JOURNAL OF THE INTERNATIONAL SOCIETY OF SPORTS NUTRITION
2025, VOL. 22, NO. 1, 2467890
https://doi.org/10.1080/15502783.2025.2467890

Effects of different dietary supplements on athletic performance in soccer players: a systematic review and network meta-analysis

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ABSTRACT

Background: As dietary supplements play a crucial role in meeting the unique nutritional needs of soccer players, a growing body of studies are exploring the effects of dietary supplements on athletic performance in soccer players. The effectiveness of certain supplements, such as caffeine and creatine, remains debated due to inconsistent results across studies. Therefore, this systematic review and Bayesian network meta-analysis was conducted to tentatively identify the most effective dietary supplements for soccer players.
Methods: We searched PubMed, Web of Science, Cochrane, Embase, and SPORTDiscus from database establishment to 5 February 2024 to identify randomized controlled trials (RCTs) evaluating the effects of different dietary supplements on athletic performance in soccer players. The risk of bias was assessed using the revised Cochrane risk-of-bias tool for randomized trials. A Bayesian network meta-analysis was performed using the R software and Stata 18.0. A subgroup analysis was conducted based on the competitive level of the athletes.
Results: Eighty RCTs were included, with 1,425 soccer players randomly receiving 31 different dietary supplements or placebo. The network meta-analysis showed that compared with placebo, carbohydrate + protein (SMD: 2.2, very large), carbohydrate + electrolyte (SMD: 1.3, large), bovine colostrum (SMD: moderate) and caffeine (SMD: 0.29, small) were associated with a significant effect on increasing the distance covered. *Kaempferia parviflora* (SMD: 0.46, small) was associated with a significant effect on enhancing muscular strength. Beta-alanine (SMD: 0.83, moderate), melatonin (SMD: 0.75, moderate), caffeine (SMD: 0.37, small), and creatine (SMD: 0.33, small) were associated with a significant effect on enhancing jump height. Magnesium creatine chelate (SMD: −3.0, very large), melatonin (SMD: −1.9, large), creatine + sodium

ARTICLE HISTORY
Received 6 May 2024
Accepted 10 February 2025

KEYWORDS
Football; sport nutrition; ergogenic aids; supplementation; sport performance

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bicarbonate (SMD: −1.4, large), and arginine (SMD: −1.2, moderate) were associated with a significant effect on decreasing sprint time. Creatine + sodium bicarbonate (SMD: −2.3, very large) and caffeine (SMD: −0.38, small) were associated with a significant effect on improving agility. Sodium pyruvate (SMD: 0.50, small) was associated with a significant effect on increasing peak power. Magnesium creatine chelate (SMD: 1.3, large) and sodium pyruvate (SMD: 0.56, small) were associated with a significant effect on increasing mean power. Carbohydrate + electrolyte (SMD: −0.56, small) was associated with a significant effect on improving the rating of perceived exertion.

Conclusions: This study suggests that a range of dietary supplements, including caffeine, creatine, creatine + sodium bicarbonate, magnesium creatine chelate, carbohydrate + electrolyte, carbohydrate + protein, arginine, beta-alanine, bovine colostrum, *Kaempferia parviflora*, melatonin, and sodium pyruvate, can improve athletic performance in soccer players. This review provides evidence-based guidance for soccer coaches and nutritionists on using dietary supplements to enhance specific performance measures.

1. Introduction

Soccer (globally referred to as football) is considered as one of the most popular sports in the world. According to the Big Count survey of the Federation International Football Association (FIFA), more than 270,000,000 individuals worldwide engage in this sport, including nearly 130,000 professional players, and the number is constantly increasing [1,2]. Modern soccer is characterized as an intermittent sport combining high-intensity and low-intensity activities. It is a sequential combination of short sprints, rapid accelerations/decelerations, and change of direction interspersed with jumps, kicks, tackles, and informal times for recovery [3]. Optimal performance in soccer requires adequate physical fitness, as well as high levels of technical and cognitive skills, involving aerobic and anaerobic endurance, running speed, jumping ability, change of direction, muscular strength and agility [1,4]. A 90-minute soccer match requires approximately 90% aerobic and 10% anaerobic energy, depending on intensity [5]. During the high-intensity and maximum-intensity phases of the game, players rely on anaerobic energy systems, specifically the alactic system (phosphocreatine) and the lactic system (anaerobic glycolysis), whereas during the general effort of a match (90 or 120 minutes), it is obtained aerobically [6]. Information on the evidence of fatigue in soccer is lacking and may be of worth to further build the rational for ergogenic aids. Regarding these needs, nutrition plays a crucial role in supporting energy supply and improving performance, making supplementation strategies essential for promoting recovery and improving physical output [7]. In addition, the global popularity of soccer and its cross-cultural socioeconomic impact highlight the importance of studying the factors that affect player performance [8], as this study has a wide-ranging impact on game preparation and competition format.

Soccer matches can be demanding, requiring athletic, tactical and technical skills from players. Therefore, nutrition can play a role both in optimizing performance when training and playing, but also in recovery [9,10]. Among all available nutritional strategies for soccer players, the usage of dietary supplements is widely established [9]. However, while supplements are widely used, their comparative effectiveness is unclear. A dietary supplement can be defined as "a food, food component, nutrient, or non-food compound that is purposefully ingested in addition to the habitually-consumed diet with the aim of achieving a specific health and/or performance benefit" [11]. The importance and influence of dietary supplements in soccer training cannot be ignored. Some dietary supplements may enhance soccer players' performance by optimizing energy supply, enhancing muscle strength, improving concentration, and accelerating the recovery process [2,12]. For example, caffeine can improve various aspects of exercise performance, including cognitive function and anaerobic and aerobic exercise performance [13]. Sodium bicarbonate has a synergistic effect on high-intensity short-term exercise [14]. Creatine supplements can enhance high-intensity exercise performance and promote the recovery after exercise [15]. Protein supplementation can counteract muscle injury and promote recovery, enhancing resistance training performance [16]. Strategic use of dietary supplements can not only help athletes maintain optimal performance during high-intensity training and competitions, but also reduce muscle injury and promote the recovery process [9]. The International Olympic Committee (IOC) Consensus Statement proposes that dietary supplements can improve athletic or cognitive performance, accelerate recovery from strenuous physical activity, and prevent nutritional deficiencies [11]. Evidence on the benefits of dietary supplements is of interest to support teams working with soccer players (e.g. dietitians, physicians, and sports scientists). Understanding whether dietary supplements have effects and how to use them according to individual goals and requirements is key to the success of nutritional interventions [12]. Although dietary supplements may offer potential benefits, their use is not without risks, such as adverse effects on health and performance, as well as the presence of banned substances [17]. In soccer, dietary supplements are often part of a nutritional strategy to support players in improving performance and recovery [9]. Available data show that 47.8% to 93.7% of soccer players report the usage of dietary supplements [18–20]. Among the reasons for doing so, "maintain health" and "improve performance" are the most reported by players [18,21]. Research on the effects of dietary supplements on performance has become an important topic for players, coaches, and sports scientists associated with soccer because of their potential to improve the winning rate for the game [4].

Recent studies have also provided evidence for the effects of dietary supplements on athletic performance in soccer players. However, to our knowledge, no network meta-analysis has yet been performed to discuss the effects of different dietary supplements on athletic performance in soccer players [1,2,12,22–24]. Compared with traditional meta-analysis, network meta-analysis allows us to compare and rank the effects of multiple interventions on performance variables simultaneously [25]. A growing body of research has evaluated the effects of different dietary supplements on soccer players' performance, in order to identify a more appropriate and efficient dietary supplement for soccer players. However, so far there is still controversy over the effects of dietary supplements on athletic performance. Therefore, we conducted this systematic review and Bayesian network meta-analysis to comprehensively compare the effects of different dietary supplements on athletic performance in soccer players. By synthesizing available evidence, we sought to identify the most effective dietary supplements that could contribute to improving athletic performance in soccer players, thereby providing practitioners, including dietitians, coaches, and sports scientists, with a reference to guide players in adjusting their nutritional strategies based on individual needs.

2. Materials and methods

2.1. Study registration

Our study was conducted on the basis of a systematic review and meta-analysis (PRISMA NMA) and prospectively registered on PROSPERO (ID: CRD42024516111). Given the complexity of comparing multiple interventions, PRISMA NMA guidelines were chosen to ensure methodological rigor.

2.2. Eligibility criteria

2.2.1. Inclusion criteria

Population (P): The population in this systematic review was trained soccer players, based on the athlete tiers framework recently established by McKay and colleagues [26]. The tiers ranged from 0 to 5, with higher tiers reflecting elite levels of competition. No restriction was imposed on the gender or age of soccer players, so as to improve the comprehensiveness of analysis.

Intervention (I): The intervention group used different dietary supplements within a reasonable range and did not involve any stimulant in the World Anti-Doping Agency Prohibited List. No limitation was imposed on whether they were used alone or in combination. During the analysis, combination supplements were considered in a way that allowed for the assessment of both individual supplement effects and the potential interactions between them.

Comparison (C): The control group received placebo, or the blank control group did not receive any supplements.

Outcome (O): In this study, we selected a series of athletic performance indicators based on the energy metabolism system (aerobic metabolism system, phosphagen system, and

Table 1. Performance measures.

Outcome indicators	Exercise test
Distance covered (the distance covered by a player during prolonged low to moderate intensity activities or running)	Yo-Yo intermittent recovery test, intermittent tolerance test, maximum running distance in soccer simulation matches, and other physical fitness tests.
Muscular strength	Upper body strength or lower body strength tests.
Jump height	Countermovent jump, vertical jump, squat jump, and other jump ability tests.
Sprint time	Short sprint tests such as 10-meter, 20-meter, and 30-meter sprints.
Agility	Agility tests such as Zig-zag test, Illinois test, Arrowhead agility test, and agility T-test.
Peak power and mean power	Anaerobic capacity tests such as repeated sprint ability test, anaerobic sprint test, and the Wingate anaerobic test.
Rating of perceived exertion (RPE)	Validated scales for subjective effort assessment.

anaerobic glycolysis system) to comprehensively evaluate the effects of dietary supplements on the athletic performance of soccer players (Table 1).

Study design (S): This systematic review included either randomized controlled trials (RCTs) or randomized controlled crossover studies to assess the effects of interventions.

2.2.2. Exclusion criteria

Population (P): Studies not conducted on soccer players were excluded. Articles exclusively on rugby, American football, Australian football, or Gaelic football players were not included.

Intervention (I): The use of substances prohibited by the World Anti-Doping Agency should be excluded from our study.

Comparison (C): None.

Outcome (O): None.

Study design (S): 1. Conference abstracts published without peer review; 2. Repeatedly published studies on the same experiment; 3. Articles published in languages other than English.

2.3. Data sources and search strategy

We systematically searched PubMed, Web of Science, Cochrane, Embase, and SPORTDiscus from their inception to 5 February 2024 using subject headings (MeSH) and free terms, without restrictions on region, year, or language of publication. These databases were selected due to their comprehensive coverage of sports nutrition and exercise science literature. The search strategy is detailed in Supplementary Material 1.

2.4. Study selection and data extraction

Retrieved records were imported into Endnote 21.0. The titles and abstracts were reviewed to initially screen potentially eligible studies. We downloaded and read the full texts of the studies to screen the original studies that ultimately matched our inclusion criteria. Before data extraction, we developed a standardized data extraction form, which included the title, first author, year of publication, study design, DOI/PMID, author's country, type of intervention, supplementation protocol, number of cases, total number of participants, gender, age, height, weight, body fat percentage, body mass index, the competitive level of the athletes, exercise test, and outcome indicators. Literature screening and data extraction were carried out independently by two researchers (HL, XZ), and cross-checked by them upon completion. Disagreements during data extraction were resolved through consensus or by involving a third researcher (CX), particularly in cases of unclear outcome measures.

2.5. Risk of bias

Quality assessment was conducted by two researchers (HL, XZ) using the revised Cochrane risk-of-bias tool for randomized trials. This tool includes the following seven items: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective outcome reporting, and other sources of bias. Each item is rated as low bias, high bias, or unclear risk of bias. For studies that did not report sufficient information on blinding, we contacted the authors when possible, or rated the risk as unclear if no further information was available.

2.6. Synthesis methods

The network meta-analysis used a Bayesian random-effects model to compare the effects of various interventions. The network figure visually represents the relationships between different dietary supplements. Each node corresponds to a supplement, and the lines between nodes indicate direct comparisons between them. The thickness of the lines reflects the number of studies contributing to each comparison, with thicker lines indicating more studies. Multiple lines between the same nodes indicate comparisons made by more than one study. The Markov chain Monte Carlo method was used for modeling, with four Markov chains running simultaneously and a set annealing number of 20,000. After 50,000 simulation iterations, modeling was completed. Specifically, this method employs repeated random sampling to estimate the properties of complex distributions, making it well-suited for analyzing multiple interventions in a network meta-analysis. The Markov chain Monte Carlo method was chosen due to its flexibility in dealing with complex hierarchical models, particularly when comparing multiple interventions in a network [27]. The Deviation Information Criterion was used to compare model fit and global consistency. If there was a closed loop, the node-splitting method was used to analyze local consistency, testing consistency within loops in the network meta-analysis. In addition, the effectiveness of each intervention was ranked based on the surface under the cumulative ranking curve (SUCRA) [28]. The SUCRA values ranged from 0 to 100%. A higher SUCRA value (closer to 100%) indicates a greater likelihood of being the optimal intervention measure, reflecting its probability of being the best treatment [29]. A league table was generated to compare the effects of different interventions. A funnel plot was used to visually reflect the heterogeneity between different studies. During the analysis, we performed subgroup analysis by the competitive level of the athletes (Elite athletes were classified into Tiers 3, 4 and 5. Non-elite athletes were classified into Tiers 0, 1 and 2) based on the recently established athlete framework [26]. The analysis was completed in Stata18.0 (Stata Corporation, College Station, TX) and R4.3.2 (R Development Core Team, Vienna, http://www.R-project.org). A value of $p < 0.05$ indicated that the difference was statistically significant. To assess the effects of each intervention, 95% credible intervals (CrIs) were utilized. The 95% CrIs provided information about significance. If the 95% CrIs did not contain zero, the result was considered statistically significant, with $p < 0.05$. Conversely, if the 95% CrIs contained zero, the result was considered not to be statistically significant, with $p > 0.05$. Effect size values were represented by the standardized mean differences (SMDs) and presented alongside 95% CrIs. Calculated effect size values were interpreted using the following scale: trivial (<0.2), small (0.2–0.6), moderate (>0.6–1.2), large (>1.2–2.0), very large (>2.0–4.0), and extremely large (>4.0) [30].

3. Results

3.1. Study selection

The numbers of publications included and excluded at each stage of the literature search are shown in Figure 1. A total of 5,937 records were identified in the initial search. From these, 2,592 duplicate publications were deleted (from different databases). Based on a review of titles and abstracts, the full texts of 128 studies were obtained for eligibility assessment. After reading of full text, 48 studies were excluded because 35 contained no useful data (no outcome measures available), 2 did not meet our inclusion criteria (non-RCTs), 10 included participants who were not soccer players, and 1 was not published in English. Finally, a total of 80 published studies [31–110] met the inclusion criteria and

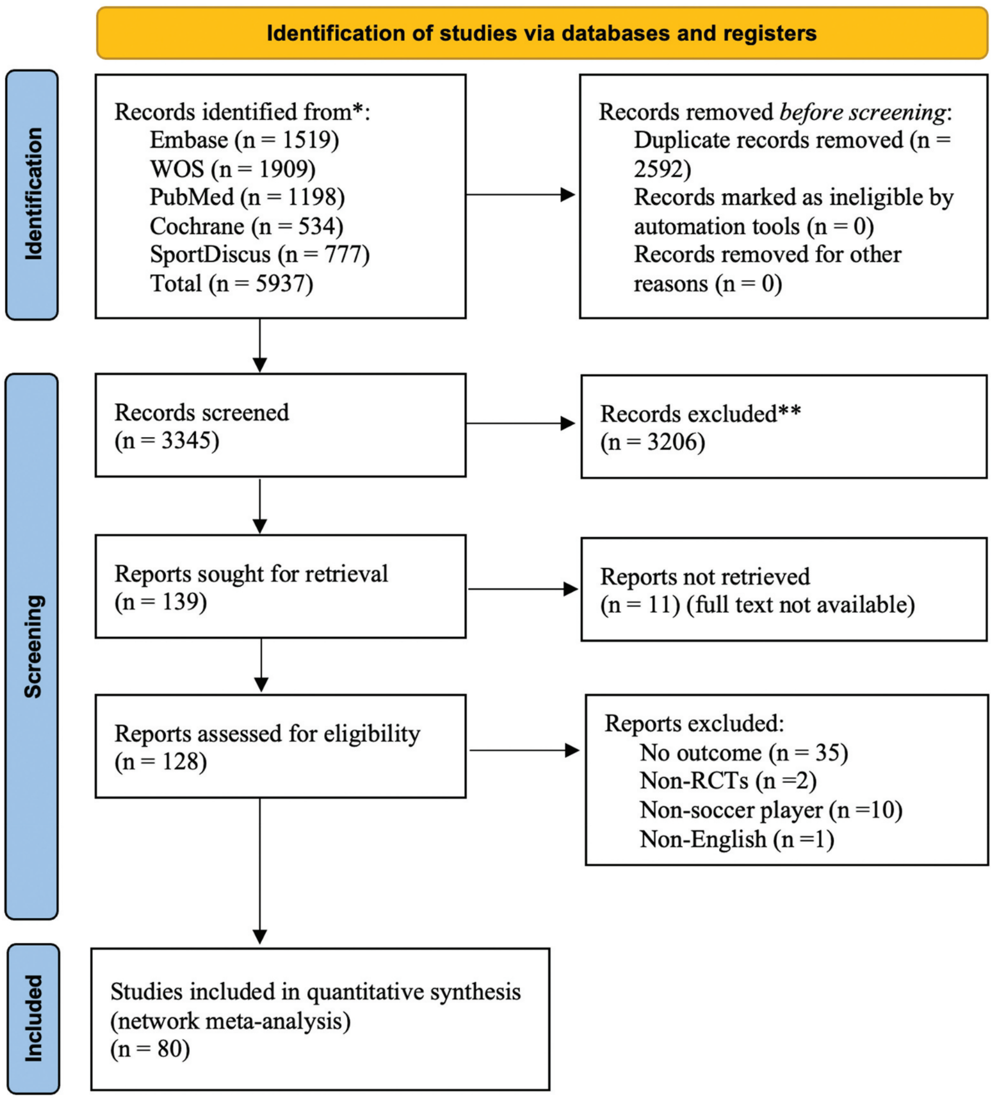

Figure 1. Flowchart of screening process.

were included in the quantitative network meta-analysis. The literature screening process is shown in Figure 1.

3.2. Study characteristics

The characteristics of the included studies are shown in Supplementary Material 2. A total of 1,425 soccer athletes were recruited in the 80 studies reviewed. In terms of gender distribution, male athletes accounted for a higher percentage of participants. Sixty-three studies recruited male soccer players (1,111 athletes). Eight studies recruited female soccer players (128 athletes). One study included male and female soccer players (19 males and 7 females). Eight studies did not describe the gender of participants (160 athletes). Based on the competitive level distribution of the athletes, elite soccer players represented a higher proportion among the participants. Fifty studies recruited elite soccer players (877 athletes), while thirty studies recruited non-elite soccer players (548 athletes).

We explored the effects of 31 different dietary supplements on athletic performance in soccer players based on the 80 included studies. Of the dietary supplements in the included studies, caffeine was the most common. Caffeine alone was evaluated in 21 studies followed by creatine and carbohydrate (12 studies, respectively). Table 2 lists the existing studies that evaluated all the 31 dietary supplements.

Table 2. Dietary supplements included in the study.

No.	Dietary supplements	Abbreviation	Existing studies
1	Caffeine	CAF	[34,41,46,51,52,61,70,73–76,78,81,83,85,89,91,101,104–106]
2	Creatine	CR	[35,37–39,47,56,62,64,67,69,94,103]
3	Carbohydrate	CHO	[32,40,44,49,53,60,78,79,82,92,106,109]
4	Beetroot extract	BRT	[57,59,68,101]
5	Carbohydrate + electrolyte	CHO_E	[54,58,107,108]
6	Melatonin	MLT	[85–87]
7	Protein	PROT	[42,50,71]
8	Vitamin D	VITD	[65,97,100]
9	Carbohydrate + caffeine	CHO_CAF	[78,106]
10	Arginine	ARG	[63,98]
11	Beta-alanine	BA	[43,45]
12	Vitamin C + Vitamin E	VITC_VITE	[31,93]
13	Magnesium creatine chelate	MGCC	[33]
14	Sodium pyruvate	PYR	[36]
15	Kaempferia parviflora	KP	[48]
16	Yohimbine	YOH	[55]
17	Branched-chain amino acids	BCAA	[64]
18	Alfa-hydroxy-isocaproic acid	HICA	[66]
19	Creatine + caffeine	CR_CAF	[67]
20	Creatine + sodium bicarbonate	CR_SB	[72]
21	Omega-3 fatty acids	O3FA	[77]
22	Blackcurrant extract	BCE	[80]
23	Glutamine peptide	GLN	[84]
24	Sodium bicarbonate	SB	[80]
25	Tyrosine	TYR	[95]
26	Bovine colostrum	BC	[96]
27	Citrulline	CIT	[99]
28	Beetroot extract + caffeine	BRT_CAF	[101]
29	Montmorency cherry	MC	[102]
30	Carbohydrate + protein	CHO_PROT	[109]
31	Tart cherry juice	TCJ	[110]

The supplementation protocols for dietary supplements, such as dosage, timing, and duration, varied significantly across studies. The dosage of caffeine included in the study ranged from 1 mg/kg to 6 mg/kg. The doses used in most studies are 3 mg/kg, 5 mg/kg, or 6 mg/kg. Caffeine was given 0–90 minutes before the test in the included studies. Most studies focused on supplementing caffeine 45–60 minutes before the test. In the research on supplementing creatine, 8 studies provided absolute doses for soccer players, with the doses ranging from 2 g/day to 30 g/day. The doses used in most studies are 5 g/day or 20 g/day. Four studies supplemented creatine based on the weight of soccer players (i.e. relative dose), with doses ranging from 0.03 g/kg/day to 0.3 g/kg/day. Among these studies, two applied 0.3 g/kg/day, while the other two applied 0.25 g/kg/day and 0.03 g/kg/day, respectively. The duration of creatine supplementation varied, ranging from 4 days to 13 weeks, with most studies adopting a 7-day regimen. For research on carbohydrate, the content of carbohydrate in the included studies ranged from 6% −12% or was approximately 1 g/kg. In the included studies, carbohydrate was given before testing or during the halftime break of the simulation. For the studies involving beetroot extract, two studies applied acute doses and supplemented with 400 mg or 6.4 mmol of nitrate prior to testing. The other two studies were supplemented continuously for 12 days (800 mg of nitrate/day) and 5 days (2 g of nitrate/day), respectively. For melatonin studies, one study involving melatonin used an acute dose of 6 mg vegetable melatonin before running exercise. Two other studies used melatonin capsules, supplementing for 6 consecutive days at a dose of 5 mg/day. In protein supplementation studies, one study provided an absolute dose, supplementing milk protein (24 g/day) for 28 consecutive days. Two other studies supplemented protein based on relative dosages for 10 days, with a range of 0.26 g/kg/day to 1.5 g/kg/day. In vitamin D studies, three studies supplemented for 6 weeks (2000 IU, 3×/day), 8 weeks (20,000 IU, 2×/week), and 12 weeks (200,000 IU), respectively. For arginine studies, one study supplemented L-arginine for 14 days with doses ranging from 3 g/day to 6 g/day. Another study used an acute dose of L-arginine (0.15 g/kg) one hour before exercise. Regarding beta-alanine, two studies supplemented for 3 weeks (4.8 g/day) and 6 weeks (6.4 g/day), respectively. For supplements reported in single studies, doses included magnesium creatine chelate (0.07 g/kg/day, 16 weeks), sodium pyruvate (0.1 g/kg/day, 7 days), *Kaempferia parviflora* (180 mg/day, 12 weeks), yohimbine (20 mg/day, 21 days), branched-chain amino acids (5000 mg/day, 7 days), alfa-hydroxy-isocaproic acid (1500 mg/day, 4 weeks), omega-3 fatty acids (2-3 g/day, 4 weeks), blackcurrant extract (600 mg/day, 7 days), glutamine peptide (3.5 g, before test), sodium bicarbonate (0.3 g/kg, before test), tyrosine (150 mg/kg, before test), bovine colostrum (3.2 g/d, 24 weeks), citrulline (6 g or 3 g, before test), montmorency cherry (60 mL/day, 7 days), tart cherry juice (30 mL, before and after match). Additionally, several combined interventions were also studied. For carbohydrate + electrolyte, the intervention included a solution with 6.4–7% carbohydrates and electrolytes. Supplementation points included pre-exercise and every 15 minutes thereafter. For carbohydrate + caffeine, supplementation before testing included 1.2 g/kg or 10% carbohydrates and 6 mg/kg caffeine. For vitamin C + vitamin E, one study supplemented 1000 mg/day vitamin C and 800 mg/day vitamin E for 90 days. Another study supplemented 1000 mg/day vitamin C and 536 mg/day vitamin E for 15 days. Creatine + caffeine included 5 g creatine and 35 mg caffeine, supplemented during the 15-minute recovery period. For creatine + sodium bicarbonate, supplementation included 7 days of creatine (20 g/day) and sodium bicarbonate (0.3 g/kg/day). Beetroot extract + caffeine consisted of 6.4 mmol nitrates and 5 mg/kg caffeine, supplemented before testing began. For carbohydrate + protein, the supplementation included 0.7 g/kg carbohydrates and 0.3 g/kg protein before the exercise protocol and during simulated halftime breaks. The supplementation protocol for each study is shown in Supplementary Material 2.

To assess the effects of different dietary supplements on athletic performance in soccer players, a network meta-analysis was conducted for the following outcome measures, including distance covered [32,44–46,50–52,57,58,60,68,70,72,73,77,82,84,88,91,95–97,101,109,110], muscular strength [31,34,42,48,50,59,66,69,77], jump height [34,35,38–41,43,46,47,49,50,55,56,59,62,69–71,74–77,81,83,86,88,90,91,93,97,100,101,105,106], sprint time [33,35,38,42–50,62,65,66,71,72,77,80–83,86–89,92–94,97,98,100,102,106–108], agility [35,42,43,47,48,72,79,86,88,89,93,94,100,102], peak power [33,34,36,37,39,41,59,61,63,64,78,90], mean power [33,34,36,37,39,41,59,61,63,64,78,90] and rating of perceived exertion [38,40,44,49,53,54,57,58,61,67,73,74,78–82,85,90,94,95,99,103–109].

3.3. Risk of bias

Of the 80 RCTs included, 77 provided an explicit description of randomization in the random sequence generation process. Only three studies described non-randomization. Seventeen studies had no sufficient information to determine whether reasonable allocation concealment was performed. The remaining studies conducted reasonable allocation concealment. Blinding was employed in 71 studies and was not mentioned in the remaining studies. Blind outcome assessment was performed in 2 studies and was not mentioned in the remaining studies. Two studies reported a large number of participants lost to follow-up. The remaining studies did not report any loss to follow-up. All studies did not show any risk of reporting bias or other biases. Results are detailed in Figures 2 and 3.

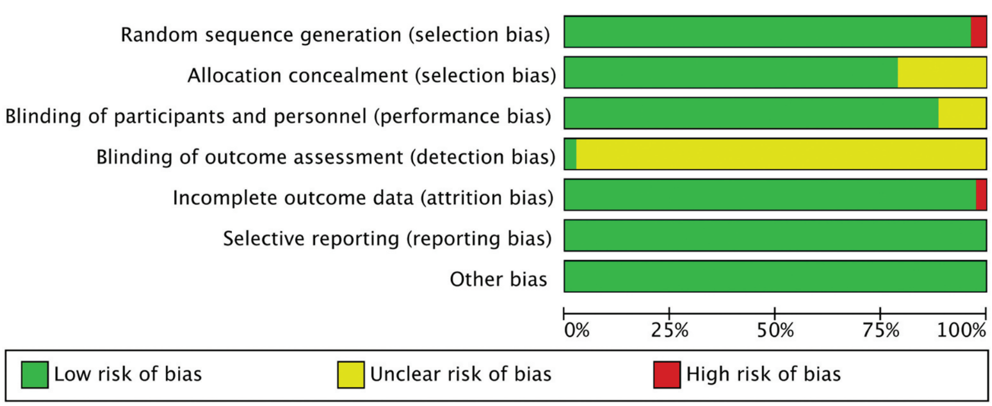

Figure 2. Risk of bias graph.

Figure 3. Risk of bias summary.

3.4. Meta-analysis

3.4.1. Distance covered

Twenty-five studies reported the effects of different dietary supplements on the distance covered in soccer players. They involved 16 different dietary supplements, mainly containing CAF, CHO, PROT and BRT. Other supplements were involved in only a small number of studies (Figure 4). This meta-analysis results showed that CHO_PROT (SUCRA = 96.2%), CHO_E (SUCRA = 85.8%) and BC (SUCRA = 81.5%) were interventions associated with the greatest impact on improving the distance covered by soccer players (Figure S1). Compared with placebo, CHO_PROT, CHO_E, BC, and CAF were associated with a significant effect on the distance covered (SMD: 2.2, 95% CrI: 0.56, 3.8; SMD: 1.3, 95% CrI: 0.20, 2.5; SMD: 1.1, 95% CrI: 0.18, 2.0; SMD: 0.29, 95% CrI: 0.045, 0.52) (Figure S2 and Table 3). Funnel plot analysis indicated symmetrical distribution, suggesting no evidence of publication bias (Figure S3).

3.4.2. Muscular strength

Nine studies reported the effects of different dietary supplements on muscular strength in soccer players, involving eight different dietary supplements, mainly CAF and PROT. Other supplements were involved in only a small number of studies (Figure 5). This meta-

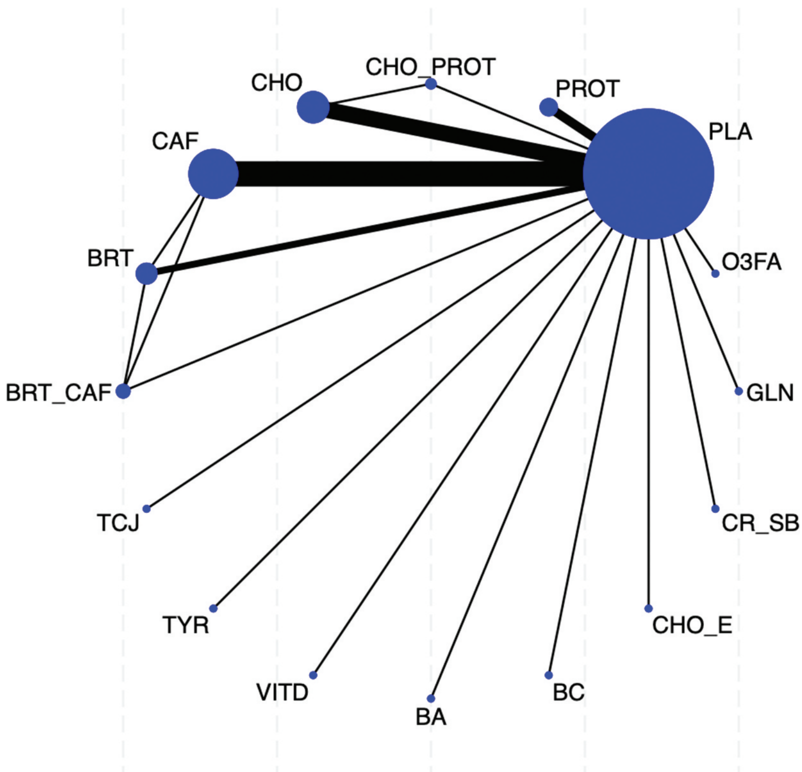

Figure 4. Network diagram of the efficacy of different dietary supplements in enhancing distance covered.

Table 3. League table of the efficacy of different dietary supplements in enhancing distance covered.

	BA	BC	BRT	BRT_CAF	CAF	CHO	CHO_E	CHO_PROT	CR_SB	GLN	O3FA	PLA	PROT	TCJ	TYR	VITD
BA	BA	0.48 (−0.81, 1.79)	−0.32 (−1.34, 0.73)	−0.32 (−1.51, 0.89)	−0.32 (−1.27, 0.66)	−0.44 (−1.42, 0.59)	0.71 (−0.74, 2.19)	1.61 (−0.24, 3.5)	−0.5 (−1.83, 0.82)	0.01 (−1.31, 1.4)	0 (−1.25, 1.26)	−0.6 (−1.53, 0.34)	−0.39 (−1.38, 0.63)	−0.35 (−1.67, 0.99)	−0.75 (−2.14, 0.67)	−0.43 (−1.69, 0.83)
BC	−0.48 (−1.79, 0.81)	BC	−0.81 (−1.77, 0.2)	−0.81 (−1.94, 0.36)	−0.8 (−1.72, 0.15)	−0.92 (−1.87, 0.06)	0.25 (−1.2, 1.63)	1.11 (−0.71, 2.95)	−0.97 (−2.25, 0.29)	−0.46 (−1.75, 0.9)	−0.47 (−1.7, 0.74)	**−1.08 (−1.98, −0.18)**	−0.88 (−1.82, 0.11)	−0.82 (−2.08, 0.48)	−1.24 (−2.58, 0.17)	−0.92 (−2.12, 0.32)
BRT	0.32 (−0.73, 1.34)	0.81 (−0.2, 1.77)	BRT	0 (−0.85, 0.84)	0.01 (−0.45, 0.46)	−0.12 (−0.61, 0.4)	1.04 (−0.15, 2.23)	**1.93 (0.23, 3.59)**	−0.17 (−1.18, 0.82)	0.34 (−0.75, 1.45)	0.33 (−0.63, 1.26)	−0.28 (−0.67, 0.1)	−0.07 (−0.6, 0.47)	−0.01 (−1.02, 0.99)	−0.43 (−1.53, 0.68)	−0.11 (−1.04, 0.79)
BRT_CAF	0.32 (−0.89, 1.51)	0.81 (−0.36, 1.94)	0 (−0.84, 0.85)	BRT_CAF	0.01 (−0.77, 0.78)	−0.11 (−0.91, 0.72)	1.05 (−0.31, 2.38)	**1.92 (0.16, 3.7)**	−0.17 (−1.35, 1.02)	0.34 (−0.87, 1.66)	0.34 (−0.77, 1.44)	−0.28 (−1.02, 0.47)	−0.06 (−0.88, 0.76)	−0.01 (−1.19, 1.18)	−0.42 (−1.72, 0.84)	−0.1 (−1.23, 0.99)
CAF	0.32 (−0.66, 1.27)	0.8 (−0.15, 1.72)	−0.01 (−0.46, 0.45)	−0.01 (−0.78, 0.77)	CAF	−0.12 (−0.51, 0.28)	1.02 (−0.12, 2.19)	**1.92 (0.27, 3.52)**	−0.18 (−1.13, 0.77)	0.34 (−0.7, 1.41)	0.32 (−0.57, 1.19)	**−0.29 (−0.52, −0.04)**	−0.07 (−0.5, 0.37)	−0.01 (−0.96, 0.93)	−0.43 (−1.51, 0.66)	−0.11 (−0.97, 0.74)
CHO	0.44 (−0.59, 1.42)	0.92 (−0.06, 1.87)	0.12 (−0.4, 0.61)	0.11 (−0.72, 0.91)	0.12 (−0.28, 0.51)	CHO	1.15 (−0.01, 2.34)	**2.04 (0.4, 3.64)**	−0.06 (−1.06, 0.9)	0.46 (−0.58, 1.53)	0.44 (−0.49, 1.33)	−0.16 (−0.49, 0.15)	0.05 (−0.44, 0.52)	0.11 (−0.88, 1.08)	−0.31 (−1.4, 0.78)	0 (−0.87, 0.88)
CHO_E	−0.71 (−2.19, 0.74)	−0.25 (−1.63, 1.2)	−1.04 (−2.23, 0.15)	−1.05 (−2.38, 0.31)	−1.02 (−2.19, 0.12)	−1.15 (−2.34, 0.01)	CHO_E	0.9 (−1.13, 2.86)	−1.22 (−2.67, 0.22)	−0.68 (−2.17, 0.82)	−0.7 (−2.16, 0.7)	**−1.31 (−2.46, −0.2)**	−1.1 (−2.3, 0.08)	−1.04 (−2.53, 0.42)	−1.45 (−3.03, 0.06)	−1.15 (−2.58, 0.26)
CHO_PROT	−1.61 (−3.5, 0.24)	−1.11 (−2.95, 0.71)	**−1.93 (−3.59, −0.23)**	**−1.92 (−3.7, −0.16)**	**−1.92 (−3.52, −0.27)**	**-2.04 (−3.64, −0.4)**	−0.9 (−2.86, 1.13)	CHO_PROT	**-2.1 (−3.96, −0.22)**	−1.6 (−3.48, 0.38)	−1.61 (−3.36, 0.25)	**-2.21 (−3.79, −0.56)**	**-2 (−3.64, −0.33)**	**-1.95 (−3.78, −0.08)**	**-2.35 (−4.26, −0.38)**	**-2.03 (−3.88, −0.22)**
CR_SB	0.5 (−0.82, 1.83)	0.97 (−0.29, 2.25)	0.17 (−0.82, 1.18)	0.17 (−1.02, 1.35)	0.18 (−0.77, 1.13)	0.06 (−0.9, 1.06)	1.22 (−0.22, 2.67)	**2.1 (0.22, 3.96)**	CR_SB	0.53 (−0.81, 1.93)	0.5 (−0.75, 1.78)	−0.11 (−1.02, 0.81)	0.11 (−0.87, 1.1)	0.15 (−1.12, 1.49)	−0.26 (−1.64, 1.15)	0.07 (−1.19, 1.31)
GLN	−0.01 (−1.4, 1.31)	0.46 (−0.9, 1.75)	−0.34 (−1.45, 0.75)	−0.34 (−1.66, 0.87)	−0.34 (−1.41, 0.7)	−0.46 (−1.53, 0.58)	0.68 (−0.82, 2.17)	1.6 (−0.38, 3.48)	−0.53 (−1.93, 0.81)	GLN	−0.02 (−1.32, 1.24)	−0.62 (−1.66, 0.38)	−0.4 (−1.5, 0.61)	−0.35 (−1.78, 0.94)	−0.78 (−2.29, 0.66)	−0.45 (−1.79, 0.8)
O3FA	0 (−1.26, 1.25)	0.47 (−0.74, 1.7)	−0.33 (−1.26, 0.63)	−0.34 (−1.44, 0.77)	−0.32 (−1.19, 0.57)	−0.44 (−1.33, 0.49)	0.7 (−0.7, 2.16)	1.61 (−0.25, 3.36)	−0.5 (−1.78, 0.75)	0.02 (−1.24, 1.32)	O3FA	−0.61 (−1.45, 0.26)	−0.39 (−1.29, 0.54)	−0.33 (−1.56, 0.89)	−0.75 (−2.1, 0.6)	−0.43 (−1.59, 0.7)
PLA	0.6 (−0.34, 1.53)	**1.08 (0.18, 1.98)**	0.28 (−0.1, 0.67)	0.28 (−0.47, 1.02)	**0.29 (0.04, 0.52)**	0.16 (−0.15, 0.49)	**1.31 (0.2, 2.46)**	**2.21 (0.56, 3.79)**	0.11 (−0.81, 1.02)	0.62 (−0.38, 1.66)	0.61 (−0.26, 1.45)	PLA	0.21 (−0.15, 0.58)	0.27 (−0.65, 1.19)	−0.15 (−1.18, 0.91)	0.17 (−0.65, 0.99)
PROT	0.39 (−0.63, 1.38)	0.88 (−0.11, 1.82)	0.07 (−0.47, 0.6)	0.06 (−0.76, 0.88)	0.07 (−0.37, 0.5)	−0.05 (−0.52, 0.44)	1.1 (−0.08, 2.3)	**2 (0.33, 3.64)**	−0.11 (−1.1, 0.87)	0.4 (−0.61, 1.5)	0.39 (−0.54, 1.29)	−0.21 (−0.58, 0.15)	PROT	0.06 (−0.93, 1.05)	−0.36 (−1.45, 0.75)	−0.04 (−0.96, 0.86)
TCJ	0.35 (−0.99, 1.67)	0.82 (−0.48, 2.08)	0.01 (−0.99, 1.02)	0.01 (−1.18, 1.19)	0.01 (−0.93, 0.96)	−0.11 (−1.08, 0.88)	1.04 (−0.42, 2.53)	**1.95 (0.08, 3.78)**	−0.15 (−1.49, 1.12)	0.35 (−0.94, 1.78)	0.33 (−0.89, 1.56)	−0.27 (−1.19, 0.65)	−0.06 (−1.05, 0.93)	TCJ	−0.4 (−1.82, 0.97)	−0.1 (−1.35, 1.14)
TYR	0.75 (−0.67, 2.14)	1.24 (−0.17, 2.58)	0.43 (−0.68, 1.53)	0.42 (−0.84, 1.72)	0.43 (−0.66, 1.51)	0.31 (−0.78, 1.4)	1.45 (−0.06, 3.03)	**2.35 (0.38, 4.26)**	0.26 (−1.15, 1.64)	0.78 (−0.66, 2.29)	0.75 (−0.6, 2.1)	0.15 (−0.91, 1.18)	0.36 (−0.75, 1.45)	0.4 (−0.97, 1.82)	TYR	0.31 (−1, 1.64)
VITD	0.43 (−0.83, 1.69)	0.92 (−0.32, 2.12)	0.11 (−0.79, 1.04)	0.1 (−0.99, 1.23)	0.11 (−0.74, 0.97)	0 (−0.88, 0.87)	1.15 (−0.26, 2.58)	**2.03 (0.22, 3.88)**	−0.07 (−1.31, 1.19)	0.45 (−0.8, 1.79)	0.43 (−0.7, 1.59)	−0.17 (−0.99, 0.65)	0.04 (−0.86, 0.96)	0.1 (−1.14, 1.35)	−0.31 (−1.64, 1)	VITD

Effects are expressed as the effect size (95% CrI) between interventions. When the 95% CrI does not include 0, $p < 0.05$; when the 95% CrI includes 0, $p > 0.05$. Bold indicates a statistically significant difference in the comparison ($p < 0.05$). A positive and bolded effect size indicates that the supplement on the horizontal is more effective than the supplement on the longitudinal; a negative and bolded effect size indicates that the supplement on the longitudinal is more effective than the supplement on the horizontal.

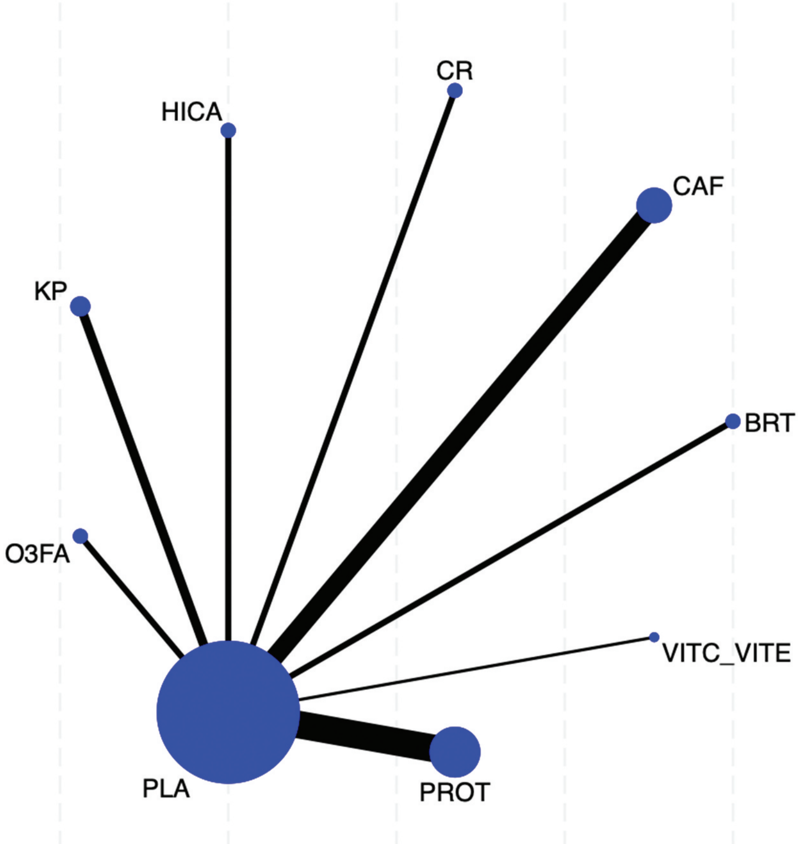

Figure 5. Network diagram of the efficacy of different dietary supplements in enhancing muscular strength.

analysis showed that BRT (SUCRA = 83.1%), KP (SUCRA = 80.9%) and CAF (SUCRA = 66.2%) were interventions associated with the greatest impact on enhancing muscular strength (Figure S4). Compared with placebo, only KP was associated with a significant effect on enhancing muscular strength (SMD: 0.46, 95% CrI: 0.15, 0.77). In contrast, BRT and CAF were not associated with a significant effect on muscular strength (SMD: 0.53, 95% CrI: −0.0096, 1.1; SMD: 0.30, 95% CrI: −0.012, 0.61) (Figure S5 and Table 4). Funnel plot analysis indicated symmetrical distribution, suggesting no evidence of publication bias (Figure S6).

3.4.3. Jump height

Thirty-four studies reported the effects of different dietary supplements on jump height in soccer players, involving 14 different dietary supplements, mainly CAF, CR and CHO. Other supplements were involved in only a small number of studies (Figure 6). This meta-analysis showed that BA (SUCRA = 90.9%), MLT (SUCRA = 89.6%) and CAF (SUCRA = 74.6%) were interventions associated with the greatest impact on improving jump height (Figure S7). Compared with placebo, BA, MLT, CAF and CR were associated with a significant effect on improving jump height (SMD.

Table 4. League table of the efficacy of different dietary supplements in enhancing muscular strength.

	BRT	CAF	CR	HICA	KP	O3FA	PLA	PROT	VITC_VITE
BRT	BRT	−0.23 (−0.87, 0.39)	−0.19 (−1.17, 0.83)	−0.62 (−1.58, 0.31)	−0.08 (−0.71, 0.56)	−0.55 (−1.35, 0.26)	−0.53 (−1.1, 0.01)	−0.48 (−1.09, 0.11)	−0.96 (−2.33, 0.42)
CAF	0.23 (−0.39, 0.87)	CAF	0.06 (−0.87, 0.98)	−0.38 (−1.24, 0.4)	0.16 (−0.28, 0.6)	−0.32 (−0.94, 0.33)	−0.3 (−0.61, 0.01)	−0.25 (−0.63, 0.15)	−0.73 (−2.08, 0.62)
CR	0.19 (−0.83, 1.17)	−0.06 (−0.98, 0.87)	CR	−0.43 (−1.61, 0.69)	0.11 (−0.83, 1.01)	−0.36 (−1.4, 0.61)	−0.35 (−1.25, 0.49)	−0.29 (−1.2, 0.57)	−0.78 (−2.35, 0.76)
HICA	0.62 (−0.31, 1.58)	0.38 (−0.4, 1.24)	0.43 (−0.69, 1.61)	HICA	0.54 (−0.25, 1.39)	0.07 (−0.84, 1.07)	0.08 (−0.64, 0.87)	0.14 (−0.62, 0.96)	−0.33 (−1.85, 1.16)
KP	0.08 (−0.56, 0.71)	−0.16 (−0.6, 0.28)	−0.11 (−1.01, 0.83)	−0.54 (−1.39, 0.25)	KP	−0.47 (−1.1, 0.18)	**−0.46 (−0.77, −0.15)**	**−0.4 (−0.79, −0.02)**	−0.9 (−2.23, 0.44)
O3FA	0.55 (−0.26, 1.35)	0.32 (−0.33, 0.94)	0.36 (−0.61, 1.4)	−0.07 (−1.07, 0.84)	0.47 (−0.18, 1.1)	O3FA	0.02 (−0.55, 0.56)	0.07 (−0.53, 0.66)	−0.41 (−1.86, 0.99)
PLA	0.53 (−0.01, 1.1)	0.3 (−0.01, 0.61)	0.35 (−0.49, 1.25)	−0.08 (−0.87, 0.64)	**0.46 (0.15, 0.77)**	−0.02 (−0.56, 0.55)	PLA	0.06 (−0.18, 0.29)	−0.44 (−1.72, 0.85)
PROT	0.48 (−0.11, 1.09)	0.25 (−0.15, 0.63)	0.29 (−0.57, 1.2)	−0.14 (−0.96, 0.62)	**0.4 (0.02, 0.79)**	−0.07 (−0.66, 0.53)	−0.06 (−0.29, 0.18)	PROT	−0.49 (−1.79, 0.81)
VITC_VITE	0.96 (−0.42, 2.33)	0.73 (−0.62, 2.08)	0.78 (−0.76, 2.35)	0.33 (−1.16, 1.85)	0.9 (−0.44, 2.23)	0.41 (−0.99, 1.86)	0.44 (−0.85, 1.72)	0.49 (−0.81, 1.79)	VITC_VITE

Effects are expressed as the effect size (95% CrI) between interventions. When the 95% CrI does not include 0, $p < 0.05$; when the 95% CrI includes 0, $p > 0.05$. Bold indicates a statistically significant difference in the comparison ($p < 0.05$). A positive and bolded effect size indicates that the supplement on the horizontal is more effective than the supplement on the longitudinal; a negative and bolded effect size indicates that the supplement on the longitudinal is more effective than the supplement on the horizontal.

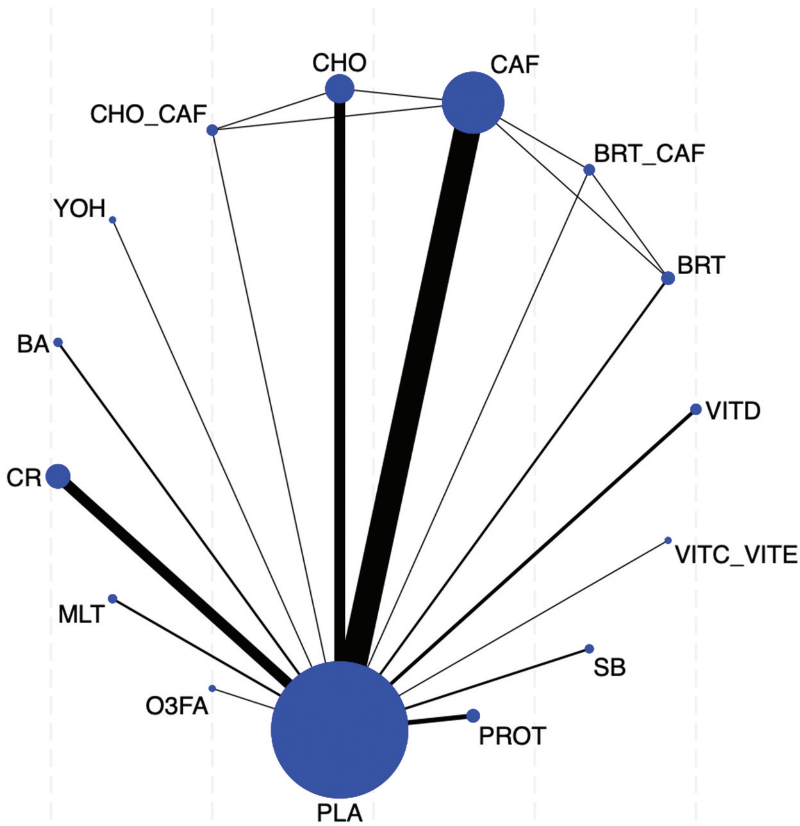

Figure 6. Network diagram of the efficacy of different dietary supplements in enhancing jump height.

Table 5. League table of the efficacy of different dietary supplements in enhancing jump height.

	BA	BRT	BRT_CAF	CAF	CHO	CHO_CAF	CR	MLT	O3FA	PLA	PROT	SB	VITC_VITE	VITD	YOH
BA	BA	−0.67 (−1.61, 0.26)	−0.76 (−1.8, 0.29)	−0.46 (−1.24, 0.31)	**−0.92 (−1.7, −0.13)**	−0.87 (−2.03, 0.3)	−0.49 (−1.29, 0.31)	−0.07 (−1.08, 0.93)	−0.76 (−1.92, 0.33)	**−0.83 (−1.59, −0.08)**	−0.83 (−1.69, 0.01)	**−0.95 (−1.9, −0.05)**	−0.59 (−1.79, 0.56)	**−1.03 (−1.92, −0.18)**	−1.09 (−2.28, 0.09)
BRT	0.67 (−0.26, 1.61)	BRT	−0.09 (−1, 0.85)	0.22 (−0.34, 0.78)	−0.24 (−0.82, 0.35)	−0.18 (−1.23, 0.87)	0.18 (−0.42, 0.79)	0.6 (−0.24, 1.45)	−0.11 (−1.07, 0.87)	−0.16 (−0.69, 0.38)	−0.16 (−0.82, 0.51)	−0.29 (−1.05, 0.47)	0.08 (−0.98, 1.1)	−0.36 (−1.06, 0.34)	−0.42 (−1.45, 0.62)
BRT_CAF	0.76 (−0.29, 1.8)	0.09 (−0.85, 1)	BRT_CAF	0.3 (−0.46, 1.06)	−0.16 (−0.93, 0.64)	−0.1 (−1.27, 1.07)	0.27 (−0.54, 1.09)	0.69 (−0.31, 1.67)	−0.02 (−1.12, 1.07)	−0.07 (−0.82, 0.68)	−0.06 (−0.93, 0.76)	−0.2 (−1.12, 0.74)	0.16 (−1.02, 1.29)	−0.28 (−1.16, 0.6)	−0.33 (−1.49, 0.87)
CAF	0.46 (−0.31, 1.24)	−0.22 (−0.78, 0.34)	−0.3 (−1.06, 0.46)	CAF	**−0.46 (−0.75, −0.18)**	−0.4 (−1.3, 0.5)	−0.04 (−0.36, 0.3)	0.38 (−0.3, 1.06)	−0.33 (−1.15, 0.52)	**−0.37 (−0.54, −0.21)**	−0.37 (−0.81, 0.06)	−0.51 (−1.07, 0.07)	−0.14 (−1.07, 0.77)	**−0.58 (−1.05, −0.11)**	−0.63 (−1.53, 0.29)
CHO	**0.92 (0.13, 1.7)**	0.24 (−0.35, 0.82)	0.16 (−0.64, 0.93)	**0.46 (0.18, 0.75)**	CHO	0.06 (−0.85, 0.96)	**0.42 (0.06, 0.8)**	**0.84 (0.15, 1.54)**	0.13 (−0.71, 0.98)	0.09 (−0.14, 0.32)	0.09 (−0.38, 0.56)	−0.05 (−0.64, 0.55)	0.32 (−0.62, 1.24)	−0.12 (−0.62, 0.38)	−0.17 (−1.08, 0.77)
CHO_CAF	0.87 (−0.3, 2.03)	0.18 (−0.87, 1.23)	0.1 (−1.07, 1.27)	0.4 (−0.5, 1.3)	−0.06 (−0.96, 0.85)	CHO_CAF	0.36 (−0.57, 1.29)	0.78 (−0.31, 1.9)	0.08 (−1.12, 1.33)	0.02 (−0.85, 0.92)	0.02 (−0.95, 1.02)	−0.1 (−1.12, 0.93)	0.25 (−0.98, 1.53)	−0.19 (−1.17, 0.82)	−0.23 (−1.49, 1.05)
CR	0.49 (−0.31, 1.29)	−0.18 (−0.79, 0.42)	−0.27 (−1.09, 0.54)	0.04 (−0.3, 0.36)	**−0.42 (−0.8, −0.06)**	−0.36 (−1.29, 0.57)	CR	0.42 (−0.3, 1.14)	−0.29 (−1.15, 0.58)	**−0.33 (−0.63, −0.05)**	−0.34 (−0.83, 0.15)	−0.46 (−1.08, 0.14)	−0.1 (−1.05, 0.83)	**−0.54 (−1.07, −0.01)**	−0.6 (−1.53, 0.35)
MLT	0.07 (−0.93, 1.08)	−0.6 (−1.45, 0.24)	−0.69 (−1.67, 0.31)	−0.38 (−1.06, 0.3)	**−0.84 (−1.54, −0.15)**	−0.78 (−1.9, 0.31)	−0.42 (−1.14, 0.3)	MLT	−0.72 (−1.71, 0.33)	**−0.75 (−1.42, −0.09)**	−0.75 (−1.51, 0.02)	**−0.89 (−1.76, −0.03)**	−0.53 (−1.66, 0.59)	**−0.96 (−1.79, −0.17)**	−1.03 (−2.11, 0.09)
O3FA	0.76 (−0.33, 1.92)	0.11 (−0.87, 1.07)	0.02 (−1.07, 1.12)	0.33 (−0.52, 1.15)	−0.13 (−0.98, 0.71)	−0.08 (−1.33, 1.12)	0.29 (−0.58, 1.15)	0.72 (−0.33, 1.71)	O3FA	−0.05 (−0.87, 0.77)	−0.05 (−0.96, 0.87)	−0.18 (−1.17, 0.78)	0.18 (−1.05, 1.39)	−0.25 (−1.17, 0.67)	−0.31 (−1.53, 0.9)
PLA	**0.83 (0.08, 1.59)**	0.16 (−0.38, 0.69)	0.07 (−0.68, 0.82)	**0.37 (0.21, 0.54)**	−0.09 (−0.32, 0.14)	−0.02 (−0.92, 0.85)	**0.33 (0.05, 0.63)**	**0.75 (0.09, 1.42)**	0.05 (−0.77, 0.87)	PLA	0 (−0.4, 0.39)	−0.13 (−0.67, 0.41)	0.23 (−0.67, 1.12)	−0.21 (−0.65, 0.24)	−0.26 (−1.15, 0.65)
PROT	0.83 (−0.01, 1.69)	0.16 (−0.51, 0.82)	0.06 (−0.76, 0.93)	0.37 (−0.06, 0.81)	−0.09 (−0.56, 0.38)	−0.02 (−1.02, 0.95)	0.34 (−0.15, 0.83)	0.75 (−0.02, 1.51)	0.05 (−0.87, 0.96)	0 (−0.39, 0.4)	PROT	−0.13 (−0.8, 0.54)	0.23 (−0.77, 1.24)	−0.21 (−0.82, 0.4)	−0.26 (−1.25, 0.73)
SB	**0.95 (0.05, 1.9)**	0.29 (−0.47, 1.05)	0.2 (−0.74, 1.12)	0.51 (−0.07, 1.07)	0.05 (−0.55, 0.64)	0.1 (−0.93, 1.12)	0.46 (−0.14, 1.08)	**0.89 (0.03, 1.76)**	0.18 (−0.78, 1.17)	0.13 (−0.41, 0.67)	0.13 (−0.54, 0.8)	SB	0.36 (−0.72, 1.4)	−0.08 (−0.8, 0.65)	−0.13 (−1.19, 0.92)
VITC_VITE	0.59 (−0.56, 1.79)	−0.08 (−1.1, 0.98)	−0.16 (−1.29, 1.02)	0.14 (−0.77, 1.07)	−0.32 (−1.24, 0.62)	−0.25 (−1.53, 0.98)	0.1 (−0.83, 1.05)	0.53 (−0.59, 1.66)	−0.18 (−1.39, 1.05)	−0.23 (−1.12, 0.67)	−0.23 (−1.24, 0.77)	−0.36 (−1.4, 0.72)	VITC_VITE	−0.43 (−1.45, 0.58)	−0.48 (−1.78, 0.79)
VITD	**1.03 (0.18, 1.92)**	0.36 (−0.34, 1.06)	0.28 (−0.6, 1.16)	**0.58 (0.11, 1.05)**	0.12 (−0.38, 0.62)	0.19 (−0.82, 1.17)	**0.54 (0.01, 1.07)**	**0.96 (0.17, 1.79)**	0.25 (−0.67, 1.17)	0.21 (−0.24, 0.65)	0.21 (−0.4, 0.82)	0.08 (−0.65, 0.8)	0.43 (−0.58, 1.45)	VITD	−0.05 (−1.04, 0.93)
YOH	1.09 (−0.09, 2.28)	0.42 (−0.62, 1.45)	0.33 (−0.87, 1.49)	0.63 (−0.29, 1.53)	0.17 (−0.77, 1.08)	0.23 (−1.05, 1.49)	0.6 (−0.35, 1.53)	1.03 (−0.09, 2.11)	0.31 (−0.9, 1.53)	0.26 (−0.65, 1.15)	0.26 (−0.73, 1.25)	0.13 (−0.92, 1.19)	0.48 (−0.79, 1.78)	0.05 (−0.93, 1.04)	YOH

Effects are expressed as the effect size (95% CrI) between interventions. When the 95% CrI does not include 0, $p < 0.05$; when the 95% CrI includes 0, $p > 0.05$. Bold indicates a statistically significant difference in the comparison ($p < 0.05$). A positive and bolded effect size indicates that the supplement on the horizontal is more effective than the supplement on the longitudinal; a negative and bolded effect size indicates that the supplement on the longitudinal is more effective than the supplement on the horizontal.

0.83, 95% CrI: 0.078, 1.6; SMD: 0.75, 95% CrI: 0.094, 1.4; SMD: 0.37, 95% CrI: 0.21, 0.54; SMD: 0.33, 95% CrI: 0.051, 0.63) (Figure S8 and Table 5). Funnel plot analysis indicated symmetrical distribution, suggesting no evidence of publication bias (Figure S9).

3.4.4. Sprint time

Thirty-six studies reported the effects of different dietary supplements on sprint time in soccer players, involving 18 different dietary supplements, mainly CR, CAF, VITD and PROT. Other supplements were involved in only a small number of studies (Figure 7). This meta-analysis showed that MGCC (SUCRA = 99.6%), MLT (SUCRA = 93.3%) and CR_SB (SUCRA = 86.8%) were interventions associated with the greatest impact on improving sprint time (Figure S10). Compared with placebo, MGCC, MLT, CR_SB, and ARG were associated with a significant effect on decreasing sprint time (SMD: −3.0, 95% CrI: −4.1, −1.8; SMD: −1.9, 95% CrI: −2.7, −1.1; SMD: −1.4, 95% CrI: −2.1, −0.64; SMD: −1.2, 95% CrI: −2.0, −0.54) (Figure S11 and Table 6). Funnel plot analysis indicated symmetrical distribution, suggesting no evidence of publication bias (Figure S12).

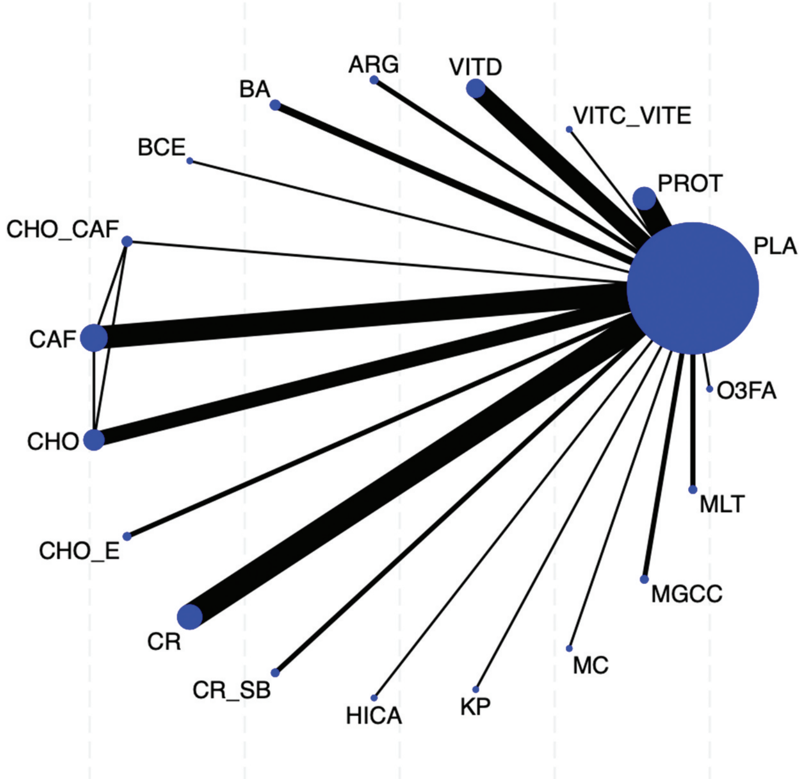

Figure 7. Network diagram of the efficacy of different dietary supplements in reducing sprint time.

3.4.5. Agility

Fourteen studies reported the effects of different dietary supplements on agility in soccer players, involving 11 different dietary supplements, mainly containing CAF, CR, CR_SB and PROT. Other supplements were involved in only a small number of studies (Figure 8). This meta-analysis showed that CR_SB (SUCRA = 99.8%), MLT (SUCRA = 79.4%) and KP (SUCRA = 71.6%) were interventions associated with the greatest impact on improving agility (Figure S13). Compared with placebo, only CR_SB and CAF were associated with a significant effect on improving agility (SMD: −2.3, 95% CrI: −3.2, −1.4; SMD: −0.38, 95% CrI: −0.68, −0.093). However, MLT and KP did not show a significant effect on agility (SMD. −0.82, 95% CrI: −1.8, 0.19; SMD: −0.53, 95% CrI: −1.2, 0.12) (Figure S14 and Table 7). Funnel plot analysis indicated symmetrical distribution, suggesting no evidence of publication bias (Figure S15).

3.4.6. Peak power

Twelve studies reported the effects of different dietary supplements on peak power in soccer players, involving 10 different dietary supplements, mainly CAF, PYR and CR. Other supplements were involved in only a small number of studies (Figure 9). This meta-analysis showed that MGCC (SUCRA = 87.3%), BCAA (SUCRA = 74.4%) and PYR (SUCRA = 74.2%) were interventions associated with the greatest impact on enhancing peak power (Figure S16). Compared with placebo, PYR was associated with a significant effect on

Table 6. League table of the efficacy of different dietary supplements in reducing sprint time.

	ARG	BA	BCE	CAF	CHO	CHO_CAF	CHO_E	CR	CR_SB	HICA	KP	MC	MGCC	MLT	O3FA	PLA	PROT	VITC_VITE	VITD
ARG	ARG	**1.45 (0.56, 2.35)**	**0.95 (0.04, 1.92)**	**1.05 (0.33, 1.82)**	**1.28 (0.53, 2.05)**	**1.12 (0.02, 2.2)**	**0.92 (0.06, 1.8)**	**1.08 (0.35, 1.86)**	−0.15 (−1.16, 0.85)	**1.87 (0.63, 3.13)**	**0.87 (0.02, 1.77)**	0.91 (−0.22, 2.13)	**−1.78 (−3.1, −0.38)**	−0.68 (−1.74, 0.41)	**1.33 (0.28, 2.39)**	**1.22 (0.54, 1.96)**	**1.18 (0.45, 1.98)**	0.8 (−0.29, 1.95)	**1.19 (0.44, 1.97)**
BA	**−1.45 (−2.35, −0.56)**	BA	−0.5 (−1.3, 0.35)	−0.39 (−1, 0.2)	−0.16 (−0.8, 0.45)	−0.35 (−1.35, 0.7)	−0.52 (−1.29, 0.19)	−0.37 (−1, 0.24)	**−1.6 (−2.51, −0.7)**	0.42 (−0.76, 1.57)	−0.58 (−1.33, 0.19)	−0.54 (−1.64, 0.58)	**−3.22 (−4.51, −1.96)**	**−2.14 (−3.1, −1.19)**	−0.12 (−1.09, 0.83)	−0.22 (−0.79, 0.32)	−0.25 (−0.86, 0.35)	−0.65 (−1.64, 0.44)	−0.25 (−0.87, 0.36)
BCE	**−0.95 (−1.92, −0.04)**	0.5 (−0.35, 1.3)	BCE	0.09 (−0.53, 0.72)	0.31 (−0.35, 0.99)	0.15 (−0.85, 1.17)	−0.04 (−0.82, 0.74)	0.12 (−0.54, 0.75)	**−1.1 (−2.05, −0.19)**	0.91 (−0.29, 2.11)	−0.09 (−0.87, 0.71)	−0.05 (−1.25, 1.15)	**−2.74 (−3.99, −1.43)**	**−1.67 (−2.61, −0.65)**	0.36 (−0.6, 1.36)	0.26 (−0.34, 0.85)	0.23 (−0.4, 0.87)	−0.16 (−1.16, 0.91)	0.23 (−0.44, 0.89)
CAF	**−1.05 (−1.82, −0.33)**	0.39 (−0.2, 1)	−0.09 (−0.72, 0.53)	CAF	0.22 (−0.17, 0.62)	0.06 (−0.83, 0.95)	−0.14 (−0.7, 0.42)	0.02 (−0.32, 0.35)	**−1.2 (−1.95, −0.43)**	0.81 (−0.26, 1.87)	−0.19 (−0.77, 0.4)	−0.14 (−1.18, 0.89)	**−2.83 (−3.99, −1.63)**	**−1.76 (−2.55, −0.94)**	0.27 (−0.54, 1.09)	0.17 (−0.08, 0.4)	0.13 (−0.21, 0.48)	−0.25 (−1.14, 0.66)	0.13 (−0.24, 0.52)
CHO	**−1.28 (−2.05, −0.53)**	0.16 (−0.45, 0.8)	−0.31 (−0.99, 0.35)	−0.22 (−0.62, 0.17)	CHO	−0.17 (−1.06, 0.74)	−0.36 (−0.95, 0.21)	−0.2 (−0.59, 0.18)	**−1.43 (−2.2, −0.62)**	0.58 (−0.5, 1.66)	−0.42 (−1, 0.22)	−0.37 (−1.42, 0.71)	**−3.05 (−4.22, −1.87)**	**−1.98 (−2.81, −1.12)**	0.05 (−0.78, 0.87)	−0.06 (−0.37, 0.24)	−0.09 (−0.49, 0.3)	−0.48 (−1.39, 0.48)	−0.09 (−0.51, 0.32)
CHO_CAF	**−1.12 (−2.2, −0.02)**	0.35 (−0.7, 1.35)	−0.15 (−1.17, 0.85)	−0.06 (−0.95, 0.83)	0.17 (−0.74, 1.06)	CHO_CAF	−0.2 (−1.18, 0.78)	−0.04 (−0.92, 0.84)	**−1.26 (−2.42, −0.12)**	0.75 (−0.67, 2.1)	−0.24 (−1.23, 0.76)	−0.19 (−1.55, 1.13)	**−2.89 (−4.27, −1.44)**	**−1.83 (−2.99, −0.68)**	0.21 (−0.93, 1.37)	0.11 (−0.75, 0.96)	0.07 (−0.83, 0.96)	−0.29 (−1.53, 0.91)	0.08 (−0.82, 0.98)
CHO_E	**−0.92 (−1.8, −0.06)**	0.52 (−0.19, 1.29)	0.04 (−0.74, 0.82)	0.14 (−0.42, 0.7)	0.36 (−0.21, 0.95)	0.2 (−0.78, 1.18)	CHO_E	0.15 (−0.39, 0.73)	**−1.06 (−1.94, −0.17)**	0.95 (−0.21, 2.1)	−0.05 (−0.76, 0.71)	−0.01 (−1.1, 1.12)	**−2.7 (−3.91, −1.38)**	**−1.62 (−2.51, −0.69)**	0.42 (−0.51, 1.34)	0.3 (−0.18, 0.8)	0.27 (−0.29, 0.85)	−0.11 (−1.09, 0.94)	0.27 (−0.28, 0.86)
CR	**−1.08 (−1.86, −0.35)**	0.37 (−0.24, 1)	−0.12 (−0.75, 0.54)	−0.02 (−0.35, 0.32)	0.2 (−0.18, 0.59)	0.04 (−0.84, 0.92)	−0.15 (−0.73, 0.39)	CR	**−1.22 (−1.99, −0.46)**	0.78 (−0.29, 1.85)	−0.21 (−0.78, 0.37)	−0.16 (−1.18, 0.87)	**−2.85 (−4.01, −1.65)**	**−1.77 (−2.58, −0.95)**	0.25 (−0.57, 1.08)	0.15 (−0.1, 0.39)	0.12 (−0.25, 0.47)	−0.27 (−1.15, 0.64)	0.11 (−0.26, 0.48)
CR_SB	0.15 (−0.85, 1.16)	**1.6 (0.7, 2.51)**	**1.1 (0.19, 2.05)**	**1.2 (0.43, 1.95)**	**1.43 (0.62, 2.2)**	**1.26 (0.12, 2.42)**	**1.06 (0.17, 1.94)**	**1.22 (0.46, 1.99)**	CR_SB	**2.01 (0.76, 3.3)**	**1.02 (0.11, 1.94)**	1.05 (−0.15, 2.3)	**−1.65 (−2.94, −0.26)**	−0.55 (−1.62, 0.54)	**1.47 (0.43, 2.52)**	**1.37 (0.64, 2.09)**	**1.34 (0.56, 2.1)**	0.96 (−0.15, 2.11)	**1.34 (0.55, 2.13)**
HICA	**−1.87 (−3.13, −0.63)**	−0.42 (−1.57, 0.76)	−0.91 (−2.11, 0.29)	−0.81 (−1.87, 0.26)	−0.58 (−1.66, 0.5)	−0.75 (−2.1, 0.67)	−0.95 (−2.1, 0.21)	−0.78 (−1.85, 0.29)	**−2.01 (−3.3, −0.76)**	HICA	−1 (−2.15, 0.19)	−0.95 (−2.37, 0.5)	**−3.65 (−5.19, −2.08)**	**−2.55 (−3.88, −1.25)**	−0.55 (−1.87, 0.77)	−0.65 (−1.7, 0.4)	−0.68 (−1.75, 0.44)	−1.07 (−2.36, 0.34)	−0.67 (−1.76, 0.43)
KP	**−0.87 (−1.77, −0.02)**	0.58 (−0.19, 1.33)	0.09 (−0.71, 0.87)	0.19 (−0.4, 0.77)	0.42 (−0.22, 1)	0.24 (−0.76, 1.23)	0.05 (−0.71, 0.76)	0.21 (−0.37, 0.78)	**−1.02 (−1.94, −0.11)**	1 (−0.19, 2.15)	KP	0.04 (−1.09, 1.17)	**−2.65 (−3.9, −1.42)**	**−1.56 (−2.54, −0.59)**	0.46 (−0.5, 1.39)	0.35 (−0.19, 0.87)	0.32 (−0.28, 0.89)	−0.06 (−1.07, 0.97)	0.32 (−0.29, 0.92)
MC	−0.91 (−2.13, 0.22)	0.54 (−0.58, 1.64)	0.05 (−1.15, 1.25)	0.14 (−0.89, 1.18)	0.37 (−0.71, 1.42)	0.19 (−1.13, 1.55)	0.01 (−1.12, 1.1)	0.16 (−0.87, 1.18)	−1.05 (−2.3, 0.15)	0.95 (−0.5, 2.37)	−0.04 (−1.17, 1.09)	MC	**−2.68 (−4.19, −1.23)**	**−1.59 (−2.88, −0.41)**	0.4 (−0.86, 1.7)	0.31 (−0.7, 1.3)	0.28 (−0.74, 1.31)	−0.1 (−1.45, 1.26)	0.28 (−0.76, 1.31)
MGCC	**1.78 (0.38, 3.1)**	**3.22 (1.96, 4.51)**	**2.74 (1.43, 3.99)**	**2.83 (1.63, 3.99)**	**3.05 (1.87, 4.22)**	**2.89 (1.44, 4.27)**	**2.7 (1.38, 3.91)**	**2.85 (1.65, 4.01)**	**1.65 (0.26, 2.94)**	**3.65 (2.08, 5.19)**	**2.65 (1.42, 3.9)**	**2.68 (1.23, 4.19)**	MGCC	1.07 (−0.31, 2.48)	**3.09 (1.69, 4.49)**	**3 (1.83, 4.13)**	**2.98 (1.75, 4.11)**	**2.57 (1.19, 4.01)**	**2.97 (1.76, 4.17)**
MLT	0.68 (−0.41, 1.74)	**2.14 (1.19, 3.1)**	**1.67 (0.65, 2.61)**	**1.76 (0.94, 2.55)**	**1.98 (1.12, 2.81)**	**1.83 (0.68, 2.99)**	**1.62 (0.69, 2.51)**	**1.77 (0.95, 2.58)**	0.55 (−0.54, 1.62)	**2.55 (1.25, 3.88)**	**1.56 (0.59, 2.54)**	**1.59 (0.41, 2.88)**	−1.07 (−2.48, 0.31)	MLT	**2.02 (0.91, 3.16)**	**1.92 (1.14, 2.69)**	**1.89 (1.05, 2.7)**	**1.5 (0.36, 2.7)**	**1.89 (1.06, 2.7)**
O3FA	**−1.33 (−2.39, −0.28)**	0.12 (−0.83, 1.09)	−0.36 (−1.36, 0.6)	−0.27 (−1.09, 0.54)	−0.05 (−0.87, 0.78)	−0.21 (−1.37, 0.93)	−0.42 (−1.34, 0.51)	−0.25 (−1.08, 0.57)	**−1.47 (−2.52, −0.43)**	0.55 (−0.77, 1.87)	−0.46 (−1.39, 0.5)	−0.4 (−1.7, 0.86)	**−3.09 (−4.49, −1.69)**	**−2.02 (−3.16, −0.91)**	O3FA	−0.1 (−0.89, 0.67)	−0.13 (−0.97, 0.67)	−0.51 (−1.71, 0.65)	−0.13 (−0.98, 0.69)
PLA	**−1.22 (−1.96, −0.54)**	0.22 (−0.32, 0.79)	−0.26 (−0.85, 0.34)	−0.17 (−0.4, 0.08)	0.06 (−0.24, 0.37)	−0.11 (−0.96, 0.75)	−0.3 (−0.8, 0.18)	−0.15 (−0.39, 0.1)	**−1.37 (−2.09, −0.64)**	0.65 (−0.4, 1.7)	−0.35 (−0.87, 0.19)	−0.31 (−1.3, 0.7)	**−3 (−4.13, −1.83)**	**−1.92 (−2.69, −1.14)**	0.1 (−0.67, 0.89)	PLA	−0.03 (−0.29, 0.23)	−0.42 (−1.27, 0.48)	−0.03 (−0.31, 0.26)
PROT	**−1.18 (−1.98, −0.45)**	0.25 (−0.35, 0.86)	−0.23 (−0.87, 0.4)	−0.13 (−0.48, 0.21)	0.09 (−0.3, 0.49)	−0.07 (−0.96, 0.83)	−0.27 (−0.85, 0.29)	−0.12 (−0.47, 0.25)	**−1.34 (−2.1, −0.56)**	0.68 (−0.44, 1.75)	−0.32 (−0.89, 0.28)	−0.28 (−1.31, 0.74)	**−2.98 (−4.11, −1.75)**	**−1.89 (−2.7, −1.05)**	0.13 (−0.67, 0.97)	0.03 (−0.23, 0.29)	PROT	−0.39 (−1.27, 0.54)	0 (−0.38, 0.39)

(*Continued*)

Table 6. (Continued).

	ARG	BA	BCE	CAF	CHO	CHO_CAF	CHO_E	CR	CR_SB	HICA	KP	MC	MGCC	MLT	O3FA	PLA	PROT	VITC_VITE	VITD
VITC_VITE	−0.8 (−1.95, 0.29)	0.65 (−0.44, 1.64)	0.16 (−0.91, 1.16)	0.25 (−0.66, 1.14)	0.48 (−0.48, 1.39)	0.29 (−0.91, 1.53)	0.11 (−0.94, 1.09)	0.27 (−0.64, 1.15)	−0.96 (−2.11, 0.15)	1.07 (−0.34, 2.36)	0.06 (−0.97, 1.07)	0.1 (−1.26, 1.45)	**-2.57 (−4.01, −1.19)**	**-1.5 (−2.7, −0.36)**	0.51 (−0.65, 1.71)	0.42 (−0.48, 1.27)	0.39 (−0.54, 1.27)	VITC_VITE	0.39 (−0.54, 1.29)
VITD	**-1.19 (−1.97, −0.44)**	0.25 (−0.36, 0.87)	−0.23 (−0.89, 0.44)	−0.13 (−0.52, 0.24)	0.09 (−0.32, 0.51)	−0.08 (−0.98, 0.82)	−0.27 (−0.86, 0.28)	−0.11 (−0.48, 0.26)	**-1.34 (−2.13, −0.55)**	0.67 (−0.43, 1.76)	−0.32 (−0.92, 0.29)	−0.28 (−1.31, 0.76)	**-2.97 (−4.17, −1.76)**	**-1.89 (−2.7, −1.06)**	0.13 (−0.69, 0.98)	0.03 (−0.26, 0.31)	0 (−0.39, 0.38)	−0.39 (−1.29, 0.54)	VITD

Effects are expressed as the effect size (95% CrI) between interventions. When the 95% CrI does not include 0, $p < 0.05$; when the 95% CrI includes 0, $p > 0.05$. Bold indicates a statistically significant difference in the comparison ($p < 0.05$). A positive and bolded effect size indicates that the supplement on the longitudinal is more effective than the supplement on the horizontal; a negative and bolded effect size indicates that the supplement on the horizontal is more effective than the supplement on the longitudinal.

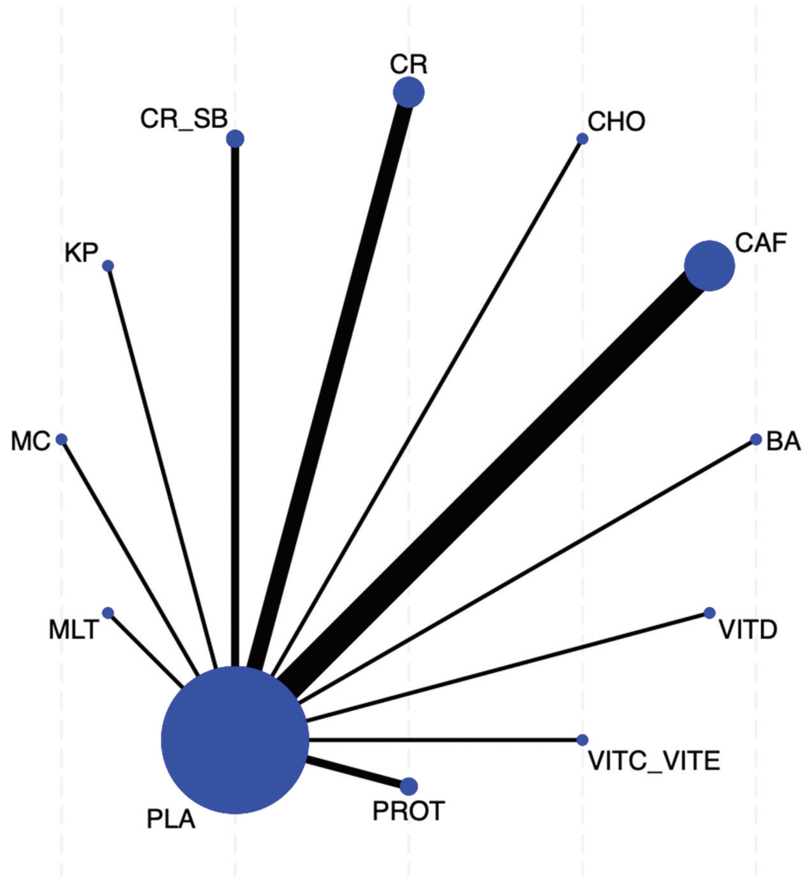

Figure 8. Network diagram of the efficacy of different dietary supplements in enhancing agility.

increasing peak power (SMD: 0.50, 95% CrI: 0.049, 0.98). However, MGCC and BCAA did not show a significant effect on peak power (SMD: 0.98, 95% CrI: −0.16, 2.1; SMD: 0.64, 95% CrI: −0.41, 1.7) (Figure S17 and Table 8). Funnel plot analysis indicated symmetrical distribution, suggesting no evidence of publication bias (Figure S18).

3.4.7. Mean power

Twelve studies reported the effects of different dietary supplements on mean power in soccer players, involving 10 different dietary supplements mainly CAF, PYR and CR. Other supplements were involved in only a small number of studies (Figure 10). This meta-analysis showed that MGCC (SUCRA = 94.5%), PYR (SUCRA = 78.0%) and CR (SUCRA = 72.6%) were interventions associated with the greatest impact on increasing mean power (Figure S19). Compared with placebo, MGCC and PYR were associated with a significant effect on increasing mean power (SMD: 1.3, 95% CrI: 0.11, 2.5; SMD: 0.56, 95% CrI: 0.093, 1.0). However, CR did not show a significant effect on mean power (SMD: 0.49, 95% CrI: −0.073, 1.0) (Figure S20 and Table 9). Funnel plot analysis indicated symmetrical distribution, suggesting no evidence of publication bias (Figure S21).

Table 7. League table of the efficacy of different dietary supplements in enhancing agility.

	BA	CAF	CHO	CR	CR_SB	KP	MC	MLT	PLA	PROT	VITC_VITE	VITD
BA	BA	−0.98 (−2.09, 0.12)	−0.79 (−2.1, 0.5)	−0.36 (−1.5, 0.8)	**−2.86 (−4.27, −1.49)**	−1.13 (−2.41, 0.13)	−0.73 (−2.24, 0.83)	−1.43 (−2.89, 0.06)	−0.6 (−1.67, 0.47)	−0.66 (−1.92, 0.6)	−0.46 (−1.91, 0.94)	−0.75 (−2.1, 0.57)
CAF	0.98 (−0.12, 2.09)	CAF	0.18 (−0.58, 0.97)	**0.61 (0.12, 1.15)**	**−1.89 (−2.83, −0.95)**	−0.15 (−0.87, 0.57)	0.26 (−0.85, 1.37)	−0.45 (−1.49, 0.6)	**0.38 (0.09, 0.68)**	0.31 (−0.41, 1.07)	0.51 (−0.46, 1.51)	0.23 (−0.62, 1.07)
CHO	0.79 (−0.5, 2.1)	−0.18 (−0.97, 0.58)	CHO	0.43 (−0.39, 1.27)	**−2.07 (−3.23, −0.94)**	−0.34 (−1.31, 0.63)	0.08 (−1.2, 1.34)	−0.62 (−1.88, 0.61)	0.19 (−0.53, 0.91)	0.13 (−0.86, 1.13)	0.32 (−0.85, 1.5)	0.05 (−1.02, 1.1)
CR	0.36 (−0.8, 1.5)	**−0.61 (−1.15, −0.12)**	−0.43 (−1.27, 0.39)	CR	**−2.5 (−3.53, −1.52)**	−0.77 (−1.57, 0)	−0.37 (−1.53, 0.78)	−1.06 (−2.16, 0.02)	−0.24 (−0.67, 0.18)	−0.3 (−1.11, 0.49)	−0.11 (−1.15, 0.92)	−0.39 (−1.27, 0.47)
CR_SB	**2.86 (1.49, 4.27)**	**1.89 (0.95, 2.83)**	**2.07 (0.94, 3.23)**	**2.5 (1.52, 3.53)**	CR_SB	**1.73 (0.63, 2.86)**	**2.14 (0.75, 3.56)**	**1.44 (0.11, 2.81)**	**2.26 (1.38, 3.17)**	**2.21 (1.1, 3.35)**	**2.39 (1.12, 3.7)**	**2.12 (0.93, 3.31)**
KP	1.13 (−0.13, 2.41)	0.15 (−0.57, 0.87)	0.34 (−0.63, 1.31)	0.77 (0, 1.57)	**−1.73 (−2.86, −0.63)**	KP	0.42 (−0.87, 1.66)	−0.29 (−1.48, 0.91)	0.53 (−0.12, 1.19)	0.47 (−0.46, 1.42)	0.66 (−0.48, 1.8)	0.38 (−0.66, 1.39)
MC	0.73 (−0.83, 2.24)	−0.26 (−1.37, 0.85)	−0.08 (−1.34, 1.2)	0.37 (−0.78, 1.53)	**−2.14 (−3.56, −0.75)**	−0.42 (−1.66, 0.87)	MC	−0.7 (−2.18, 0.77)	0.12 (−0.95, 1.2)	0.05 (−1.2, 1.3)	0.24 (−1.14, 1.67)	−0.04 (−1.34, 1.29)
MLT	1.43 (−0.06, 2.89)	0.45 (−0.6, 1.49)	0.62 (−0.61, 1.88)	1.06 (−0.02, 2.16)	**−1.44 (−2.81, −0.11)**	0.29 (−0.91, 1.48)	0.7 (−0.77, 2.18)	MLT	0.82 (−0.19, 1.83)	0.76 (−0.42, 1.98)	0.94 (−0.42, 2.32)	0.67 (−0.61, 1.94)
PLA	0.6 (−0.47, 1.67)	**−0.38 (−0.68, −0.09)**	−0.19 (−0.91, 0.53)	0.24 (−0.18, 0.67)	**−2.26 (−3.17, −1.38)**	−0.53 (−1.19, 0.12)	−0.12 (−1.2, 0.95)	−0.82 (−1.83, 0.19)	PLA	−0.06 (−0.73, 0.62)	0.13 (−0.81, 1.07)	−0.15 (−0.93, 0.62)
PROT	0.66 (−0.6, 1.92)	−0.31 (−1.07, 0.41)	−0.13 (−1.13, 0.86)	0.3 (−0.49, 1.11)	**−2.21 (−3.35, −1.1)**	−0.47 (−1.42, 0.46)	−0.05 (−1.3, 1.2)	−0.76 (−1.98, 0.42)	0.06 (−0.62, 0.73)	PROT	0.18 (−0.97, 1.36)	−0.09 (−1.13, 0.94)
VITC_VITE	0.46 (−0.94, 1.91)	−0.51 (−1.51, 0.46)	−0.32 (−1.5, 0.85)	0.11 (−0.92, 1.15)	**−2.39 (−3.7, −1.12)**	−0.66 (−1.8, 0.48)	−0.24 (−1.67, 1.14)	−0.94 (−2.32, 0.42)	−0.13 (−1.07, 0.81)	−0.18 (−1.36, 0.97)	VITC_VITE	−0.27 (−1.49, 0.95)
VITD	0.75 (−0.57, 2.1)	−0.23 (−1.07, 0.62)	−0.05 (−1.1, 1.02)	0.39 (−0.47, 1.27)	**−2.12 (−3.31, −0.93)**	−0.38 (−1.39, 0.66)	0.04 (−1.29, 1.34)	−0.67 (−1.94, 0.61)	0.15 (−0.62, 0.93)	0.09 (−0.94, 1.13)	0.27 (−0.95, 1.49)	VITD

Effects are expressed as the effect size (95% CrI) between interventions. When the 95% CrI does not include 0, $p < 0.05$; when the 95% CrI includes 0, $p > 0.05$. Bold indicates a statistically significant difference in the comparison ($p < 0.05$). A positive and bolded effect size indicates that the supplement on the longitudinal is more effective than the supplement on the horizontal; a negative and bolded effect size indicates that the supplement on the horizontal is more effective than the supplement on the longitudinal.

3.4.8. Rating of perceived exertion

Twenty-nine studies reported the effects of different dietary supplements on rating of perceived exertion in soccer players, involving 13 different dietary supplements, mainly CAF, CHO, CHO_E and CR. Other supplements were involved in only a small number of studies (Figure 11). This meta-analysis showed that CHO_PROT (SUCRA = 93.7%), CHO_E (SUCRA = 80.2%) and MLT (SUCRA = 77.4%) were interventions associated with the greatest impact on improving rating of perceived exertion (Figure S22). Compared with placebo, CHO_E was associated with a significant improvement in rating of perceived exertion (SMD: −0.56, 95% CrI: −0.99, −0.13). However, CHO_PROT and MLT did not show a significant improvement in rating of perceived exertion (SMD: −1.4, 95% CrI: −2.8, 0.015; SMD: −0.62, 95% CrI: −1.4, 0.24) (Figure S23 and Table 10). Funnel plot analysis indicated symmetrical distribution, suggesting no evidence of publication bias (Figure S24).

3.4.9. Subgroup analysis

We performed a subgroup analysis of outcome measures according to the athletes' competitive level (elite and non-elite athletes). The results are detailed in Supplementary Material 4, and the analysis is summarized as follows.

Subgroup analysis based on the competitive level of soccer players revealed that, among elite soccer players, caffeine (SMD: 0.28, 95% CrI: 0.012, 0.55) was associated with a significant effect on increasing the distance covered. Melatonin (SMD: 0.74, 95% CrI: 0.019, 1.5) and caffeine (SMD: 0.39, 95% CrI: 0.18, 0.61) were associated with

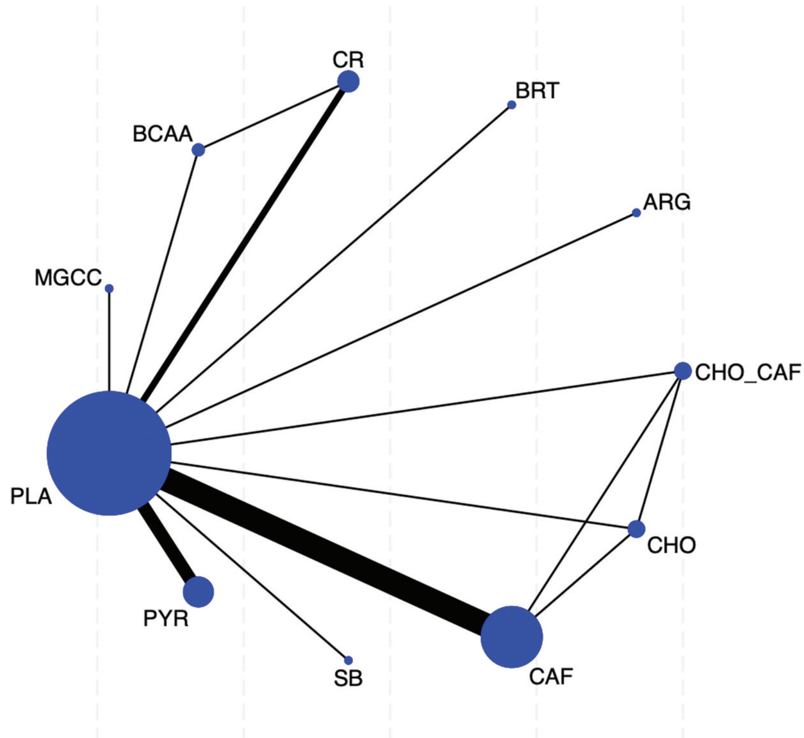

Figure 9. Network diagram of the efficacy of different dietary supplements in enhancing peak power.

Table 8. League table of the efficacy of different dietary supplements in enhancing peak power.

	ARG	BCAA	BRT	CAF	CHO	CHO_CAF	CR	MGCC	PLA	PYR	SB
ARG	ARG	1.09 (−0.23, 2.43)	0.51 (−0.63, 1.64)	0.64 (−0.22, 1.49)	0.4 (−0.86, 1.66)	0.72 (−0.5, 2)	0.83 (−0.15, 1.79)	**1.44 (0.04, 2.81)**	0.47 (−0.35, 1.27)	**0.96 (0.03, 1.91)**	0.27 (−0.85, 1.4)
BCAA	−1.09 (−2.43, 0.23)	BCAA	−0.59 (−1.89, 0.72)	−0.46 (−1.55, 0.64)	−0.7 (−2.1, 0.75)	−0.37 (−1.81, 1.07)	−0.28 (−1.44, 0.93)	0.35 (−1.19, 1.84)	−0.64 (−1.68, 0.41)	−0.13 (−1.27, 1.02)	−0.83 (−2.13, 0.49)
BRT	−0.51 (−1.64, 0.63)	0.59 (−0.72, 1.89)	BRT	0.13 (−0.7, 0.97)	−0.11 (−1.36, 1.14)	0.22 (−1.01, 1.5)	0.31 (−0.61, 1.28)	0.93 (−0.45, 2.28)	−0.05 (−0.83, 0.75)	0.46 (−0.47, 1.39)	−0.24 (−1.34, 0.88)
CAF	−0.64 (−1.49, 0.22)	0.46 (−0.64, 1.55)	−0.13 (−0.97, 0.7)	CAF	−0.24 (−1.26, 0.77)	0.09 (−0.91, 1.11)	0.19 (−0.42, 0.8)	0.8 (−0.36, 1.94)	−0.18 (−0.45, 0.11)	0.32 (−0.2, 0.87)	−0.37 (−1.19, 0.47)
CHO	−0.4 (−1.66, 0.86)	0.7 (−0.75, 2.1)	0.11 (−1.14, 1.36)	0.24 (−0.77, 1.26)	CHO	0.31 (−1.04, 1.74)	0.43 (−0.67, 1.55)	1.03 (−0.51, 2.54)	0.07 (−0.91, 1.04)	0.57 (−0.51, 1.63)	−0.13 (−1.36, 1.14)
CHO_CAF	−0.72 (−2, 0.5)	0.37 (−1.07, 1.81)	−0.22 (−1.5, 1.01)	−0.09 (−1.11, 0.91)	−0.31 (−1.74, 1.04)	CHO_CAF	0.1 (−1.02, 1.19)	0.72 (−0.8, 2.17)	−0.27 (−1.24, 0.69)	0.23 (−0.86, 1.32)	−0.46 (−1.72, 0.77)
CR	−0.83 (−1.79, 0.15)	0.28 (−0.93, 1.44)	−0.31 (−1.28, 0.61)	−0.19 (−0.8, 0.42)	−0.43 (−1.55, 0.67)	−0.1 (−1.19, 1.02)	CR	0.62 (−0.64, 1.85)	−0.36 (−0.9, 0.17)	0.14 (−0.56, 0.83)	−0.56 (−1.51, 0.4)
MGCC	**-1.44 (−2.81, −0.04)**	−0.35 (−1.84, 1.19)	−0.93 (−2.28, 0.45)	−0.8 (−1.94, 0.36)	−1.03 (−2.54, 0.51)	−0.72 (−2.17, 0.8)	−0.62 (−1.85, 0.64)	MGCC	−0.98 (−2.09, 0.16)	−0.48 (−1.69, 0.78)	−1.17 (−2.51, 0.22)
PLA	−0.47 (−1.27, 0.35)	0.64 (−0.41, 1.68)	0.05 (−0.75, 0.83)	0.18 (−0.11, 0.45)	−0.07 (−1.04, 0.91)	0.27 (−0.69, 1.24)	0.36 (−0.17, 0.9)	0.98 (−0.16, 2.09)	PLA	**0.5 (0.05, 0.98)**	−0.2 (−0.97, 0.59)
PYR	**-0.96 (−1.91, −0.03)**	0.13 (−1.02, 1.27)	−0.46 (−1.39, 0.47)	−0.32 (−0.87, 0.2)	−0.57 (−1.63, 0.51)	−0.23 (−1.32, 0.86)	−0.14 (−0.83, 0.56)	0.48 (−0.78, 1.69)	**-0.5 (−0.98, −0.05)**	PYR	−0.7 (−1.59, 0.22)
SB	−0.27 (−1.4, 0.85)	0.83 (−0.49, 2.13)	0.24 (−0.88, 1.34)	0.37 (−0.47, 1.19)	0.13 (−1.14, 1.36)	0.46 (−0.77, 1.72)	0.56 (−0.4, 1.51)	1.17 (−0.22, 2.51)	0.2 (−0.59, 0.97)	0.7 (−0.22, 1.59)	SB

ffects are expressed as the effect size (95% CrI) between interventions. When the 95% CrI does not include 0, $p < 0.05$; when the 95% CrI includes 0, $p > 0.05$. Bold indicates a statistically significant difference in the comparison ($p < 0.05$). A positive and bolded effect size indicates that the supplement on the horizontal is more effective than the supplement on the longitudinal; a negative and bolded effect size indicates that the supplement on the longitudinal is more effective than the supplement on the horizontal.

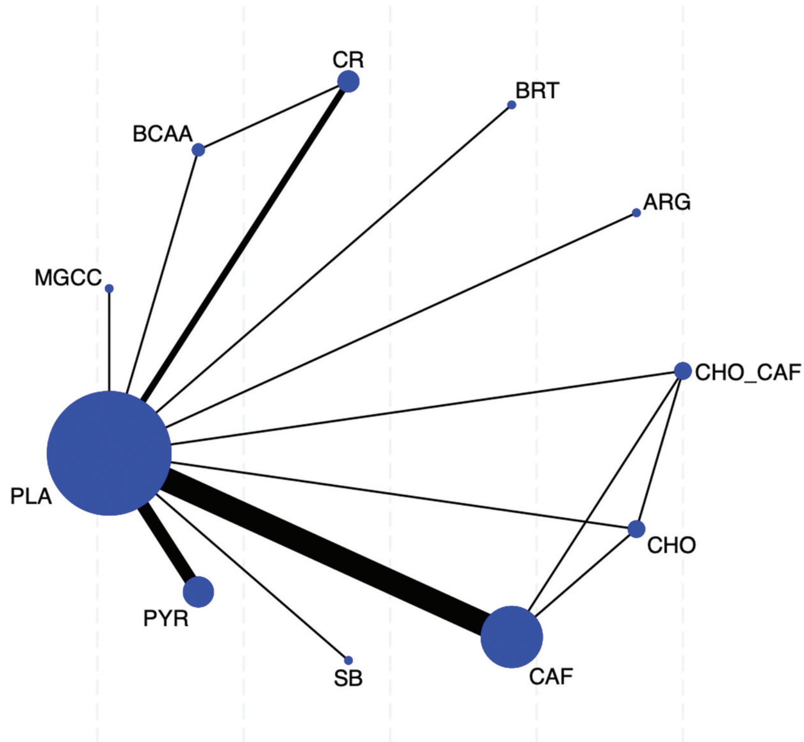

Figure 10. Network diagram of the efficacy of different dietary supplements in enhancing mean power.

Table 9. League table of the efficacy of different dietary supplements in enhancing mean power.

	ARG	BCAA	BRT	CAF	CHO	CHO_CAF	CR	MGCC	PLA	PYR	SB
ARG	ARG	0.62 (−0.71, 2.03)	−0.1 (−1.25, 1.1)	0.47 (−0.39, 1.37)	0.17 (−1.12, 1.48)	0.01 (−1.3, 1.32)	0.74 (−0.26, 1.75)	**1.56 (0.13, 3.05)**	0.25 (−0.57, 1.1)	0.81 (−0.15, 1.78)	0.31 (−0.83, 1.48)
BCAA	−0.62 (−2.03, 0.71)	BCAA	−0.72 (−2.1, 0.6)	−0.15 (−1.3, 0.96)	−0.45 (−1.93, 0.99)	−0.61 (−2.13, 0.8)	0.12 (−1.11, 1.28)	0.93 (−0.7, 2.55)	−0.37 (−1.48, 0.68)	0.19 (−0.99, 1.35)	−0.32 (−1.68, 1.02)
BRT	0.1 (−1.1, 1.25)	0.72 (−0.6, 2.1)	BRT	0.58 (−0.31, 1.43)	0.27 (−1.04, 1.55)	0.11 (−1.23, 1.38)	0.83 (−0.16, 1.82)	**1.65 (0.2, 3.14)**	0.35 (−0.48, 1.16)	0.9 (−0.05, 1.85)	0.4 (−0.75, 1.56)
CAF	−0.47 (−1.37, 0.39)	0.15 (−0.96, 1.3)	−0.58 (−1.43, 0.31)	CAF	−0.31 (−1.32, 0.74)	−0.47 (−1.53, 0.58)	0.26 (−0.37, 0.89)	1.08 (−0.15, 2.33)	−0.23 (−0.51, 0.06)	0.34 (−0.21, 0.89)	−0.16 (−1.02, 0.69)
CHO	−0.17 (−1.48, 1.12)	0.45 (−0.99, 1.93)	−0.27 (−1.55, 1.04)	0.31 (−0.74, 1.32)	CHO	−0.17 (−1.58, 1.25)	0.56 (−0.58, 1.7)	1.39 (−0.18, 2.97)	0.08 (−0.93, 1.06)	0.64 (−0.47, 1.74)	0.14 (−1.15, 1.41)
CHO_CAF	−0.01 (−1.32, 1.3)	0.61 (−0.8, 2.13)	−0.11 (−1.38, 1.23)	0.47 (−0.58, 1.53)	0.17 (−1.25, 1.58)	CHO_CAF	0.74 (−0.4, 1.88)	1.55 (0, 3.11)	0.24 (−0.76, 1.27)	0.81 (−0.29, 1.92)	0.31 (−1.01, 1.62)
CR	−0.74 (−1.75, 0.26)	−0.12 (−1.28, 1.11)	−0.83 (−1.82, 0.16)	−0.26 (−0.89, 0.37)	−0.56 (−1.7, 0.58)	−0.74 (−1.88, 0.4)	CR	0.81 (−0.47, 2.15)	−0.49 (−1.04, 0.07)	0.08 (−0.65, 0.79)	−0.42 (−1.41, 0.55)
MGCC	**-1.56 (−3.05, −0.13)**	−0.93 (−2.55, 0.7)	**-1.65 (−3.14, −0.2)**	−1.08 (−2.33, 0.15)	−1.39 (−2.97, 0.18)	−1.55 (−3.11, 0)	−0.81 (−2.15, 0.47)	MGCC	**-1.3 (−2.52, −0.11)**	−0.74 (−2.04, 0.53)	−1.25 (−2.72, 0.19)
PLA	−0.25 (−1.1, 0.57)	0.37 (−0.68, 1.48)	−0.35 (−1.16, 0.48)	0.23 (−0.06, 0.51)	−0.08 (−1.06, 0.93)	−0.24 (−1.27, 0.76)	0.49 (−0.07, 1.04)	**1.3 (0.11, 2.52)**	PLA	**0.56 (0.09, 1.03)**	0.06 (−0.75, 0.88)
PYR	−0.81 (−1.78, 0.15)	−0.19 (−1.35, 0.99)	−0.9 (−1.85, 0.05)	−0.34 (−0.89, 0.21)	−0.64 (−1.74, 0.47)	−0.81 (−1.92, 0.29)	−0.08 (−0.79, 0.65)	0.74 (−0.53, 2.04)	**-0.56 (−1.03, −0.09)**	PYR	−0.5 (−1.44, 0.45)
SB	−0.31 (−1.48, 0.83)	0.32 (−1.02, 1.68)	−0.4 (−1.56, 0.75)	0.16 (−0.69, 1.02)	−0.14 (−1.41, 1.15)	−0.31 (−1.62, 1.01)	0.42 (−0.55, 1.41)	1.25 (−0.19, 2.72)	−0.06 (−0.88, 0.75)	0.5 (−0.45, 1.44)	SB

Effects are expressed as the effect size (95% CrI) between interventions. When the 95% CrI does not include 0, $p < 0.05$; when the 95% CrI includes 0, $p > 0.05$. Bold indicates a statistically significant difference in the comparison ($p < 0.05$). A positive and bolded effect size indicates that the supplement on the horizontal is more effective than the supplement on the longitudinal; a negative and bolded effect size indicates that the supplement on the longitudinal is more effective than the supplement on the horizontal.

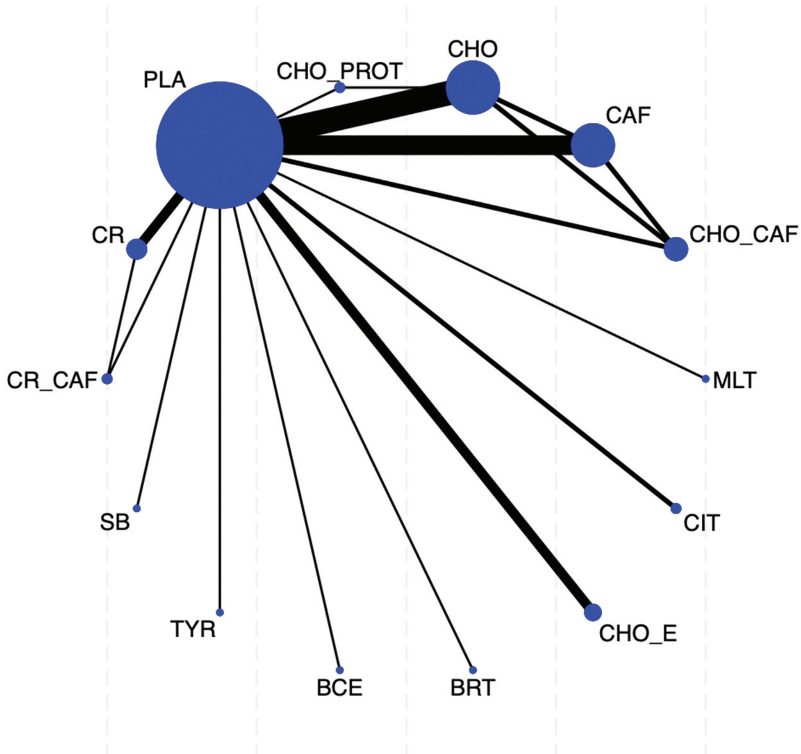

Figure 11. Network diagram of the efficacy of different dietary supplements in improving the rating of perceived exertion.

a significant effect on increasing jump height. Magnesium creatine chelate (SMD: −3.0, 95% CrI: −4.1, −1.8), melatonin (SMD: −1.9, 95% CrI: −2.7, −1.1), creatine + sodium bicarbonate (SMD: −1.4, 95% CrI: −2.2, −0.67), and arginine (SMD: −1.2, 95% CrI: −1.9, −0.51) were associated with a significant effect on reducing sprint time. Creatine + sodium bicarbonate (SMD: −2.3, 95% CrI: −3.2, −1.4) and caffeine (SMD: −0.38, 95% CrI: −0.70, −0.092) were associated with a significant effect on improving agility. Sodium pyruvate (SMD: 0.56, 95% CrI: 0.048, 1.1) was associated with a significant effect on increasing mean power. Carbohydrate + electrolyte (SMD: −0.75, 95% CrI: −1.5, −0.16) was associated with a significant effect on improving the rating of perceived exertion. Among non-elite soccer players, carbohydrate + protein (SMD: 2.3, 95% CrI: 0.48, 4.1) was associated with a significant effect on increasing the distance covered. *Kaempferia parviflora* (SMD: 0.46, 95% CrI: 0.054, 0.86) was associated with a significant effect on enhancing muscular strength. Beta-alanine (SMD: 0.83, 95% CrI: 0.061, 1.6) and caffeine (SMD: 0.34, 95% CrI: 0.019, 0.67) were associated with a significant effect on increasing jump height. Caffeine (SMD: 0.35, 95% CrI: 0.0017, 0.69) was associated with a significant effect on increasing mean power. Carbohydrate + protein (SMD: −1.4, 95% CrI: −2.8, −0.012) was associated with a significant effect on improving rating of perceived exertion.

Table 10. League table of the efficacy of different dietary supplements in improving the rating of perceived exertion.

	BCE	BRT	CAF	CHO	CHO_CAF	CHO_E	CHO_PROT	CIT	CR	CR_CAF	MLT	PLA	SB	TYR
BCE	BCE	−0.15 (−1.04, 0.71)	−0.12 (−0.82, 0.56)	−0.03 (−0.72, 0.64)	0.12 (−0.77, 1.03)	−0.56 (−1.32, 0.21)	−1.39 (−2.92, 0.19)	−0.03 (−1.06, 0.99)	−0.3 (−1.1, 0.47)	0.38 (−0.62, 1.34)	−0.62 (−1.65, 0.42)	0 (−0.63, 0.63)	−0.21 (−1.18, 0.79)	−0.18 (−1.41, 1)
BRT	0.15 (−0.71, 1.04)	BRT	0.02 (−0.63, 0.66)	0.12 (−0.54, 0.75)	0.27 (−0.61, 1.14)	−0.42 (−1.13, 0.31)	−1.24 (−2.74, 0.27)	0.12 (−0.88, 1.1)	−0.16 (−0.91, 0.6)	0.53 (−0.42, 1.47)	−0.48 (−1.48, 0.56)	0.15 (−0.43, 0.72)	−0.07 (−1.05, 0.93)	−0.04 (−1.26, 1.16)
CAF	0.12 (−0.56, 0.82)	−0.02 (−0.66, 0.63)	CAF	0.09 (−0.31, 0.48)	0.24 (−0.47, 0.96)	−0.43 (−0.96, 0.08)	−1.25 (−2.7, 0.17)	0.1 (−0.77, 0.97)	−0.17 (−0.74, 0.38)	0.51 (−0.29, 1.29)	−0.48 (−1.37, 0.41)	0.13 (−0.17, 0.43)	−0.09 (−0.93, 0.77)	−0.05 (−1.15, 1)
CHO	0.03 (−0.64, 0.72)	−0.12 (−0.75, 0.54)	−0.09 (−0.48, 0.31)	CHO	0.16 (−0.55, 0.85)	**−0.53 (−1.03, −0.03)**	−1.35 (−2.78, 0.07)	0 (−0.85, 0.87)	−0.27 (−0.83, 0.28)	0.42 (−0.37, 1.19)	−0.59 (−1.43, 0.31)	0.03 (−0.23, 0.3)	−0.18 (−1.01, 0.65)	−0.15 (−1.22, 0.92)
CHO_CAF	−0.12 (−1.03, 0.77)	−0.27 (−1.14, 0.61)	−0.24 (−0.96, 0.47)	−0.16 (−0.85, 0.55)	CHO_CAF	−0.68 (−1.48, 0.08)	**-1.5 (−3.05, −0.02)**	−0.16 (−1.2, 0.9)	−0.43 (−1.23, 0.39)	0.26 (−0.75, 1.24)	−0.74 (−1.79, 0.31)	−0.12 (−0.77, 0.53)	−0.34 (−1.35, 0.72)	−0.31 (−1.53, 0.91)
CHO_E	0.56 (−0.21, 1.32)	0.42 (−0.31, 1.13)	0.43 (−0.08, 0.96)	**0.53 (0.03, 1.03)**	0.68 (−0.08, 1.48)	CHO_E	−0.83 (−2.28, 0.64)	0.54 (−0.39, 1.45)	0.26 (−0.38, 0.88)	**0.94 (0.05, 1.79)**	−0.06 (−0.98, 0.91)	**0.56 (0.13, 0.99)**	0.35 (−0.52, 1.26)	0.37 (−0.77, 1.49)
CHO_PROT	1.39 (−0.19, 2.92)	1.24 (−0.27, 2.74)	1.25 (−0.17, 2.7)	1.35 (−0.07, 2.78)	**1.5 (0.02, 3.05)**	0.83 (−0.64, 2.28)	CHO_PROT	1.37 (−0.26, 2.95)	1.09 (−0.38, 2.55)	**1.75 (0.2, 3.33)**	0.76 (−0.8, 2.4)	1.38 (−0.01, 2.79)	1.18 (−0.36, 2.76)	1.2 (−0.56, 2.97)
CIT	0.03 (−0.99, 1.06)	−0.12 (−1.1, 0.88)	−0.1 (−0.97, 0.77)	0 (−0.87, 0.85)	0.16 (−0.9, 1.2)	−0.54 (−1.45, 0.39)	−1.37 (−2.95, 0.26)	CIT	−0.28 (−1.21, 0.68)	0.41 (−0.7, 1.51)	−0.59 (−1.74, 0.58)	0.03 (−0.79, 0.85)	−0.18 (−1.3, 0.94)	−0.14 (−1.51, 1.15)
CR	0.3 (−0.47, 1.1)	0.16 (−0.6, 0.91)	0.17 (−0.38, 0.74)	0.27 (−0.28, 0.83)	0.43 (−0.39, 1.23)	−0.26 (−0.88, 0.38)	−1.09 (−2.55, 0.38)	0.28 (−0.68, 1.21)	CR	0.68 (−0.19, 1.56)	−0.32 (−1.26, 0.66)	0.3 (−0.17, 0.79)	0.09 (−0.8, 1.02)	0.11 (−1.02, 1.24)
CR_CAF	−0.38 (−1.34, 0.62)	−0.53 (−1.47, 0.42)	−0.51 (−1.29, 0.29)	−0.42 (−1.19, 0.37)	−0.26 (−1.24, 0.75)	**−0.94 (−1.79, −0.05)**	**-1.75 (−3.33, −0.2)**	−0.41 (−1.51, 0.7)	−0.68 (−1.56, 0.19)	CR_CAF	−1 (−2.11, 0.15)	−0.38 (−1.11, 0.36)	−0.59 (−1.68, 0.49)	−0.56 (−1.86, 0.74)
MLT	0.62 (−0.42, 1.65)	0.48 (−0.56, 1.48)	0.48 (−0.41, 1.37)	0.59 (−0.31, 1.43)	0.74 (−0.31, 1.79)	0.06 (−0.91, 0.98)	−0.76 (−2.4, 0.8)	0.59 (−0.58, 1.74)	0.32 (−0.66, 1.26)	1 (−0.15, 2.11)	MLT	0.62 (−0.24, 1.44)	0.4 (−0.75, 1.53)	0.42 (−0.94, 1.72)
PLA	0 (−0.63, 0.63)	−0.15 (−0.72, 0.43)	−0.13 (−0.43, 0.17)	−0.03 (−0.3, 0.23)	0.12 (−0.53, 0.77)	**-0.56 (−0.99, −0.13)**	−1.38 (−2.79, 0.01)	−0.03 (−0.85, 0.79)	−0.3 (−0.79, 0.17)	0.38 (−0.36, 1.11)	−0.62 (−1.44, 0.24)	PLA	−0.21 (−0.99, 0.57)	−0.19 (−1.25, 0.85)
SB	0.21 (−0.79, 1.18)	0.07 (−0.93, 1.05)	0.09 (−0.77, 0.93)	0.18 (−0.65, 1.01)	0.34 (−0.72, 1.35)	−0.35 (−1.26, 0.52)	−1.18 (−2.76, 0.36)	0.18 (−0.94, 1.3)	−0.09 (−1.02, 0.8)	0.59 (−0.49, 1.68)	−0.4 (−1.53, 0.75)	0.21 (−0.57, 0.99)	SB	0.02 (−1.28, 1.35)
TYR	0.18 (−1, 1.41)	0.04 (−1.16, 1.26)	0.05 (−1, 1.15)	0.15 (−0.92, 1.22)	0.31 (−0.91, 1.53)	−0.37 (−1.49, 0.77)	−1.2 (−2.97, 0.56)	0.14 (−1.15, 1.51)	−0.11 (−1.24, 1.02)	0.56 (−0.74, 1.86)	−0.42 (−1.72, 0.94)	0.19 (−0.85, 1.25)	−0.02 (−1.35, 1.28)	TYR

Effects are expressed as the effect size (95% CrI) between interventions. When the 95% CrI does not include 0, $p < 0.05$; when the 95% CrI includes 0, $p > 0.05$. Bold indicates a statistically significant difference in the comparison ($p < 0.05$). A positive and bolded effect size indicates that the supplement on the longitudinal is more effective than the supplement on the horizontal; a negative and bolded effect size indicates that the supplement on the horizontal is more effective than the supplement on the longitudinal.

4. Discussion

4.1. Summary of the main results

This systematic review and network meta-analysis aimed at evaluating the effects of different dietary supplements on athletic performance in soccer players. In this study, 80 RCTs were included, with 1,425 soccer players randomly receiving 31 different dietary supplements. Twenty-one studies evaluated caffeine, making it the most studied supplement. Creatine and carbohydrate were each evaluated in 12 studies, followed by beetroot extract and carbohydrate + electrolyte, each assessed in 4 studies. Three studies each evaluated melatonin, protein, and vitamin D. Two studies each assessed carbohydrate + caffeine, arginine, beta-alanine, and vitamin C + vitamin E. The remaining supplements were each evaluated in a single study, including magnesium creatine chelate, sodium pyruvate, *Kaempferia parviflora*, yohimbine, branched-chain amino acids, alfa-hydroxy-isocaproic acid, creatine + caffeine, creatine + sodium bicarbonate, omega-3 fatty acids, blackcurrant extract, glutamine peptide, sodium bicarbonate, tyrosine, bovine colostrum, citrulline, beetroot extract + caffeine, Montmorency cherry, carbohydrate + protein, and tart cherry juice. The number of participants in individualized studies ranged from 6 to 60.

Based on the 80 studies, the network meta-analysis evaluated the effects of interventions compared with a control/placebo group and pairwisely compared interventions. The results showed that compared with placebo, carbohydrate + protein, carbohydrate + electrolyte, bovine colostrum and caffeine were associated with a significant effect on increasing the distance covered. *Kaempferia parviflora* was associated with a significant effect on enhancing muscular strength. Beta-alanine, melatonin, caffeine, and creatine were associated with a significant effect on increasing jump height. Magnesium creatine chelate, melatonin, creatine + sodium bicarbonate, and arginine were associated with a significant effect on reducing sprint time. Creatine + sodium bicarbonate and caffeine were associated with a significant effect on improving agility. Sodium pyruvate was associated with a significant effect on increasing peak power. Magnesium creatine chelate and sodium pyruvate were associated with a significant effect on increasing mean power. Carbohydrate + electrolyte was associated with a significant effect on improving the rating of perceived exertion. Although certain dietary supplements, such as beetroot extract (which may enhance blood oxygen delivery), branched-chain amino acids (which could aid in recovery by reducing muscle protein breakdown), and sodium bicarbonate (which may help delay fatigue by buffering lactate accumulation), have shown potential for improving performance, these supplements did not demonstrate statistically significant improvements in soccer players' performance. The lack of significant improvement may be influenced by individual variability and the type of exercise tasks performed. Moreover, the limited number of studies on these supplements highlights the need for further research to validate their potential effects.

4.2. Dietary supplements that significantly improve athletic performance

4.2.1. Caffeine

From a physiological mechanism perspective, caffeine (1,3,7-trimethylxanthine) is an adenosine receptor antagonist that delays fatigue, improves athlete alertness and reaction speed, increases fat oxidation, and improves exercise performance through central nervous system mechanisms [13,111–114]. In this study, we found that caffeine supplementation alone had a significant effect on improving the distance covered, jump height, and agility of soccer players compared to placebo. This finding is similar to some previous review studies, especially the confirmed effect of caffeine on improving jump height [1,12] and distance covered [1] of soccer players. Caffeine significantly improves distance covered, which may be attributed to its ability to promote fat oxidation by increasing the mobilization of free fatty acids and enhancing their utilization as an energy source. This shift in substrate utilization helps to spare glycogen stores, delaying the onset of glycogen depletion and associated fatigue during exercise [13]. For the improvement of jump height and agility, caffeine may achieve it by enhancing neuromuscular coordination and explosive power [13,111,114]. In addition, these system review results also showed that caffeine had a significant improvement effect on the sprint performance of soccer players [1,12]. However, our network meta-analysis did not show this significant effect. There may be many reasons for this difference. For example, the study conducted by Abreu and colleagues focused on elite soccer players, and the intake of caffeine was concentrated between 3 mg/kg and 6 mg/kg [12]. A more diverse population was included in this study, including elite and non-elite soccer players, and a wider range of caffeine doses (1 mg/kg to 6 mg/kg) was covered. A lower dose (e.g. 1 mg/kg) of caffeine may not be sufficient to significantly improve the sprint performance of soccer players. In addition, the training and competitive state of participants may also be another important factor. Non-elite athletes have lower competitive levels [115] and may have weaker reactiveness to caffeine. Therefore, this population difference may affect the results of sprint performance. In addition, different measurement methods may result in differences results. Mielgo-Ayuso and colleagues adopted a repeat sprint test, reflecting the athlete's sustained performance in multiple high-intensity sprints [1], while our study focused more on the transient maximum velocity using a single sprint test. These differences indicated that caffeine supplementation had a broad positive effect on improving athletic performance, but the effect might not be consistent. Another previous review found that caffeine had no significant effect on improving the athletic performance of soccer players [22]. Specifically, caffeine did not improve the distance covered, jump height, sprint performance, agility, and rating of perceived exertion [22]. In these studies, participants' habitual caffeine intake ranged from 0 to 350 mg/day, mainly from common sources such as coffee, tea, and chocolate [22]. This habitual intake may have an impact on the effectiveness of caffeine supplementation in the experiment. However, other studies suggest that habitual caffeine consumers may still benefit from acute supplementation, particularly at higher doses, as tolerance does not completely negate its ergogenic effects [116]. In contrast, our study did not explicitly record the habitual caffeine intake of participants. Therefore, the potential impact of this variable cannot be ruled out, and future research should consider controlling for or reporting participants' habitual caffeine consumption to better elucidate its role in caffeine's performance-enhancing effects.

4.2.2. Creatine, creatine combined with sodium bicarbonate, and magnesium creatine chelate

Creatine (α-methyl guanidino-acetic acid) is a non-protein amino acid compound found naturally in muscles, mainly stored in the form of phosphocreatine (PCr), which can quickly provide energy for high-intensity short-term exercise [15]. Creatine supplementation can increase the reserve of phosphocreatine in muscles, thereby improving the regeneration rate of adenosine triphosphate (ATP) [15,117–119]. This physiological mechanism explains the results of our meta-analysis, which showed that supplementing creatine can significantly improve the jump height of soccer players, and magnesium creatine chelate can significantly reduce the sprint time and improve mean power. In addition, additional intake of sodium bicarbonate can alleviate the accumulation of H^+ caused by exercise (i.e. muscle acidosis or decreased muscle pH value) [14]. Therefore, our meta-analysis findings showed that the combined supplementation of creatine and sodium bicarbonate has a significant impact on reducing the sprint time and improving the agility of soccer players. These findings are consistent with review results obtained by Abreu and colleagues [12]. These findings further support the effectiveness of different forms of creatine supplementation in improving athletic performance, especially when combined with other supplements. In addition, there are some differences between the results of previous reviews and our findings. Specifically, previous review studies have shown that supplementing with creatine alone significantly improves the sprint performance [2,12], agility [2], and anaerobic test power (peak power and mean power) [2,23] of soccer players. However, our study did not show a significant effect of supplementing with creatine on these performances. There may be many reasons for this difference. For example, the study conducted by Aguinaga-Ontoso and colleagues focused on supplementing creatine in professional or semiprofessional soccer players (doses ranging from 20 g/day-0.03 g/kg/day; lasting for 6–14 days) [2]. Although similar doses and cycles of creatine supplementation were given in our study (0.03 g/kg/day-0.25 g/kg/day or 5 g/day-20 g/day; lasting for 4–15 days), no significant effects of creatine supplementation on sprint, agility, and anaerobic power were found. This difference may be due to varying levels of training among the participants. A more diverse population was included in this study, including soccer players at different levels. Professional, semiprofessional, and elite athletes have higher training levels [115] and may be more sensitive to creatine supplementation, thus exhibiting significant effects during short-term supplementation. The review by Abreu and colleagues also found similar results, namely that creatine supplementation (doses ranging from 5 g/day-20 g/day, lasting for 6 days to 6 weeks) had a significant impact on improving the sprint performance of elite soccer players [12]. In addition, different creatine supply cycles may result in differences results. Mielgo-Ayuso and colleagues assessed the effects of continuous supplementation of creatine for 9 weeks on the athletic performance of soccer players at different levels [23]. The results showed that creatine had a significant impact on improving anaerobic power [23]. In contrast, our study applied a shorter supplementation cycle (4–15 days), which may not be sufficient to produce similar effects in improving anaerobic power as in the study by Mielgo-Ayuso and colleagues. The differences in these factors might affect the overall effect and significance of creatine supplementation on exercise performance.

4.2.3. Carbohydrate-containing electrolyte solutions and carbohydrate combined with protein

The intake of carbohydrates before and during exercise is an effective strategy for providing exogenous fuel supply to muscles and the central nervous system, while electrolyte solutions help maintain fluid and electrolyte balance, thereby reducing fatigue caused by dehydration [9,120]. Electrolyte solutions containing carbohydrates can provide an immediate source of energy and maintain fluid balance [9]. Therefore, our study found that supplementing electrolyte solutions containing 6.4%-7% carbohydrates immediately before exercise or after every 15 minutes of exercise had a significant effect on improving distance covered and rating of perceived exertion in soccer players. However, Abreu and colleagues found that supplementing electrolyte drinks containing 6% carbohydrates alone was not enough to benefit the athletic performance of adult elite soccer players [12]. This discrepancy may be attributed to the fact that elite soccer players typically have higher levels of adaptation to endurance exercise. In contrast, our study included soccer players with different competitive levels (elite and non-elite), which may account for the variability in the observed effects of carbohydrate-electrolyte supplementation. Non-elite soccer players may benefit more from carbohydrate-electrolyte supplementation due to a lower baseline level of metabolic adaptation, making them more responsive to the energy support provided by the supplement. Therefore, the differences in competitive levels may affect the overall effect of supplementing carbohydrate containing electrolyte solutions on athletic performance. In addition, the increase in protein intake (from food or dietary supplements) may improve neuromuscular performance as it can enhance the anti-fatigue effect of skeletal muscles or reduce the decline in skeletal muscle performance after damaging exercise [16,121]. Therefore, our study found that adding carbohydrates (0.7 g/kg) and proteins (0.3 g/kg) simultaneously to 515 ± 33 mL of liquid, when administered 15 minutes prior to the exercise protocol and during the simulated half-time interval, can accelerate recovery and improve anti-fatigue ability. This supplementation was shown to significantly affect the distance covered during the subsequent exercise, specifically in terms of run time to fatigue, which is the distance covered before exhaustion during a simulated game or exercise protocol. These findings suggest that carbohydrate and protein supplementation may improve performance during both the exercise period and recovery phases.

4.2.4. Melatonin

Melatonin, as a potent antioxidant, can reduce oxidative stress and free radicals generated during exercise, protect muscle cells, and promote the recovery and strengthening of muscle function [24,122–126]. Enhancing mitochondrial function is also one of the important mechanisms by which melatonin acts [127]. Melatonin improves ATP production during high-intensity exercise by reducing oxidative damage to mitochondria, improving mitochondrial function and energy generation efficiency [127]. In addition, the anti-inflammatory effects of melatonin help reduce inflammation caused by exercise, promote muscle recovery, and reduce delayed-onset muscle soreness (DOMS), thereby increasing the training frequency and intensity of athletes [124,125]. The physiological effects associated with melatonin supplementation may promote the improvement of athletic performance, such as increased glucose levels in muscles, weight loss, decreased oxidative stress in muscles, maintenance of muscle strength, enhanced anti-inflammatory effects, and improved adaptability to physical activity [122]. Overall, Through various physiological mechanisms such as antioxidant effects, enhanced mitochondrial function, and anti-inflammatory properties, continuous supplementation of melatonin (5 mg/day) for 6 days may indirectly have a significant impact on improving the jump height and reducing the sprint time of soccer players.In addition, the differences in competitive levels may affect the effectiveness of supplementing melatonin. A previous review found that supplementing melatonin seemed to alleviate oxidative stress, inflammation, and muscle injury in professional soccer players during exercise, but did not have a direct impact on physical performance [24].

4.2.5. Arginine

The meta-analysis found that supplementing arginine (0.15 g/kg) one hour before exercise had a significant effect on reducing sprint time for soccer players compared to placebo. Arginine, as a precursor of nitric oxide, increases the production of nitric oxide in muscles during training. Nitric oxide can cause vasodilation in the body, thereby increasing blood flow and oxygen delivery, which is particularly important in high-intensity short-term exercise [128,129]. The increase in blood flow can improve protein synthesis and promote rapid muscle recovery [130]. In addition, nitric oxide plays a crucial role in regulating blood flow and blood pressure, and relaxing skeletal muscles during training [131,132]. In addition, arginine may also have a positive impact on improving the sprint performance of soccer players by improving the metabolic environment of muscle cells, increasing the rate of ATP synthesis, and reducing fatigue [133].

4.2.6. Beta-alanine

From a physiological mechanism perspective, beta-alanine is the rate limiting precursor of carnosine (β-alanyl-L-histidine) [134,135]. Increasing the concentration of carnosine in muscles can improve athletic performance in activities with high levels of muscle acidosis [136]. Beta-alanine supplements can increase the carnosine content in muscles, thereby enhancing muscle buffering capacity, alleviating muscle fatigue, and enhancing athletic performance during high-intensity short-term exercise [136–140]. Therefore, the meta-analysis found that supplementing with beta-alanine (4.8 g/day) for 6 weeks had a significant effect on improving the jump height of soccer players compared to placebo. This effect was attributed to the chronic supplementation, which led to increased muscle carnosine levels over time.

4.2.7. Sodium pyruvate

The meta-analysis showed that supplementing with sodium pyruvate (0.1 g/kg/day) for 7 days had a significant effect on improving the anaerobic test power (peak power and mean power) in soccer players. Pyruvate is an important product of glucose metabolism and a key substrate for mitochondrial oxidative metabolism [141]. Supplementing exogenous sodium pyruvate can activate pyruvate dehydrogenase, thereby increasing the flux of mitochondrial tricarboxylic acid cycle [141–143]. This enhanced aerobic metabolism ability can help improve the efficiency of ATP generation, providing more energy support for high-intensity exercise. In addition, sodium pyruvate can effectively alleviate lactate accumulation, reduce muscle acidification, maintain intracellular acid-base balance, and correct metabolic acidosis [141]. This improvement in acid-base balance helps alleviate fatigue during exercise and provides support for longer periods of high-intensity performance. Additionally, sodium pyruvate promotes the regeneration of PCr, enhances the function of ATP-PCr system, and improves the energy supply for anaerobic exercise in a short period of time [36]. The combined effect of these physiological mechanisms not only enhanced the energy supply of muscles during high-intensity exercise, but also improved the overall performance of athletes. By enhancing ATP generation, optimizing acid-base balance, improving mitochondrial function, and supporting PCr regeneration, sodium pyruvate may have a significant impact on improving the peak power and mean power of soccer players in anaerobic testing [36,141–143].

4.2.8. Kaempferia parviflora

Our meta-analysis findings showed that supplementing *Kaempferia parviflora* extract (180 mg/day) for 12 weeks had a significant effect on enhancing muscular strength in soccer players. *Kaempferia parviflora* is a plant in the ginger family, and its rhizome extract contains various flavonoids [144]. The antioxidant activity of flavonoids in *Kaempferia parviflora* can reduce oxidative stress caused by exercise [145], thereby protecting muscle cells, and promoting muscle recovery and functional enhancement. In addition, *Kaempferia parviflora* can increase the expression of nitrite and endothelial nitric oxide synthase (eNOS) mRNA and protein, promoting the production of nitric oxide [146] and improving vasodilation [147], thus improving vascular endothelial function. Better blood flow and oxygen delivery are crucial for athletes' performance, especially during high-intensity exercise. *Kaempferia parviflora* improves vascular endothelial function and promotes vasodilation through various physiological mechanisms such as antioxidant effects, effectively enhancing the muscular strength of soccer players.

4.2.9. Bovine colostrum

Bovine colostrum, as a supplement rich in immune factors, active antimicrobial peptides, and nutrients, may enhance exercise performance and help restore physical strength through its physiological mechanisms [148,149]. On the one hand, bovine colostrum supplementation can improve muscle buffering capacity and enhance immune function, and is beneficial for running performance [149,150]. On the other hand, nutrients such as protein, carbohydrates, vitamins, and minerals in bovine colostrum can provide energy support and promote recovery [148]. In our included study, the placebo was powdered milk (lactose, 1.6 g; protein, 1.08 g; fat, 0.04 g; and ash, 0.25) administered in the same dosage (3.2 g/day) over 24 weeks, ensuring a well-matched comparison. In summary, these mechanisms can explain our research findings that supplementing with 24 weeks of bovine colostrum (3.2 g/day) has a significant effect on improving the distance coverage of soccer players.

4.3. Subgroup analysis

The subgroup analysis showed that the effect of dietary supplements on the athletic performance of soccer players was influenced by their competitive level. Some authors also believed that elite athletes may have different reactions to dietary supplements compared to non-elite athletes [151,152]. Elite athletes who have been in a high-intensity training state for a long time usually show highly optimized energy metabolism and neuromuscular coordination abilities, which can more effectively utilize energy supply; Non-elite athletes often perform relatively poorly in terms of strength, endurance, and neural control due to their weaker physical foundation [115]. Therefore, the effects of dietary supplements on athletes of different competitive levels may vary.

Caffeine, as a neurostimulant, can promote neuromuscular transmission and improve the attention of elite soccer players, helping them achieve better performance in high-intensity burst movements [13,111,114]. This indicates that caffeine helps improve the agility and jump height of elite soccer players. In addition, the significant impact of caffeine on the distance covered is attributed to its ability to promote fat oxidation, reduce glycogen consumption, and thus alleviate fatigue during exercise [13]. Melatonin, through its antioxidant properties, reduces oxidative stress caused by high-intensity exercise, indirectly promoting the improvement of jump height and sprint performance of elite soccer players [124,125]. Given that supplementing with creatine can provide rapid energy for high-intensity, short-term exercise [15], it is explained that magnesium creatine chelate has shown a significant effect in reducing sprint time. In addition, additional intake of sodium bicarbonate can alleviate muscle acidosis caused by exercise [14]. Therefore, the combined supplementation of creatine and sodium bicarbonate has a significant impact on reducing the sprint time and improving the agility of elite soccer players. Supplementing arginine has a positive impact on improving the sprint performance of elite soccer players, thanks to its ability to improve the metabolic environment of muscle cells and increase the rate of ATP synthesis [133]. Sodium pyruvate can effectively maintain intracellular acid-base balance, and improving this balance can help alleviate fatigue during exercise, thereby supporting longer periods of high-intensity performance [141]. Therefore, sodium pyruvate has a positive impact on enhancing the mean power of elite soccer players. Electrolyte solutions containing carbohydrates have a positive impact on improving rating of perceived exertion in elite soccer players by providing an immediate source of energy and maintaining fluid balance [9].

For non-elite soccer athletes, caffeine also has positive effects. The effect of caffeine on improving mean power and jump performance of non-elite soccer players depends on its role in promoting neuromuscular transmission and improving attention [13,111,114]. This indicates that regardless of the competitive level, caffeine has a good effect on enhancing the athlete's explosive power in a short period of time. In addition, due to the weaker physical foundation and lack of sufficient nutritional support of non-elite soccer players, carbohydrate combined with protein supplementation has a positive impact on improving their rating of perceived exertion and distance covered by enhancing energy reserves and accelerating recovery ability [16,121]. Beta-alanine can effectively alleviate muscle fatigue by increasing the content of carnosine in muscles, and provide energy enhancing benefits for athletic performance during short-term high-intensity exercise [138–140]. Therefore, beta-alanine has a positive impact on improving the jump performance of non-elite soccer players. *Kaempferia parviflora* extract further helps non-elite soccer players with lower physical foundation improve muscular strength by reducing oxidative stress and promoting vasodilation [147].

However, the effectiveness of some dietary supplements in soccer players of different competitive levels has not been fully evaluated. For example, there is insufficient research on the effectiveness of supplements such as carbohydrate + protein, *Kaempferia parviflora*, and beta-alanine in elite soccer athletes. Similarly, the effects of supplements such as melatonin, magnesium creatine chelate, creatine + sodium bicarbonate, arginine, and sodium pyruvate in non-elite soccer athletes have also not been sufficiently studied. This limits our comprehensive evaluation of the widespread use of these supplements based on different competitive levels. Future research should further explore the potential of these supplements in different competitive levels and athletic performance, in order to develop more scientific and personalized nutritional supplementation strategies.

4.4. Practical implications

The results of this systematic review and network meta-analysis emphasized the importance of customized dietary supplement strategies to improve the performance of soccer players in a targeted manner. Coaches and sports nutritionists should consider the different effects of different dietary supplements on specific athletic performance and adjust their supplementation schemes to meet the needs and competitive levels of each athlete. Based on the research findings, coaches and sports nutritionists can develop personalized nutrition supplementation strategies to optimize the application of supplements for soccer players of different competitive levels, thus improving their athletic performance. Moreover, it is crucial to adjust the dosage and timing of supplements scientifically, considering individual physical conditions and the competition requirements of athletes. This is essential to guarantee the safety and efficacy of supplements, thereby optimizing training and competition outcomes.

4.5. Advantages and limitations of the study

To our knowledge, this is the largest and most comprehensive review of available efficacy data on supplemental dietary supplements for soccer players. However, this study has several limitations. First, the dosage, timing and duration of dietary supplements were not standardized across studies. This may affect the interpretation of the results from some studies included in this review. Second, although we performed subgroup analysis according to the competitive level, there were still differences in gender, age distribution and soccer field position in the studies analyzed. Moreover, the limited number of articles prevented us from understanding whether the effects of different dietary supplements on athletic performance of soccer players depended on the gender, the age of the player or the soccer field position. Thirdly, some research results are limited by the relatively small sample size of studies on selected dietary supplements(e.g. melatonin, arginine, beta-alanine, *Kaempferia parviflora*, bovine colostrum, and sodium pyruvate, supported by limited evidence from a single study). Therefore, in such cases, although indirect comparisons can be established through network analysis, the results may be influenced by the design and characteristics of a single study. This may affect the statistical analysis and reliability of the research results, requiring cautious interpretation. In addition, the efficacy may increase over time, but the duration of supplementation is too short, which may not fully capture long-term benefits or adaptability and limit our interpretation of the results.

5. Conclusion

Our systematic review and network meta-analysis evaluated the effects of different dietary supplements on the athletic performance of soccer players and identified dietary supplements that had a positive impact on specific athletic performance. Given the different physiological mechanisms of dietary supplements, their effects on specific athletic performance may vary. Therefore, in order to improve the specific athletic performance of soccer players, more targeted dietary supplements should be given. Specifically, in order to improve aerobic endurance, carbohydrate + protein, carbohydrate + electrolyte, bovine colostrum and caffeine should be prioritized. *Kaempferia parviflora* is the most effective in enhancing muscular strength. To enhance vertical jump ability, it is recommended to use beta-alanine, melatonin, caffeine, and creatine. To improve sprint performance, priority should be given to magnesium creatine chelate, melatonin, creatine + sodium bicarbonate, and arginine. To improve agility, creatine + sodium bicarbonate and caffeine should be prioritized. Magnesium creatine chelate and sodium pyruvate are effective in increasing anaerobic power. Carbohydrate + electrolyte is beneficial for improving psychological state and reducing physiological load. In addition, the results of this study suggested that the efficacy of dietary supplements may be influenced by the competitive level of soccer players. Therefore, it is recommended to supplement different dietary supplements according to the athletes' competitive level. For elite soccer players, priority should be given to caffeine, melatonin, magnesium creatine chelate, creatine + sodium bicarbonate, arginine, sodium pyruvate, and carbohydrate + electrolyte to enhance athletic performance. For non-elite soccer players, priority should be given to caffeine, *Kaempferia parviflora*, beta-alanine, and carbohydrate + protein to improve athletic performance.

The results of this network meta-analysis may help enhance people's confidence in using dietary supplements such as caffeine and creatine. However, future research still needs to further validate fields with less clear evidence, such as the inconsistent findings regarding the effects of caffeine on sprint performance and creatine on athletic performance during high-intensity exercise. In addition, given the limited research on supplements such as melatonin, arginine, beta-alanine, *Kaempferia parviflora*, bovine colostrum, and sodium pyruvate, more studies are needed in the future to validate their efficacy for soccer players. Future research needs to further explore the potential impact of supplementation regimens (such as dosage, timing, and duration) on the efficacy of dietary supplements. More research on female soccer players is needed in the future to better understand the efficacy of dietary supplements for soccer players of different genders. Finally, future studies can standardize outcome measures and use more consistent methods to evaluate performance variables. This will help to compare the results from different studies and contribute to a clearer understanding of the overall efficacy of nutritional interventions for soccer players.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The author(s) reported there is no funding associated with the work featured in this article.

Author contributions

Study design and data collection were performed by HL and XZ; literature screening was carried out by HL and XZ, with disagreements resolved by CX; data extraction was completed by HL and XZ, with verification by CX; data analysis was conducted by HL, NAN, and TFTK; results interpretation was done by HL, NAN, and TFTK; quality assessment was performed by HL and XZ; and manuscript writing was carried out by HL.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

Abbreviations

ARG	Arginine
ATP	Adenosine triphosphate
BA	Beta-alanine
BC	Bovine colostrum
BCAA	Branched-chain amino acids
BCE	Blackcurrant extract
BRT	Beetroot extract
BRT_CAF	Beetroot extract + caffeine
CAF	Caffeine

CHO	Carbohydrate
CHO_CAF	Carbohydrate + caffeine
CHO_E	Carbohydrate + electrolyte
CHO_PROT	Carbohydrate + protein
CIT	Citrulline
CR	Creatine
CR_CAF	Creatine + caffeine
CR_SB	Creatine + sodium bicarbonate
CrI	credible interval
GLN	Glutamine peptide
HICA	Alfa-hydroxy-isocaproic acid
KP	*Kaempferia parviflora*
MC	Montmorency cherry
MGCC	Magnesium creatine chelate
MLT	Melatonin
O3FA	Omega-3 fatty acids
PCr	Phosphocreatine
PRISMA NMA	Preferred reporting items for systematic reviews and network meta-analyses
PROSPERO	International prospective register of systematic reviews
PROT	Protein
PYR	Sodium pyruvate
RCTs	Randomized controlled trials
SB	Sodium bicarbonate
SMD	Standardized mean difference
SUCRA	Surface under the cumulative ranking curve
TCJ	Tart cherry juice
TYR	Tyrosine
VITC_VITE	Vitamin C + Vitamin E
VITD	Vitamin D
YOH	Yohimbine

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