ecological validity and practical relevance of the findings for real-world soccer settings. In addition, the subgroup analyses according to age and competitive level offer further practical insight into the potential need for individualized training prescription in different soccer populations. Nevertheless, several limitations should also be acknowledged. First, the overall certainty of evidence was low according to the CINeMA assessment, with many comparisons rated as low or very low certainty. Therefore, the comparative effects and P-score rankings should be interpreted cautiously. Although HIIT had the highest P-score in the primary analysis, this should be regarded as an exploratory indication of relative ranking rather than definitive evidence that HIIT is superior to all other interventions. In addition, some intervention nodes were supported by a small number of studies, which may reduce the stability of the network estimates and rankings. Second, only English-language studies were included, which may have led to the omission of relevant evidence published in other languages, thereby introducing potential language bias and limiting the generalizability of the findings. Future research should aim to include non-English studies to minimize language bias. Finally, although subgroup analyses were conducted according to age and competitive level, the number of studies included in some subgroups was limited, and these stratified results should therefore be interpreted with caution. Moreover, because the present review only analyzed changes in VO_{2max}, the conclusions should be limited to aerobic capacity. As soccer performance is largely determined by both aerobic and anaerobic abilities, the present findings should not be interpreted as evidence that HIIT, SSG, and CODT have the greatest overall impact on soccer-specific physical performance. Future high-quality research is warranted to confirm these findings, strengthen subgroup evidence across different age groups and competitive levels, and incorporate both aerobic and anaerobic performance variables, long-term follow-up, and broader soccer-specific performance outcomes to refine training prescriptions for male soccer players.

Conclusions

This study is the first NMA to compare the effects of different training interventions on VO_{2max} in male soccer players. Overall, HIIT, SSG, and CODT were associated with favorable improvements in VO_{2max} compared with soccer training only, with HIIT showing the highest P-score in the primary analysis. However, because the overall certainty of evidence was low and clear superiority among active interventions was uncertain, these findings should be interpreted as suggestive rather than definitive. These findings suggest that training methods characterized by higher physiological demands and closer alignment with the intermittent nature of soccer may be more effective for improving aerobic capacity in male soccer players. In addition, the subgroup analyses indicate that age and competitive level may influence training responses, suggesting the potential value of individualized training prescription.

List of abbreviations

CI: Confidence interval

CINeMA: Confidence in Network Meta-Analysis

CODT: Sprint training with change of direction

CON: Soccer training only

HIIT: High-intensity interval training

IMT: Inspiratory muscle training

MeSH: Medical Subject Headings

SPT: Strength and power training

HICT: HIIT-based combined training

NMA: Network meta-analysis

non-RCTs: Non-randomized controlled trials

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses

RCTs: Randomized controlled trials

RoB2: Cochrane Risk of Bias 2.0

SD: Standard deviation

SIDE: Separate indirect from direct evidence

SMD: Standardized mean difference

SSG: Small-sided games

VO_{2max}: Maximal oxygen uptake

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References

1. Nédélec M, McCall A, Carling C, Legall F, Berthoin S, Dupont G. Recovery in soccer: part I - post-match fatigue and time course of recovery. *Sports Med*. 2012;42(12):997-1015. doi:10.2165/11635270-000000000-00000
2. Di Salvo V, Gregson W, Atkinson G, Tordoff P, Drust B. Analysis of high intensity activity in Premier League soccer. *Int J Sports Med*. 2009;30(3):205-212. doi:10.1055/s-0028-1105950
3. Stølen T, Chamari K, Castagna C, Wisløff U. Physiology of soccer: an update. *Sports Med*. 2005;35(6):501-536. doi:10.2165/00007256-200535060-00004
4. Bangsbo J, Mohr M, Krustrup P. Physical and metabolic demands of training and match-play in the elite football player. *J Sports Sci*. 2006;24(7):665-674. doi:10.1080/02640410500482529
5. Kavanagh R, McDaid K, Rhodes D, Connor M, Oliveira R, et al. (2023) The Relationship between VO2 max and 1200m Shuttle Run Performance in Elite Academy Football Players. Int J Sports Exerc Med 9:261. doi.org/10.23937/2469-5718/1510261
6. Poole DC, Jones AM. Measurement of the maximum oxygen uptake Vo_{2max}: Vo_{2peak} is no longer acceptable. *J Appl Physiol (1985)*. 2017;122(4):997-1002. doi:10.1152/japplphysiol.01063.2016
7. Bangsbo J, Mohr M, Krustrup P. Physical and metabolic demands of training and match-play in the elite football player. *J Sports Sci*. 2006;24(7):665-674.

doi:10.1080/02640410500482529
8. Tønnessen E, Hem E, Leirstein S, Haugen T, Seiler S. Maximal aerobic power characteristics of male professional soccer players, 1989-2012. *Int J Sports Physiol Perform*. 2013;8(3):323-329. doi:10.1123/ijspp.8.3.323
9. Slimani M, Znazen H, Miarka B, Bragazzi NL. Maximum Oxygen Uptake of Male Soccer Players According to their Competitive Level, Playing Position and Age Group: Implication from a Network Meta-Analysis. J Hum Kinet. 2019 Mar 27;66:233-245. doi: 10.2478/hukin-2018-0060. PMID: 30988857; PMCID: PMC6458571.
10. Metaxas TI. Match Running Performance of Elite Soccer Players: Vo2max and Players Position Influences. *J Strength Cond Res*. 2021;35(1):162-168. doi:10.1519/JSC.0000000000002646
11. Rowan A, Atkins S, Comfort P: A comparison of maximal aerobic speed and maximal sprint speed in elite youth soccer players. *Prof Strength Cond J* 2019, 53:24–29.
12. Billat LV, Koralsztein JP. Significance of the velocity at VO2max and time to exhaustion at this velocity. *Sports Med*. 1996;22(2):90-108. doi:10.2165/00007256-199622020-00004
13. Coates AM, Joyner MJ, Little JP, Jones AM, Gibala MJ. A Perspective on High-Intensity Interval Training for Performance and Health. *Sports Med*. 2023;53(Suppl 1):85-96. doi:10.1007/s40279-023-01938-6
14. Liu Q, Wang W, Shu C. Effects of Short Sprint Interval Training Frequency on Physical and Physiological Performance Adaptations in Male Soccer Players. *J Sports Sci Med*. 2024;23(4):707-717. Published 2024 Dec 1. doi:10.52082/jssm.2024.707
15. Boraczyński MT, Laskin JJ, Gajewski J, Podstawski RS, Brodnicki MA, Boraczyński TW. Effects of two low-volume high-intensity interval training protocols in professional soccer: sprint interval training versus small-sided games. *J Sports Med Phys Fitness*. 2023;63(1):23-33. doi:10.23736/S0022-4707.22.13589-9
16. Buchheit M. Repeated-sprint performance in team sport players: associations with measures of aerobic fitness, metabolic control and locomotor function. *Int J Sports Med*. 2012;33(3):230-239. doi:10.1055/s-0031-1291364
17. Silva AF, Aghidemand MH, Kharatzadeh M, et al. Effects of High-Intensity Resistance Training on Physical Fitness, Hormonal and Antioxidant Factors: A Randomized Controlled Study Conducted on Young Adult Male Soccer Players. *Biology (Basel)*. 2022;11(6):909. Published 2022 Jun 13. doi:10.3390/biology11060909
18. Mackała K, Kurzaj M, Okrzymowska P, Stodółka J, Coh M, Rożek-Piechura K. The Effect of Respiratory Muscle Training on the Pulmonary Function, Lung Ventilation, and Endurance Performance of Young Soccer Players. *Int J Environ Res Public Health*. 2019;17(1):234. Published 2019 Dec 28. doi:10.3390/ijerph17010234
19. Casamichana D, Castellano J. Time-motion, heart rate, perceptual and motor behaviour demands in small-sides soccer games: effects of pitch size. *J Sports Sci*. 2010;28(14):1615-1623. doi:10.1080/02640414.2010.521168
20. Arslanoglu C, Celgin GS, Arslanoglu E, Demirci N, Karakas F, Dogan E, Cakaloglu E, Sahin FN, Kucuk H. An Effective Method of Aerobic Capacity Development: Combined Training with Maximal Aerobic Speed and Small-Sided Games for Amateur Football Players. *Applied Sciences*. 2024; 14(19):9134. https://doi.org/10.3390/app14199134
21. Marzouki H, Ouergui I, Doua N, Gmada N, Bouassida A, Bouhlel E. Effects of 1 vs. 2 sessions per week of equal-volume sprint training on explosive, high-intensity and endurance-intensive performances in young soccer players. *Biol Sport*. 2021;38(2):175-183. doi:10.5114/biolsport.2020.97675
22. Yunus M, Pratama MH, Wahjuni ES: Meta Analysis Study: The Effect of HIIT Training on VO2max Improvement of Football Athletes. *Jp jok (Jurnal Pendidikan Jasmani Olahraga dan Kesehatan)* 2023, 6(2):319-333. doi: 10.33503/jp.jok.v6i2.1018
23. Clemente FM, Moran J, Ramirez-Campillo R, Beato M, Afonso J: **Endurance Performance Adaptations between SSG and HIIT in Soccer Players: A Meta-analysis**. *Int J Sports Med* 2024, **45**(3):183-210.
24. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Shamseer L,

Tetzlaff JM, Akl EA, Brennan SE: The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *bmj* 2021, 372. doi: 10.1136/bmj.n71
25. Chandler J, Cumpston M, Li T, Page MJ, Welch V: Cochrane handbook for systematic reviews of interventions. *Hoboken: Wiley* 2019, 4(1002):14651858.
26. Ye C, Fu H, Zhou X, Zhang Z. Time-efficient and beneficial strategy: low-volume high-intensity interval training for cardiometabolic health and body composition outcomes in children and adolescents with overweight or obesity-a systematic review and meta-analysis. *Front Physiol*. 2026;16:1732253. Published 2026 Jan 30. doi:10.3389/fphys.2025.1732253
27. Impellizzeri FM, Bizzini M. Systematic review and meta-analysis: a primer. *Int J Sports Phys Ther*. 2012;7(5):493-503.
28. Team RDC: R: A Language and Environment for Statistical Computing, Reference Index. *Vienna: R Foundation for Statistical Computing* 2010.
29. Higgins JP, Jackson D, Barrett JK, Lu G, Ades AE, White IR. Consistency and inconsistency in network meta-analysis: concepts and models for multi-arm studies. *Res Synth Methods*. 2012;3(2):98-110. doi:10.1002/jrsm.1044
30. Dias S, Welton NJ, Caldwell DM, Ades AE. Checking consistency in mixed treatment comparison meta-analysis. *Stat Med*. 2010;29(7-8):932-944. doi:10.1002/sim.3767
31. Lambrich J, Muehlbauer T. Effects of athletic training on physical fitness and stroke velocity in healthy youth and adult tennis players: A systematic review and meta-analysis. *Front Sports Act Living*. 2023;4:1061087. Published 2023 Jan 10. doi:10.3389/fspor.2022.1061087
32. McKay AKA, Stellingwerff T, Smith ES, et al. Defining Training and Performance Caliber: A Participant Classification Framework. *Int J Sports Physiol Perform*. 2022;17(2):317-331. doi:10.1123/ijspp.2021-0451
33. Higgins JP, Altman DG, Gøtzsche PC, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ*. 2011;343:d5928. Published 2011 Oct 18. doi:10.1136/bmj.d5928
34. Minozzi S, Cinquini M, Gianola S, Gonzalez-Lorenzo M, Banzi R. The revised Cochrane risk of bias tool for randomized trials (RoB 2) showed low interrater reliability and challenges in its application. *J Clin Epidemiol*. 2020;126:37-44. doi:10.1016/j.jclinepi.2020.06.015
35. Minozzi S, Dwan K, Borrelli F, Filippini G. Reliability of the revised Cochrane risk-of-bias tool for randomised trials (RoB2) improved with the use of implementation instruction. *J Clin Epidemiol*. 2022;141:99-105. doi:10.1016/j.jclinepi.2021.09.021
36. Diker G, Darendeli A, Chamari K, et al. Recovery time variation during sprint interval training impacts amateur soccer players adaptations - a pilot study. *Biol Sport*. 2023;40(2):417-424. doi:10.5114/biolsport.2023.116008
37. Karahan M. Effect of skill-based training vs. small-sided games on physical performance improvement in young soccer players. Biol Sport. 2020 Sep;37(3):305-312. doi: 10.5114/biolsport.2020.96319. Epub 2020 Jun 26. PMID: 32879553; PMCID: PMC7433329.
38. Ortiz JG, de Lucas RD, Teixeira AS, Mohr PA, Guglielmo LGA. The Effects of a Supramaximal Intermittent Training Program on Aerobic and Anaerobic Running Measures in Junior Male Soccer Players. *J Hum Kinet*. 2023;90:253-267. Published 2023 Oct 11. doi:10.5114/jhk/170755
39. Sagelv EH, Selnæs I, Pedersen S, Pettersen SA, Randers MB, Welde B. Effects of Linear Versus Changes of Direction Repeated Sprints on Intermittent High Intensity Running Performance in High-level Junior Football Players over an Entire Season: A Randomized Trial. *Sports (Basel)*. 2019;7(8):189. Published 2019 Aug 6. doi:10.3390/sports7080189
40. Samavati Sharif MA, Ramezani M, Siavoshi H: A Comparative Study of Intense Continuous and Intermittent Aerobic Training on Physiological Factors in Football Players. *International Journal of Sport Studies for Health* 2024, 7(1):74-81. doi: 10.61838/kman.intjssh.7.1.9

41. Selmi W, Hammami R, Kasmi S, et al. Effects of Aerobic and Speed Training Versus Active Control on Repeated Sprint Ability and Measures of Self-confidence and Anxiety in Highly Trained Male Soccer Players. *Sports Med Open*. 2023;9(1):63. Published 2023 Jul 27. doi:10.1186/s40798-023-00619-y
42. Ouerghi N, Khammassi M, Boukorraa S, Feki M, Kaabachi N, Bouassida A. Effects of a high-intensity intermittent training program on aerobic capacity and lipid profile in trained subjects. *Open Access J Sports Med*. 2014;5:243-248. Published 2014 Oct 17. doi:10.2147/OAJSM.S68701
43. Helgerud J, Engen LC, Wisloff U, Hoff J. Aerobic endurance training improves soccer performance. *Med Sci Sports Exerc*. 2001;33(11):1925-1931. doi:10.1097/00005768-200111000-00019
44. Wong PL, Chamari K, Wisløff U. Effects of 12-week on-field combined strength and power training on physical performance among U-14 young soccer players. *J Strength Cond Res*. 2010;24(3):644-652. doi:10.1519/JSC.0b013e3181ad3349
45. Yang G, Chen W, Qi D, Zhang J, Men Z. The Effects of a 6-Week Plyometric and Sprint Interval Training Intervention on Soccer Player's Physical Performance. *J Sports Sci Med*. 2024;23(1):526-536. Published 2024 Sep 1. doi:10.52082/jssm.2024.526
46. Wells C, Edwards A, Fysh M, Drust B. Effects of high-intensity running training on soccer-specific fitness in professional male players. *Appl Physiol Nutr Metab*. 2014;39(7):763-769. doi:10.1139/apnm-2013-0199
47. Perween S, Hussain ME, Hejazi II, Siddiqui MYS, Saif A, Parveen A: Comparison of sprint training and high intensity interval training on oxidative stress and aerobic capacity in male soccer players. *Comparative Exercise Physiology* 2020, 16(5):357-366. doi:10.3920/CEP190078
48. Kavaliauskas M, Kilvington R, Babraj J. Effects of in-season uphill sprinting on physical characteristics in semi-professional soccer players. *J Sports Med Phys Fitness*. 2017;57(3):165-170. doi:10.23736/S0022-4707.16.06066-7
49. Gunduz K, Nas K, Arici H, Pamuk O: The effect of endurance training on cardiac and muscle damage in male football players. *Journal of Mens Health* 2024, 20(10):158-165. doi: 10.22514/jomh.2024.175
50. Arslan E, Orer GE, Clemente FM. Running-based high-intensity interval training vs. small-sided game training programs: effects on the physical performance, psychophysiological responses and technical skills in young soccer players. *Biol Sport*. 2020;37(2):165-173. doi:10.5114/biolsport.2020.94237
51. Hill-Haas SV, Coutts AJ, Rowsell GJ, Dawson BT. Generic versus small-sided game training in soccer. *Int J Sports Med*. 2009;30(9):636-642. doi:10.1055/s-0029-1220730
52. Jastrzebski Z, Barnat W, Dargiewicz R, Jaskulska E, Szwarc A, Radziminski L: Effect of In-Season Generic and Soccer-Specific High-Intensity Interval Training in Young Soccer Players. *International Journal of Sports Science & Coaching* 2014, 9(5):1169-1179.
53. Mohamed KS, Mohamed K, Mohammed S, Mokrani D, Belkadi A: The Effect of Heavy Weight Training on Physiological Abilities of Soccer Players Under the Age 21 Years Old. *Acta Facultatis Educationis Physicae Universitatis Comenianae* 2019, 59(1):33-43. doi: 10.2478/afepuc-2019-0004
54. Amani-Shalamzari S, Khoshghadam E, Donyaei A, Parnow A, Bayati M, Clemente FM. Generic vs. small-sided game training in futsal: Effects on aerobic capacity, anaerobic power and agility. *Physiol Behav*. 2019;204:347-354. doi:10.1016/j.physbeh.2019.03.017
55. Özgider C, Korkusuz F: Four Weeks of Respiratory Muscle Training Improves Intermittent Recovery Performance But Not Pulmonary Functions and Maximum Oxygen Consumption (VO2 max) Capacity in Young Soccer Players. *Dissertation/Thesis.* 2010.
56. Safania AM: A Comparison of Small-Side Games and Interval Training on Same Selected Physical Fitness Factors in Amateur Soccer Players 1 2 3. *Journal of Social Sciences*

2011, 7:349-353.
57. Radziminski L, Rompa P, Barnat W, Dargiewicz R, Jastrzębski Z: A Comparison of the Physiological and Technical Effects of High-Intensity Running and Small-Sided Games in Young Soccer Players. *International Journal of Sports Science & Coaching* 2013, 8:455-466. doi:10.1260/1747-9541.8.3.455
58. Impellizzeri FM, Marcora SM, Castagna C, et al. Physiological and performance effects of generic versus specific aerobic training in soccer players. *Int J Sports Med*. 2006;27(6):483-492. doi:10.1055/s-2005-865839
59. Nikolakopoulou A, Higgins JPT, Papakonstantinou T, et al. CINeMA: An approach for assessing confidence in the results of a network meta-analysis. *PLoS Med*. 2020;17(4):e1003082. Published 2020 Apr 3. doi:10.1371/journal.pmed.1003082
60. Coates AM, Joyner MJ, Little JP, Jones AM, Gibala MJ. A Perspective on High-Intensity Interval Training for Performance and Health. *Sports Med*. 2023;53(Suppl 1):85-96. doi:10.1007/s40279-023-01938-6
61. Bassett DR Jr, Howley ET. Limiting factors for maximum oxygen uptake and determinants of endurance performance. *Med Sci Sports Exerc*. 2000;32(1):70-84. doi:10.1097/00005768-200001000-00012
62. Hellsten Y, Nyberg M. Cardiovascular Adaptations to Exercise Training. *Compr Physiol*. 2015;6(1):1-32. Published 2015 Dec 15. doi:10.1002/cphy.c140080
63. MacInnis MJ, Gibala MJ. Physiological adaptations to interval training and the role of exercise intensity. *J Physiol*. 2017;595(9):2915-2930. doi:10.1113/JP273196
64. Laursen PB, Jenkins DG. The scientific basis for high-intensity interval training: optimising training programmes and maximising performance in highly trained endurance athletes. *Sports Med*. 2002;32(1):53-73. doi:10.2165/00007256-200232010-00003
65. Mohr M, Krustrup P, Bangsbo J. Match performance of high-standard soccer players with special reference to development of fatigue. *J Sports Sci*. 2003;21(7):519-528. doi:10.1080/0264041031000071182
66. Hill-Haas SV, Dawson B, Impellizzeri FM, Coutts AJ. Physiology of small-sided games training in football: a systematic review. *Sports Med*. 2011;41(3):199-220. doi:10.2165/11539740-000000000-00000
67. Harper DJ, McBurnie AJ, Santos TD, Eriksrud O, Evans M, Cohen DD, Rhodes D, Carling C, Kiely J. Biomechanical and Neuromuscular Performance Requirements of Horizontal Deceleration: A Review with Implications for Random Intermittent Multi-Directional Sports. Sports Med. 2022 Oct;52(10):2321-2354. doi: 10.1007/s40279-022-01693-0.
68. Nygaard Falch H, Guldteig Rædergård H, van den Tillaar R. Effect of Different Physical Training Forms on Change of Direction Ability: a Systematic Review and Meta-analysis. *Sports Med Open*. 2019;5(1):53. Published 2019 Dec 19. doi:10.1186/s40798-019-0223-y
69. Olthof SBH, Ferrandis J, de Dios V, Riboli A. Pitch Size, Player Numbers, and Playing Rules: How Small-Sided Game Constraints Shape the Training Demands in Male Academy Soccer. *J Strength Cond Res*. Published online January 30, 2026. doi:10.1519/JSC.0000000000005351
70. Lloyd RS, Oliver JL, Faigenbaum AD, Myer GD, De Ste Croix MB: Chronological age vs. biological maturation: implications for exercise programming in youth. *J Strength Cond Res* 2014, 28(5):1454-1464.
71. Bejm C, Klimek A: Dynamics of Change in Aerobic Capacity in 7–12 Year-Old Children Playing Soccer in Relation to Training Load. *Journal of Human Kinetics* 2006.
72. Dolci F, Hart NH, Kilding A, Chivers P, Piggott B, Spiteri T: Movement Economy in Soccer: Current Data and Limitations. *Sports (Basel)* 2018, 6(4).
73. Osses-Rivera A, Yáñez-Sepúlveda R, Jannas-Vela S, Vigh-Larsen JF, Monsalves-Álvarez M: Effects of strength training on repeated sprint ability in team sports players: a systematic review. *PeerJ* 2024, 12:e17756.

Figure 1. PRISMA flow diagram

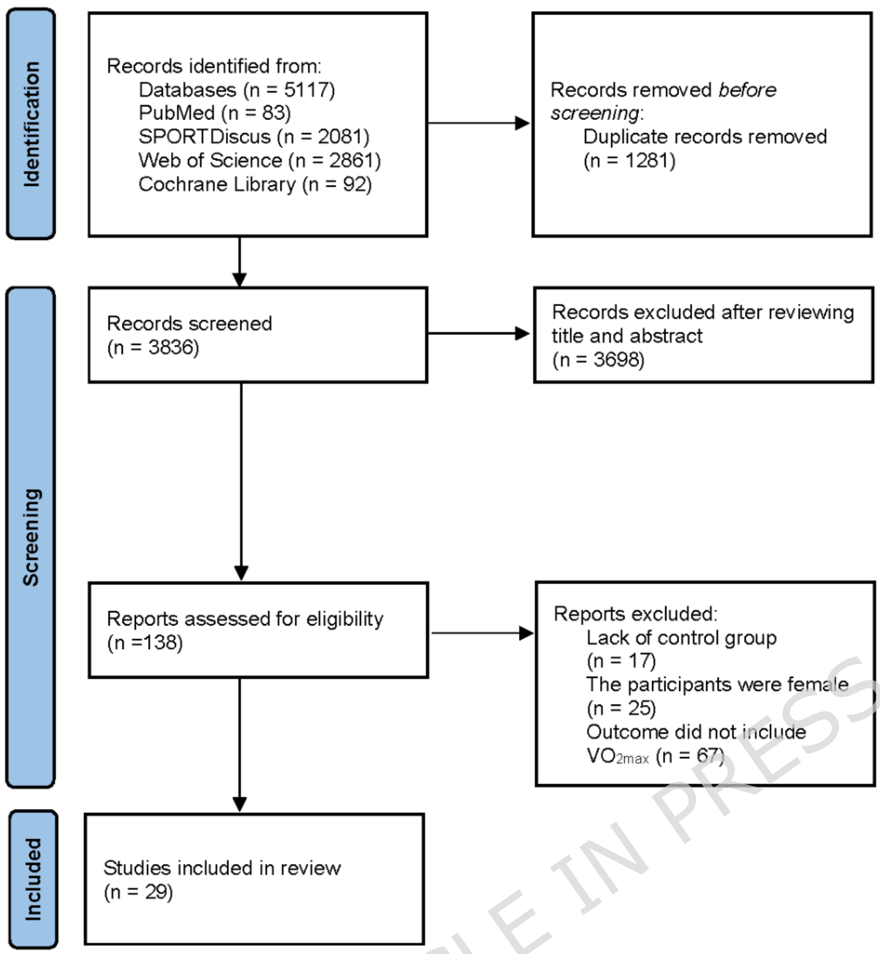
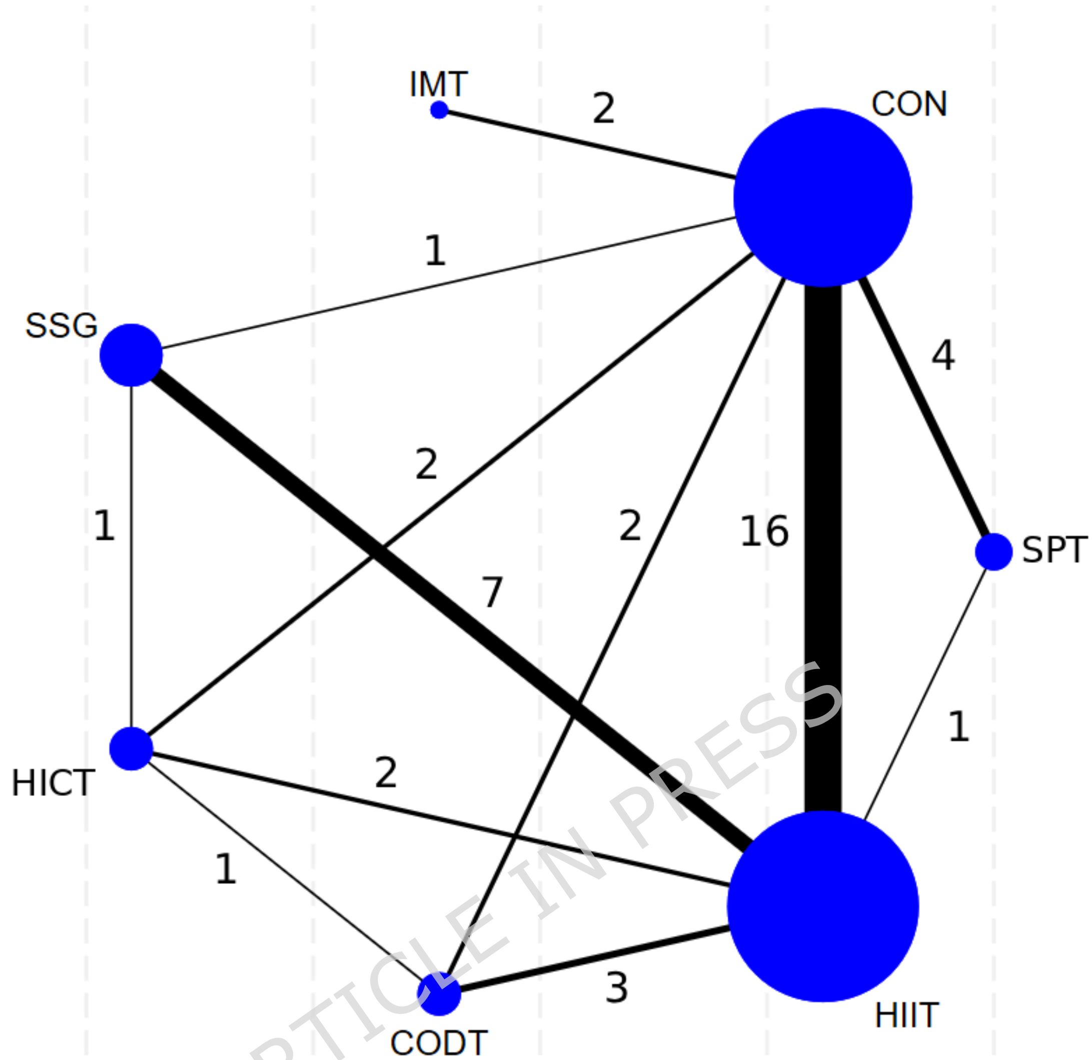
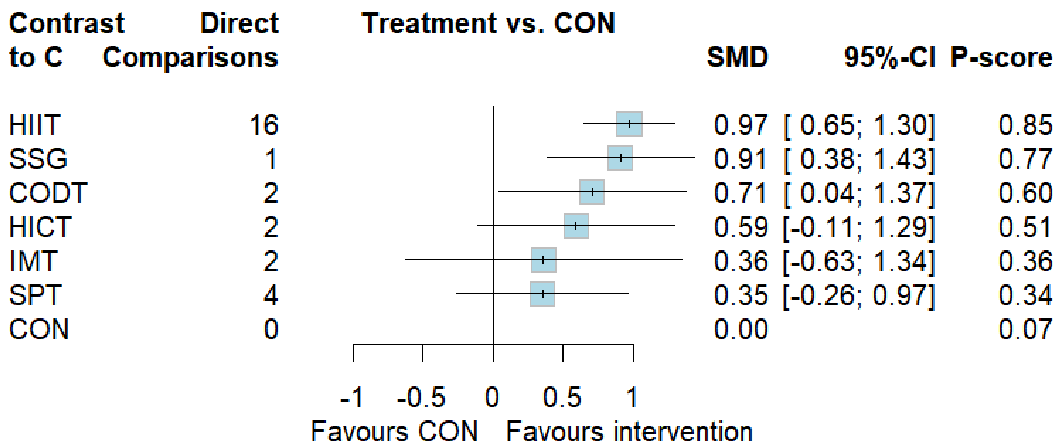


Figure 2. Network plot of exercise interventions for VO_{2max}



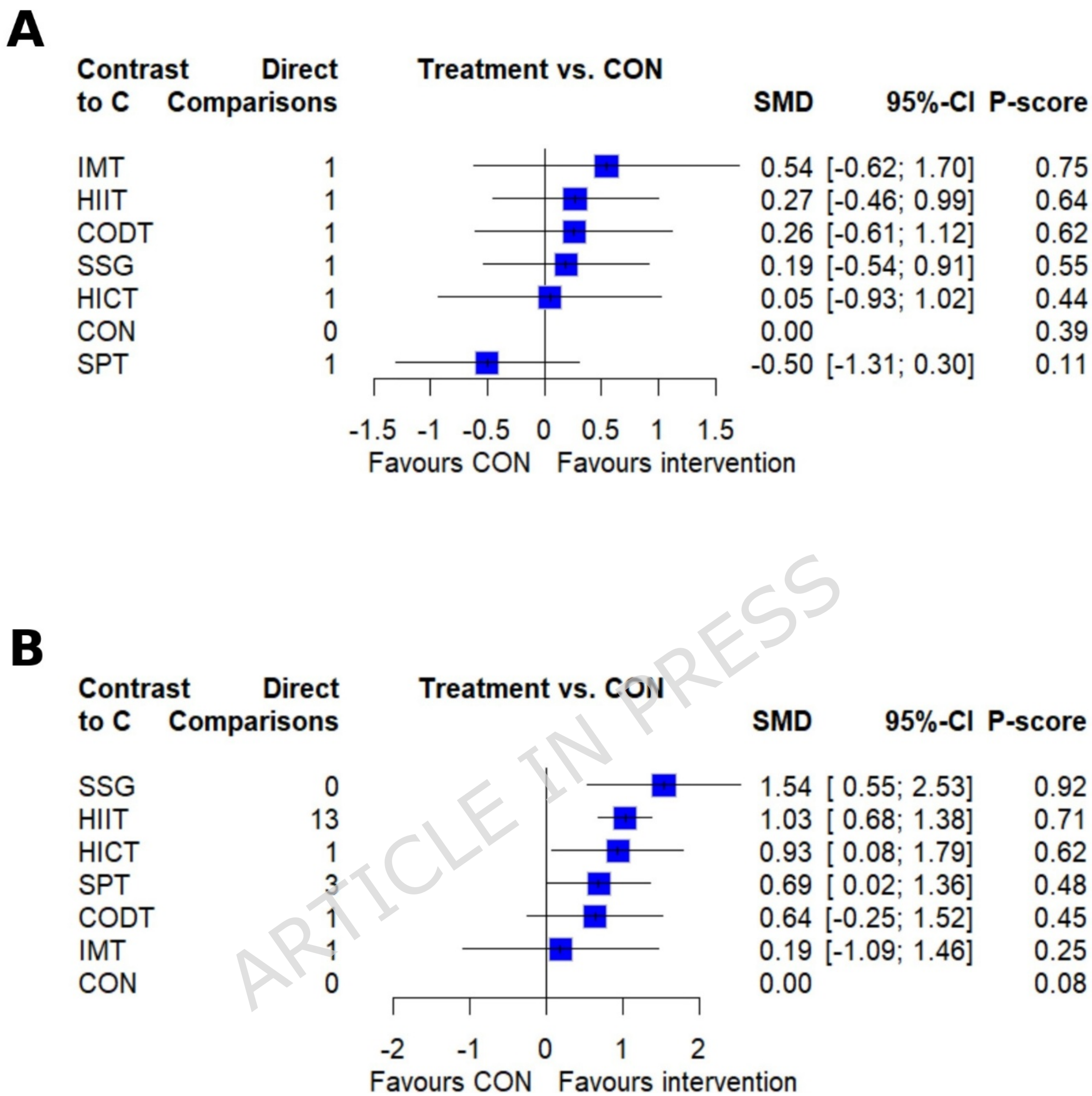
Note: Each node represents a specific intervention, with the node size proportional to the total sample size of studies involving that intervention. The thickness of the connecting lines reflects the number of direct comparisons between pairs of interventions. CON: Soccer training only, CODT: Sprint with change of direction, HIIT: High - intensity interval training, IMT: Inspiratory muscle training, SSG: Small - sided games, SPT: Strength and power training, HICT: HIIT-based combined training.

Figure 3. Forest plot of VO_{2max} across exercise interventions



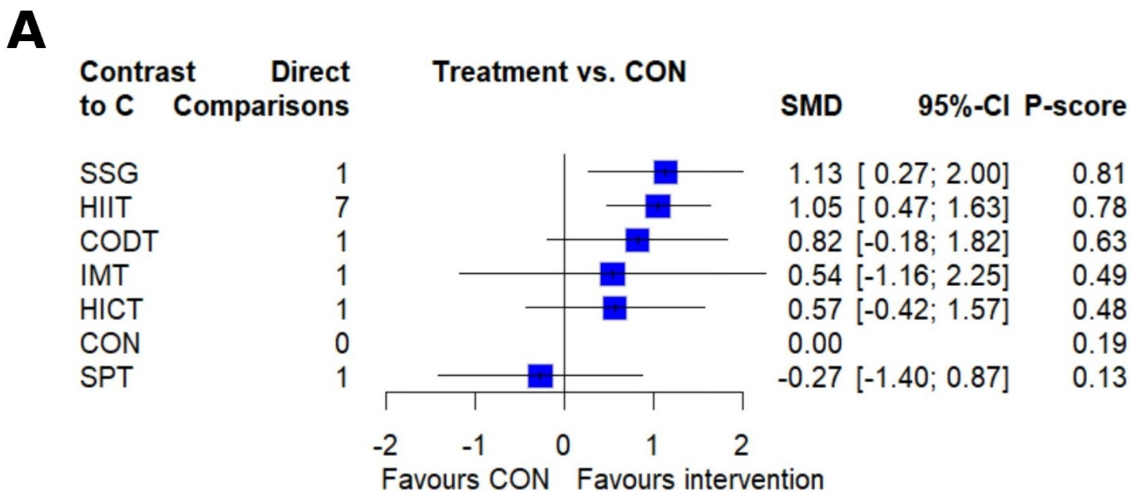
Note: CON: Soccer training only, CODT: Sprint with change of direction, HIIT: High - intensity interval training, IMT: Inspiratory muscle training, SSG: Small - sided games, SPT: Strength and power training, HICT: HIIT-based combined training. Positive SMD values indicate greater improvements in VO_{2max} favoring the intervention compared with CON.

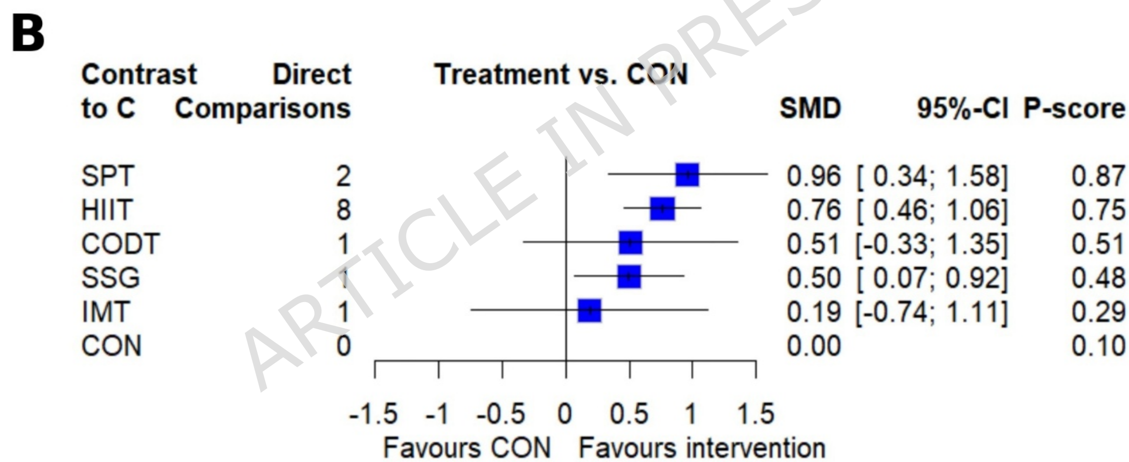
Figure 4. Mirror forest plot of age-based subgroup analyses for VO_{2max} in soccer players



*Note: **A** players aged <18 years; **B** players aged ≥18 years. Positive SMD values indicate greater improvements in VO_{2max} favoring the intervention compared with CON.*

Figure 5. Mirror forest plot of competitive level–based subgroup analyses for VO_{2max} in soccer players.





*Note: **A** lower-level players; **B** higher-level players. Positive SMD values indicate greater improvements in VO_{2max} favoring the intervention compared with CON.*

Figure 6. Cochrane Risk of Bias Tool

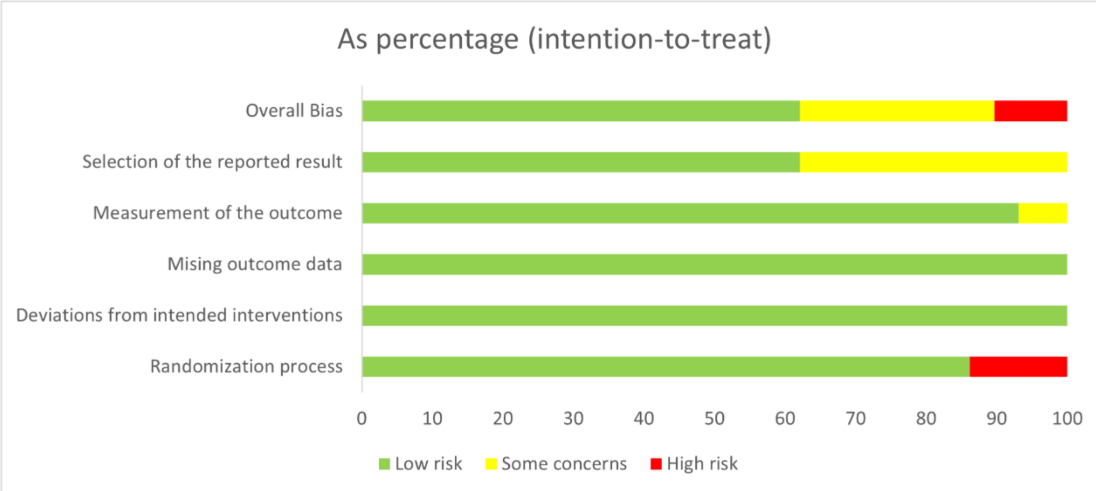


Table 1. League table of comparative effects of exercise interventions on VO_{2max} in soccer players.

HIIT	0.05 (-0.45; 0.55)	0.08 (-0.70; 0.85)	0.12 (-0.77; 1.00)	.	0.00 (-1.34; 1.34)	**1.05 (0.70; 1.39)**
0.07 (-0.39; 0.52)	SSG	.	0.93 (-0.46; 2.32)	.	.	0.27 (-1.02; 1.56)
0.26 (-0.38; 0.91)	0.20 (-0.57; 0.97)	CODT	0.23 (-1.10; 1.57)	.	.	0.37 (-0.56; 1.31)
0.38 (-0.30; 1.06)	0.31(-0.44; 1.07)	0.12 (-0.75; 0.98)	HICT	-0.23 (-1.58; 1.11)	.	0.71 (-0.19; 1.60)
0.62 (-0.42; 1.65)	0.55 (-0.57; 1.67)	0.35 (-0.84; 1.54)	0.24 (-0.97; 1.44)	IMT	.	0.36 (-0.63; 1.34)
0.62 (-0.05; 1.29)	0.55 (-0.24; 1.35)	0.35 (-0.54; 1.25)	0.24 (-0.68; 1.16)	0.00 (-1.16; 1.17)	SPT	0.31 (-0.32; 0.95)
0.97 (0.65; 1.30)	**0.91 (0.38; 1.43)**	**0.71 (0.04; 1.37)**	0.59 (-0.11; 1.29)	0.36 (-0.63; 1.34)	0.35 (-0.26; 0.97)	CON

Note: For interpretation, a positive value in each cell favors the row-defined intervention over the column-defined intervention, indicating greater improvement in VO_{2max}. Values depicted are standardized mean differences with associated 95% confidence intervals. Cells shown in bold *indicate statistically significant results, defined as 95% confidence intervals not crossing zero. The upper half is results of direct comparison and the lower half of mixed comparison. CON: Soccer training only, CODT: Sprint with change of direction, HIIT: High-intensity interval training, IMT: Inspiratory muscle training, SSG: Small-sided games, SPT: Strength and power training, HICT: HIIT-based combined training*