Article

Do nutrition interventions influence the performance of professional soccer players? A systematic review.

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Simple Summary: Soccer is a widely popular sport with over 270 million participants globally, including over 128,000 professional players. Maintaining and improving performance is crucial for these athletes, and nutrition plays a significant role. However, there is limited information on the best nutritional strategies for professional soccer players. This systematic review aimed to determine which dietary interventions are most effective in enhancing their performance and recovery. Researchers searched various databases and clinical trial records, ultimately reviewing 16 studies involving 310 participants. The studies focused on professional or semi-professional soccer players. The findings showed that several interventions positively affected soccer performance aspects like endurance, speed, agility, strength, power, explosiveness, and anaerobic capacity. These interventions included high carbohydrate diets, bicarbonate, mineral solutions, and supplements such as creatine, betaine, and tart cherry. However, none of the nutritional interventions during the recovery period effectively improved recovery. In conclusion, professional soccer players can increase their performance by using specific nutritional strategies like high carbohydrate diets, bicarbonate, mineral solutions, and supplements like creatine, betaine, and tart cherry. With these dietary interventions, professional soccer players can optimize their performance and gain a competitive edge, improving their chances of success in the highly competitive world. Despite these positive findings, researchers must identify effective nutritional interventions for enhancing recovery in professional soccer players.

Abstract: Background: More than 270 million participants and 128,893 professional players play soccer. Research only weakly supports the impact of diets and supplements on the performance and recovery of professional soccer players. Methods: We conducted a comprehensive search in PubMed, Scopus, Web of Science, and clinical trial registers. Inclusion criteria focused on professional or semi-professional soccer players, nutrition or diet interventions, performance improvement outcomes, and randomized clinical trial study types. We assessed quality using the Risk of Bias 2 (RoB 2) tool. We identified 16 eligible articles involving 310 participants. No nutritional interventions during the recovery period effectively improved recovery. However, several performance-based interventions showed positive effects, such as tart cherry supplementation, raw pistachio nut kernels, bicarbonate and mineral ingestion, creatine supplementation, betaine consumption, symbiotic supplements, and a high carbohydrate diet. These interventions influenced various aspects of soccer performance, including endurance, speed, agility, strength, power, explosiveness, and anaerobic capacity. Conclusions: Specific strategies, such as solutions with bicarbonate and minerals, high carbohydrate diets, and supplements like creatine, betaine, and tart cherry, can enhance the performance of professional soccer players. These targeted nutritional interventions may help optimize performance and provide the competitive edge required in professional soccer. We did not find any dietary interventions that could enhance recovery during recovery.

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Keywords: soccer performance, supplements, diet, systematic review, high carbohydrate diet, creatine supplementation, tart cherry, betaine, bicarbonate and minerals, professional players.

1. Introduction

Soccer is a highly popular sport played by more than 270 million participants worldwide [1,2], including an estimated 128,893 professional players [3]. Soccer is an intermittent sport with unique physical demands. It combines high-intensity critical events like sprints and anaerobic activities with lower-intensity aerobic exercises and rest. It features rapid direction changes and extended periods of exertion[4]. Soccer players typically cover 10–14 km per match [5–10]. Of this distance, more than 8% is high-intensity running (more than 19.8 km/hour)[11]. In comparison, the remaining 92% is low or moderate intensity (0-19.8 km/hour)[12]. Researchers have extensively studied the physical match demands of professional soccer players. However, researchers have not extensively studied the physical demands of training and have generally limited their focus to short periods, usually a week. [13].

Soccer demands high levels of physical fitness, strength, endurance, and agility, making it essential for players to optimize their performance through various strategies [14–16]. One such strategy is effective nutritional interventions, which can significantly impact a soccer player's ability to maintain and improve performance. However, there is limited evidence available regarding the effects of nutrition on the performance of professional soccer players. One of the problems of athletes is Delayed Onset Muscle Soreness (DOMS), a type of muscle pain and stiffness typically occurring 24-72 hours after engaging in an unfamiliar or intense physical activity [17]. DOMS is often associated with eccentric muscle contractions, which involve the lengthening of a muscle as it contracts, such as downhill running or lowering weights during strength training. The exact cause of DOMS is not fully understood, but it is believed to result from microscopic damage to muscle fibers and connective tissue [18,19]. This damage leads to an inflammatory response, including releasing substances like cytokines and prostaglandins. These substances contribute to pain, swelling, and reduced muscle function, manifesting as the symptoms of DOMS. Increased intramuscular pressure and impaired blood flow may also exacerbate soreness and discomfort[20,21].

In recent years, an increasing interest has been in understanding the relationship between nutrition and athletic performance. Various nutrition interventions, such as carbohydrate ingestion [22], dietary supplementation, and specific diet regimens, have been suggested to improve athletic performance, including endurance, strength, and recovery. In 2108, the International Olympic Committee (IOC) issued a consensus statement identifying several ergogenic aids with sufficient scientific backing, deemed safe and effective for enhancing athletes' performance. These aids include caffeine, creatine, nitrate, sodium bicarbonate, and beta-alanine [23]. Other sports organizations have also issued guidelines [24–26]. However, the extent to which these interventions can impact the performance of professional soccer players remains unclear. Therefore, it is crucial to determine which nutritional interventions are most effective for enhancing performance in this specific population.

There is limited evidence base information on the effects of nutrition on professional soccer players' performance. This systematic review aims to synthesize a comprehensive understanding of the potential benefits of nutrition interventions for professional soccer players by exploring their influence on performance. Examining the available literature aims to inform future research and practical applications within the sport, ultimately enhancing various nutrition strategies for soccer professionals.

2. Materials and Methods

2.1. Outcome

The expected outcome of this study is to review and analyze the influence of nutrition interventions on the performance of professional soccer players.

2.2. Design

We carried out this systematic review using the PRISMA recommendations and the guidelines of the Cochrane Handbook of Systematic Reviews **[27] [28]**.

2.3. Search strategy

A systematic search was conducted in PubMed, Scopus, and Web of Science (WOS), covering all studies published before February 25, 2023.

We searched clinical trial registers, including ClinicalTrials.gov, the WHO International Clinical Trials Registry Platform, and the European Clinical Trials Database. We also searched the web of clinical trials to identify relevant publications. We initially created search queries (Figure 1) to link generic keywords associated with clinical trial interventions on nutrition or diet for professional or semi-professional soccer players. We applied no filters based on the players' gender or age. When available, we included the publication of a clinical trial's results in the review.

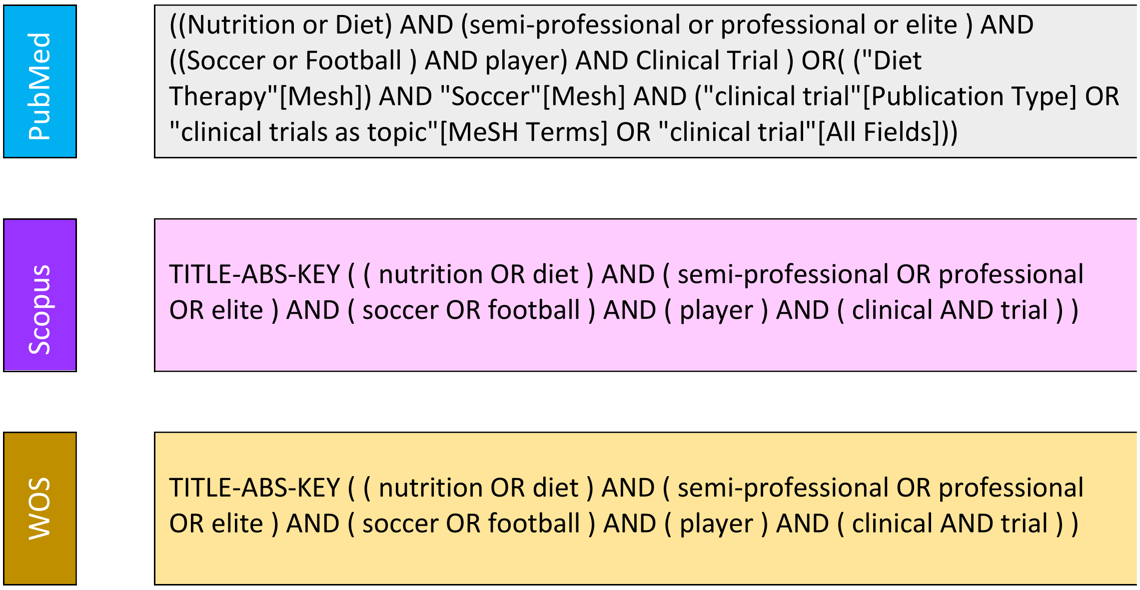

Figure 1. Descriptors employed in the systematic search on PubMed, Scopus, and WOS databases.

We searched Google Scholar for published articles of registered clinical trials not yet indexed in the databases (PubMed, Scopus, and WOS).

2.4. Inclusion criteria and exclusion criteria

The inclusion criteria of this study were formulated according to the PICOS principles as follows: (1) P: The subjects were professional or semi-professional soccer players (2) I: The experimental group needs to use a nutrition or diet Intervention. C: The control group required a different intervention (e.g., another supplement). (4) O: The outcomes were improvement in the players' performance (without specific outcome measures specified). (5) S: The study type was Randomized Clinical trials.

We applied the following exclusion criteria: (1) repeated publication; (2) inability to obtain the full text; (3) incomplete or unavailable data; and (4) studies not published in

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Spanish or English. We excluded clinical trials recruiting participants or had not published results in clinical trial registries or scientific publications. If available, we selected the most up-to-date information from the clinical trials registry and scientific publications.

2.5. Data extraction

We removed duplicate studies using EndNote (version 20; Clarivate Analytics).[29]. The study selection process counted with assistance from the Rayyan website and a mobile application[30]. Two reviewers (SGA and FGG) independently screened the titles, abstracts, and keywords. If a study was considered a candidate, the full text was independently assessed and evaluated based on inclusion and exclusion criteria. The third reviewer (LGA) resolved disagreements through consultation with the first two. The authors accessed the full text whenever a study met the inclusion criteria. After searching and evaluating complete articles, four authors (SGA, FGG, LGA, and IAO) independently reviewed the text of all selected studies to determine their inclusion. The authors resolved any differences in their selections through discussion. The writers consulted a fifth author(RAB) if they could not agree.

The information extracted from the included articles contained: the author (year), country, participants, the sample size in the experimental and control group(E/C), intervention (E/C), length of intervention days, and outcomes.

2.6. Quality assessment

We used the Risk of Bias 2 (RoB 2) tool, recommended by the Cochrane Systematic Review Manual (5.1.0) (5.1.0)[31] [28], to assess the risk of bias in the included literature. This tool was employed to evaluate the quality of the literature strictly. In crossover designs, we used the Risk of Bias tools - RoB 2 for crossover trials[32]. Two reviewers (IAO and LGA) conducted independent assessments of the risk of bias for each included article, categorizing them as "low risk," "some concerns," or "high risk.". Another reviewer (RAB) reviewed the results and resolved any disagreements.3. Results

3.1. Study selection

A database search identified 60 records, of which 14 articles met the eligibility criteria[33–45]. Web searching of clinical trials identified two additional articles [46,47]. Thus 16 articles were included in this review [33–47]. The articles included in this study were published between 1992 and 2023. Figure 1 presents the study selection flow.

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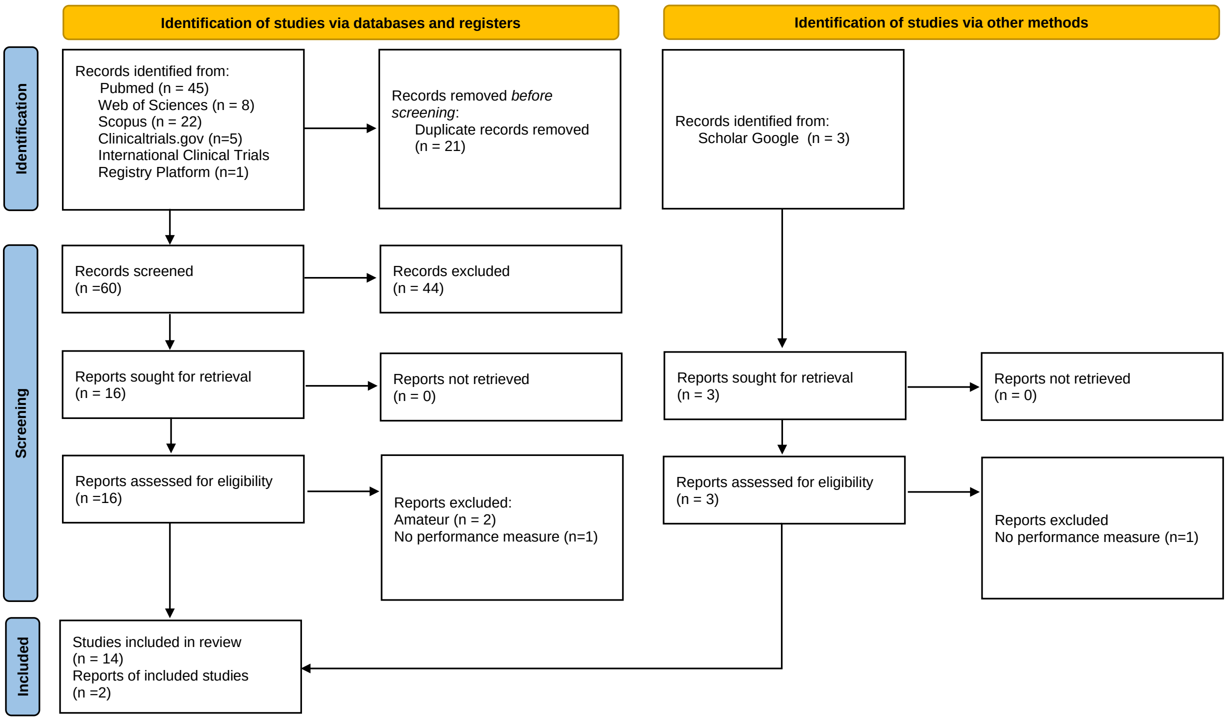

Figure 1. PRISMA 2020 flow diagram

3.2. General Characteristics of included studies.

There were 11 parallel clinical trials[17,35–37,40–43,45–47] and 5 cross-over studies[33,34,38,39,44]. The included studies had publication dates ranging from 1992 to 2023, with a median publication year of 2017.5 and a quartile deviation (QD) of 7 years. Of the sixteen studies included, the participants were female only in one study [37], while the remaining fifteen were male players. There were studies on all the continents except Africa. In 68.8% of the studies, researchers conducted their investigations in Europe. The countries with more studies were the UK (3) and Brazil (2). (Figure 1)

Figure 2. Geographic distribution of publications by country.

Some studies used several groups, like sedentary people and soccer players. We only study the soccer players group [43,47]. The Total of Participants was 310. The studies were of reduced size, with a median of 18.5 participants (QD=5).

3.3. Risk of Bias in the Studies.

The Risk of Bias was evaluated separately for Parallel Clinical Trials and Cross Over studies.

3.3.1. Parallel Clinical Trials

According to the RoB2 assessment of the risk of bias in RCTs, 30% of the studies showed a high risk of bias, 72.7% showed some concerns about the risk of bias (moderate risk of bias), and no one showed a low risk of bias. Specifically, 90.9% of the studies had a moderate to low risk of bias in the randomization process, and 100% had a low risk of bias in the deviation from the intended interventions and missing outcome data. In the measurement of the outcome dimension, 81.8% had a low to moderate risk of bias in selecting outcomes, and 18.2% had a high risk (Figure 3).

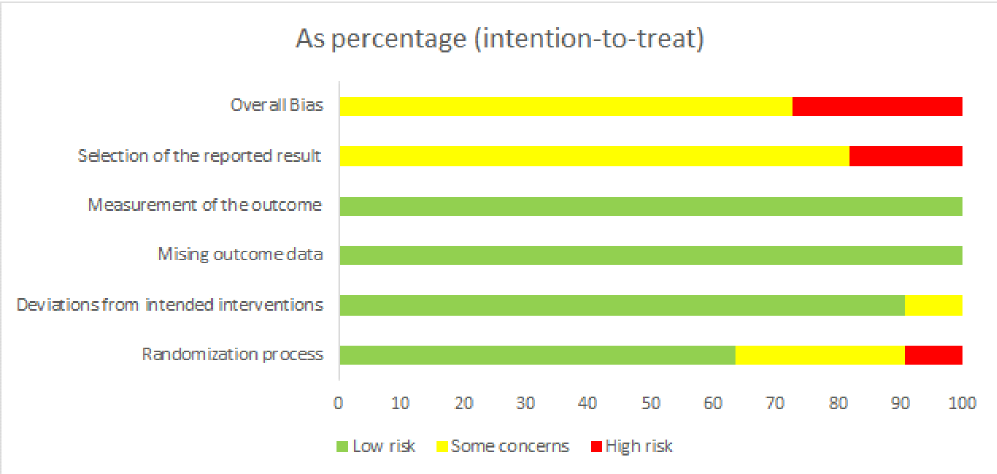

Figure 3. Risk of bias assessment in Parallel Clinical Trials (RoB2).

We present the evaluation of each study in Figure 4.

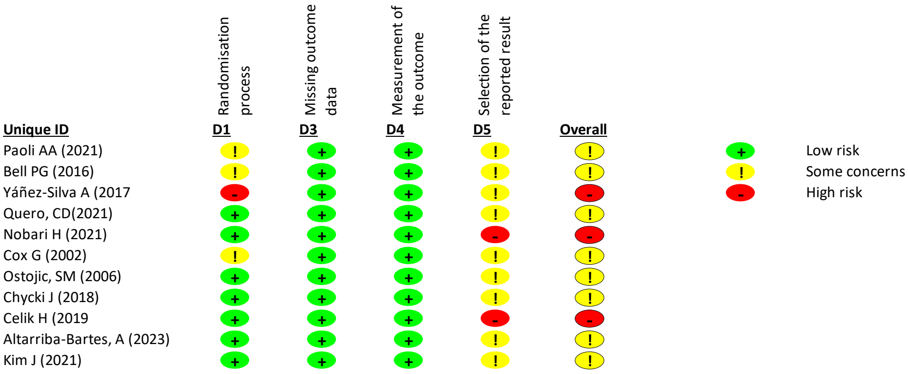

Figure 4. Risk of bias assessment for each parallel clinical trial included (RoB2).

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3.3.2. Cross Over

In the RoB2 assessment of the risk of bias in crossover studies, 100% of the studies showed some concerns about the risk of bias (moderate risk of bias). Specifically, 20% of studies had a low risk of bias in the randomization process, and 80% had a low risk of bias that arose from period and carryover effects and the deviation from the intended interventions and measurement of the outcome. There was a low risk of bias from missing outcome data in 100% of the studies. In the "selection of the reported result," dimension 100% had a moderate (Figure 4). The evaluation of each crossover study is shown below (Figure 5).

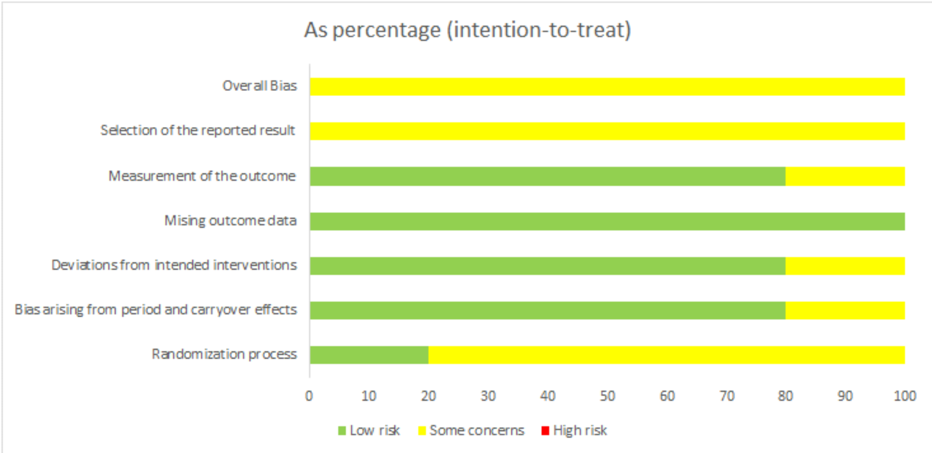

Figure 5. Risk of bias assessment in crossover studies (RoB2).

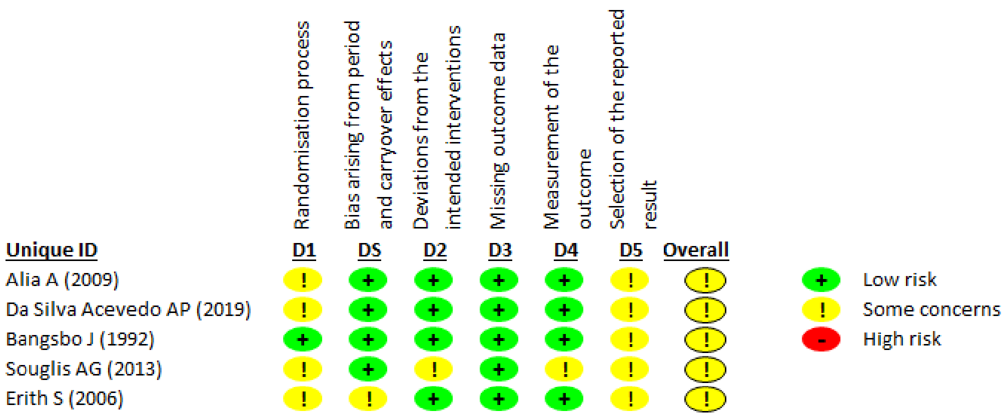

Figure 6. Risk of bias assessment for each crossover study included (RoB2).

3.4. Intervention Strategies.

Our review includes a range of studies examining various nutritional interventions, such as carbohydrate ingestion, supplementation with Creatine, Betaine, Yohimbine, and other compounds, and the implementation of specific diets, such as the ketogenic diet. Of all the interventions, the more frequent interventions, 10 (66.7%) were dietetics supplements, while only 5 (33,3%) were diet interventions. The intervention more frequent was carbohydrate ingestion (26%), followed by Creatinine supplementation (20%) and Tart Cherry supplementation (13.3%). In Table 1, we present a detailed list of studies, including author, Country, Design, Participants, Sex, Intervention, Control, Timing, and Duration of the intervention. Three studies (20%) conducted interventions during recovery following a game or training session. The remaining 12 studies (80%) were in the prior period to the

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measurement. In the post-studies, the mean of the treatment was one day (SD=0.99). In the prior intervention, the average time of treatment was 14.95 days (SD=11.11)

3.5. Outcome Measurements.

The included studies encompassed various outcome measures, reflecting the multifaceted nature of physical performance and recovery in soccer players. The authors categorized these measures into four main groups: physical performance tests, muscular strength and power assessments, physiological markers, and subjective assessments. (Table 2) Researchers frequently utilized physical performance tests, including the Loughborough Intermittent Shuttle Test (LIST), countermovement jump (CMJ), sprint tests, agility runs, and Yo-Yo Intermittent Recovery tests, in their studies. These tests evaluate various aspects of soccer performance, including endurance, speed, and agility. Muscular strength and power assessments included maximal voluntary isometric contraction (MVIC) measurements, leg press, bench press, and vertical jump. These outcomes provide insights into the soccer players' strength, power, and explosiveness.

Additionally, mean power output (MPO) and fatigue index (FI) were assessed in some studies, offering further information about the players' anaerobic capacity and fatigue resistance. Physiological markers comprised a range of measures, including oxidative stress markers, vertical ground reaction force (VGRF), electromyography (EMG) muscle activation, and energy expenditure. These markers help evaluate the soccer players' physiological responses to the interventions and their potential effects on performance and recovery.

Table 1. Summary of Included Studies: Author, Country, Design, Participants, Sex, Intervention, Control, Timing, and Duration.

Author (Year of Publication)	Country	Design	N	sex	Intervention	Control	Timing	Duration
Ali A (2009)[33]	UK	crossover	17	Male	6.4% carbohydrate drink	Placebo	Post	after every 15 min of exercise
Altarriba-Bartes, A (2023)[46]	Mexico	clinical trial	18	Male	foam roller CWI tart cherry juice	stretching, intermittent CWI	Post	After the game and the day after
Bangsbo J (1992)[34]	Denmark	crossover	7	Male	65 % carbohydrate diet	39% carbohydrate diet	Pre	2 days
Bell PG (2016)[35]	UK	clinical trial	16	Male	tart cherry juice	Placebo	Pre	4 days
Celik H (2019)[47]	Turkey	clinical trial	40	Male	pistachio (25 g/day)	No pistachio control	Pre	25 days
Chycki J (2018)[36]	Poland	clinical trial	26	Male	Na bicarbonate, K dicarbonate, Ca phosphate, K citrate, Mg citrate, Ca citrate	Placebo	Pre	9 days
Cox G (2002)[37]	Australia	clinical trial	12	Female	Creatine (5 g QID)	Placebo	Pre	6 days
da Silva Azevedo AP (2019)[38]	Brazil	crossover	8	Male	Creatine monohydrate (0.3 g/kg/day)	Placebo	Pre	7 days r
Erith S (2006)[39]	UK	crossover	27	Male	High Glycemic Diet (GI: 70)	Low Glycemic Diet (GI: 30)	Post	22 h
Nobari H (2021)[40]	Iran	clinical trial	29	Male	betaine (2 g/day)	Placebo	Pre	4 weeks
Ostojic SM (2006)[41]	Serbia	clinical trial	20	Male	Yohimbine (20mg/day)	Placebo	Pre	21 days
Paoli AA (2021)[42]	Italy	clinical trial	16	Male	iso-protein ketogenic diet (1.8 g/kg/day	Western diet	Pre	30 days
Quero CD (2021)[43]	Spain	clinical trial	14	Male	synbiotic	Placebo	Pre	1 Month
Souglis AG (2013)[44]	Greece	crossover	21	Male	high carbohydrate diet 8 g CHO/kg/day	Low carbohydrate diet 3 g CHO/kg/d	Pre	3,5 days
Yáñez-Silva A (2017)[45]	Brazil	clinical trial	19	Male	Creatine Monohydrate 0.03 g/kg/day	Placebo	Pre	14 days
Kim J (2021)[17]	Korea	clinical trial	20	Male	creatine (20 g/day) sodium bicarbonate (0.3 g/kg/day)	Placebo	Pre	7 days

CWI Cold Water Immersion. QID=four times a day, CHO=Carbohydrate,

Table 2. Summary of Included Studies: Author, Outcome, Magnitude, and Significance.

Author (Year of Publication)	Outcome Measurements	Effect size Intervention vs. Control	P
Ali A (2009)[33]	LIST[18], LSPT[19]	11% Performance	$p < 0.07$
Altarriba-Bartes, A (2023)[46]	countermovement jump, hamstring maximal voluntary contraction, perceived recovery, muscle soreness	No differences	NS
Bangsbo J (1992)[34]	total mean running distance (km)	0.9	$p < 0.05$
Bell PG (2016)[35]	LIST	No differences	NS
	MVIC,	19%	$p < 0.05$
	20 m Sprint*,(s)	0.1/0.9/0.5	NS
	CMJ	6%	$p = 0.017$
	5-0-5 Agility* (s)	-0.1/0.5/0.2	$p = 0.043$
	DOMS* (mm)	33/46/23	$p = 0.013$
Celik H (2019)[47]	Total thiol (µmol/L)	4.86	$p = 0.015$
	Disulfide (µmol/L)	9.49	$p < 0.001$
	%Disulfide/native thiol	1.78	$p < 0.001$
	% Disulfide/total thiol	1.51	$p < 0.001$
	% Native thiol/total thiol	-3.01	$p < 0.001$
Chycki J (2018)[36]	RAST	1.06	$p < 0.001$
Cox G (2002)[37]	Repeated Sprints (s)	0.05	$p <0.05$
	Agility Runs (s)	0.2	$p <0.05$
	Precision Ball-Kicking	-0.3	NS
da Silva Azevedo AP (2019)[38]	VGRF, EMG activation intensity during stance phase		
	GL (au)	1.05	$p <0.05$
	VM (au)	1.00	$p <0.05$
Erith S (2006)[39]	LIST		
	Number attempted Sprinting	4	NS
	Distance sprint (m)	377	NS
	jogging to fatigue (minutes)	2.4	NS
Nobari H (2021)[40]	Leg press (kg)	2.8	$p <0.05$
	Bench press(kg)	4.3	$p <0.05$
Ostojic SM (2006)[41]	Bench press, leg press, vertical jump, dribble, power test, shuttle run	No differences	NS
Paoli AA (2021)[42]	CMJ	No differences	NS
	yo-yo intermittent recovery		
Quero CD (2021)[43]	Accelerometry		
	Kcal/week	281.8	$p <0.05$
	METS	0.06	$p <0.05$
	MVPA (min)	-34.93	NS
	Steps (Total/week)	8309.34	NS
	Sedentary bouts (> 1 min)	-108.33	NS
Souglis AG (2013)[44]	Distance covered (m)	1303	$P <0.01$
	Game result (won)	2 of 2	NS
Yáñez-Silva A (2017)[45]	Wingate Anaerobic Test		
	PPO	5%	$p < 0.05$
	MPO	4%	$p < 0.05$
	FI	No differences	NS
	Total Work	1%	$p < 0.05$
Kim, J (2021)[17]	10m sprint	No differences	NS
	30-m sprint,	-3%	$p=0.007$
	coordination,	No differences	NS
	right/left arrowhead agility,	-6.6%; -4.3%	$P< 0.001$
	Yo-Yo intermittent recovery.	No differences	NS

*24h, 48h, 72h NS= No significative, au= arbitrary unit CMJ= counter movement jump, LIST=Loughborough Intermittent Shuttle Test, LSPT= Loughborough Soccer Passing Test.; MVIC=Maximal voluntary isometric contraction, DOMS= Delayed Onset Muscle Soreness; RAST=Repeated Anaerobic Sprint Test, VGRF= Vertical component of Ground Reaction Force; EMG= Electromyography, GL= gastrocnemius lateralis, VM=vastus medialis, MVPA=Moderate to Vigorous Physical Activity; PPO= peak power output; MPO= mean power output, FI= Fatigue Index.

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Subjective assessments, such as perceived recovery and delayed onset muscle soreness (DOMS), were also reported in the studies. These outcomes provide valuable insights into the soccer players' subjective experience of recovery and overall well-being. Players participated in two soccer matches in one crossover study, and the intervention group won both. This result highlights the potential impact of nutritional interventions on real-world competitive outcomes for soccer players.

Overall, the various outcome measures reported across the 15 studies emphasize the complexity of evaluating the effects of nutritional interventions on soccer performance and recovery. In Table 2, we present a detailed summary of the outcome measures employed in each study, offering an overview of the performance and recovery variables assessed.

3.6. Recovery Studies

Three studies looked at interventions during the recovery, but none proved effective[33,39,46].

3.6.1. carbohydrate-electrolyte solution

A crossover study investigated [33] the effect of ingesting a carbohydrate-electrolyte solution during a soccer test on skill performance. It used the Loughborough Intermittent Shuttle Test (LIST) [18]and the Loughborough Soccer Passing Test as outcomes. The Loughborough Intermittent Shuttle Test is a fitness test designed to measure an individual's ability to perform high-intensity intermittent exercise. The Loughborough Soccer Passing Test is a skill-based test that measures an individual's ability to perform accurate and consistent passes in a soccer-specific context. The study failed to detect improved soccer skill performance after drinking a carbohydrate solution.

3.6.2 Tart Cherry

A crossover paper compared the effectiveness of two comprehensive recovery interventions and stretching to see how protocols in elite soccer players' physiological, neuromuscular, and perceptual outcomes [46]. One intervention included tart cherry, Cold Water Immersion (CWI), and foam roller, while the other had intermittent CWI and stretching. Both interventions provided benefits in recovery but did not find any significant differences between the two interventions.

3.6.3. High Glycemic diet.

A crossover study that compared a high glycemic diet with a Glycemic Index (GI) of 70 with a diet of 30 did not find any significant difference [39].

3.7. Performance-based nutritional interventions

Thirteen investigations studied Performance-based nutritional interventions. [17,34–38,40–45,47]

3.7.1. Tart Cherry

Tart cherry was used in a clinical trial comparing the use of tart Jerry juice during the previous four days to the evaluation[35]. This study detected significant differences in countermovement jump (CMJ), maximal voluntary isometric contraction (MVIC), and delayed onset muscle soreness (DOMS).

3.7.2. *Raw pistachio nut kernels*

A clinical trial found that consuming raw pistachio nut kernels (25 g/day) for 21 days may positively impact the redox status of professional soccer players compared to the control group, which did not consume pistachios[47]. The redox status, crucial for overall health, reflects the balance between oxidants and antioxidants. In the intervention group, total thiol increased, disulfide/native thiol and disulfide/total thiol ratios rose, while native thiol/total thiol decreased.

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3.7.3. Bicarbonate and Minerals.

One clinical trial *[36]* found a significant increase in RAST (Repeated Anaerobic Sprint Test) in those soccer players that ingested Bicarbonate & Minerals. The experimental group took 3000 mg of sodium bicarbonate, 6000 mg of potassium bicarbonate, 1000 mg of calcium phosphate and calcium citrate, 1000 mg of potassium citrate, and 1000 mg of magnesium citrate twice a day, 90 minutes before each practice session. The supplementation protocol included additional bicarbonates and minerals 90 minutes before the exercise test protocol and the day before the test. The participants took the supplements in addition to their regular daily dose.

3.7.4 . Creatine

A crossover study *[37]*and three clinical trials studied the effect of creatine *[38,45]*. The duration of interventions has a median of 7 days with a range from 6 to 14 days. The doses used were 5 g (four times a day) in the Australian clinical trial of female soccer players *[37]*, while in the two Brazilian studies performed with male players, the dose was creatinine monohydrate 0.03 g/kg/day *[38,45]*. One study detected significant differences in repeated sprints and agility runs *[37]*, and another study detected EMG activation intensity during the stance phase in the muscle activation in gastrocnemius lateralis (GL) and vastus medialis (VM). The third study detected significant changes in the peak power output (PPO) and the mean power output (MPO). Another clinical trial studied the combination of bicarbonate and creatine versus placebo seven days before the measurement *[17]*. It detected significant differences in sprint

3.7.5. Betaine.

A double-blind clinical trial found that the daily ingestion of 2g/day of betaine during four weeks positively affects player strength measured by bench and leg press.*[40]*

3.7.6. Yohimbine

A clinical trial with Yohimbine for 21 days found no difference in strength with the placebo group*[41]*.

3.7.7. Isoprotein Ketogenic diet.

A clinical trial comparing the ketogenic diet to the Mediterranean diet found no difference in physical performance tests, such as CMJ and Yo-Yo Intermittent Recovery test, indicating that both diets have similar effects on physical performance. *[42]*.

3.7.8. Symbiotic

A clinical trial with a symbiotic found a significant increase in Kcal/week and Mets measured by accelerometry*[43]*.

3.7.9. High carbohydrate diet

In a clinical trial, researchers compared a high-carbohydrate diet of 8g CHO/kg/day to a low-carbohydrate diet of 3g CHO/kg/day [44]. The study detected a significant increase in the distance covered, indicating the effectiveness of the high-carbohydrate diet.

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4. Discussion

4.1. Methodological issues.

The size of the studies is very small, and in some of the crossover studies, there are two studies with eight or fewer individuals *[34]*, with a median of 18, which may lead to a lack of power and make statistically significant differences undetectable. In the future, conducting studies with more players or even multicenter studies would be interesting. A further issue is that most studies have involved male professional players. Given the increasing number of professional women's soccer teams, conducting studies involving professional women soccer players is necessary. The pistachio trial*[47]* has inconvenient and was not blind because of the difficulties because participants ate pistachio

4.2. Output measurement

Fifteen studies in this systematic review have utilized a broad range of measurements to comprehensively evaluate the potential impact of nutritional interventions on soccer performance. While this approach has provided a comprehensive understanding of the various aspects of soccer performance that interventions can influence, the use of various outcome measures presents both strengths and weaknesses in evaluating the effects of these interventions on performance and recovery.

In this systematic review, various outcome measures across studies offer a comprehensive insight into various aspects of soccer performance and recovery influenced by interventions. Employing a diverse range of outcome measures is a strength of intervention evaluation, as it enables a robust assessment of effectiveness, increases external validity, and accounts for individual differences, ultimately enhancing applicability to a broader range of players and situations. Specifically, various outcome measures provide a comprehensive understanding of the various aspects of soccer performance that interventions may influence.

This diversity of outcomes allows for a more robust evaluation of the effectiveness of the interventions and their potential applications in optimizing soccer performance and recovery. Including multiple outcome measures allows for a more accurate representation of the multifaceted nature of soccer performance, as different outcome measures may be more relevant to specific aspects of the sport. This diversity also helps enhance the external validity, i.e., the generalizability of the study findings to a broader range of soccer players and situations. Lastly, various outcome measures can help account for individual differences among soccer players. It acknowledges that different players may respond differently to nutritional interventions, and the variety of measures helps identify which aspects of performance are most affected by the interventions for different individuals.

On the other hand, the heterogeneity of outcome measures complicates the comparison and synthesis of results, potentially hindering definitive conclusions on the effectiveness of nutritional interventions. This diversity may introduce bias, risk of selective reporting, and challenges in conducting meta-analyses. Inconsistency in assessment methods can affect the reliability and validity of the results, complicating the derivation of accurate conclusions. The heterogeneity of outcome measures across the studies can make comparing and synthesizing the results challenging. This variability may hinder the ability to draw definitive conclusions regarding the overall effectiveness of nutritional interventions on soccer performance and recovery. The diversity of outcome measures may introduce a risk of bias, as researchers may be more likely to report outcomes that show favorable results for their interventions. This selective reporting can potentially lead to an overestimation of the effectiveness of the nutritional interventions. The wide variety of outcome measures can make it challenging to conduct a meta-analysis, as pooling data from different measures may not be feasible or appropriate. As a result, it may be challenging to synthesize the findings quantitatively and derive a more precise estimate of the overall intervention effect. Different outcome measures may also introduce variability in the methods and tools used to assess these outcomes. This inconsistency can affect the reliability and validity of the results, making it difficult to draw accurate and meaningful conclusions.

4.3. Interventions

One methodological issue arises from the simultaneous evaluation of multiple interventions in two studies, which makes it impossible to discern the individual effect of each intervention.**[17,46]**. In the future, conducting multi-arm clinical trials to test various interventions or clinical trials with a factorial design would be beneficial. Alternatively, evaluating a single measure in a clinical trial may prove valuable.

4.3.1. Carbohydrate-electrolyte solution

A crossover study investigated [25] the effect of ingesting a carbohydrate-electrolyte solution during a soccer test on skill performance. The study failed to detect improved soccer skill performance after drinking a carbohydrate solution. These results are like another study by the same authors that did not find significant differences between the carbohydrate-electrolyte solution and the control group**[20]**

4.3.2. Bicarbonate and Minerals.

In this systematic review, one study found that soccer players that ingested bicarbonate and minerals had a better performance measured by RAST[36]. This is compatible with similar findings in sports like taekwondo, judo, and Jiu-Jitsu.[21,48,49] Sport performance in disciplines like soccer relies heavily on anaerobic capacity and repeated sprint ability. Fatigue factors include central and peripheral components, with central fatigue relating to the central nervous system and peripheral fatigue involving metabolite accumulation and energy substrate depletion[50,51]. In team sports, muscle glycogen depletion contributes to decreased sprint ability. In order to combat exercise-induced acidosis and fatigue and improve anaerobic performance and lactate utilization, experts have suggested using buffering agents such as sodium bicarbonate, sodium citrate, potassium bicarbonate, and alkalized water.[52].

4.3.3. Raw pistachio nut kernels

Raw pistachio nut kernels have gained increasing attention recently as a potential functional food to improve sports performance. These nutrient-dense nuts are known to be among the products with the highest potent antioxidant content [53]. They are also rich sources of phenolic[54], essential fatty acids, and micronutrients, which may contribute to enhanced physical and cognitive functions necessary for optimal soccer performance. The ingest of Ripe Pistachio Hulls Hydro-alcoholic by rats with diabetes has found an improvement in Learning and Memory[55]. The Celik study [47]detected increases in total thiol, disulfide/native thiol ratio, and disulfide/total thiol ratio. It also detected a decrease in the native thiol/total thiol ratio. The increased total thiol suggests pistachio consumption boosts soccer players' antioxidant capacity. The elevated disulfide/native thiol ratio indicates a shift towards a more oxidized state, enhancing the body's ability to neutralize harmful substances. The increased disulfide/total thiol ratio implies that pistachio consumption promotes disulfide bond formation, supporting redox balance and protection against free radicals. The decreased native thiol/total thiol ratio aligns with previous findings, suggesting pistachio intake positively impacts soccer players' redox status. The results suggest that the consumption of pistachios may improve the redox status in professional soccer players, potentially by increasing their antioxidant capacity and

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promoting the formation of disulfide bonds. These findings could affect soccer players' performance, recovery, health, and well-being.

Further research is needed to confirm these findings and explore the underlying mechanisms by which pistachios may affect redox status. The results of the Celik[47] study should be taken with caution as they may disagree with other studies. A study with healthy males eating pistachios two weeks before and throughout recovery from an intense exercise bout did not detect any effect on cardiometabolic risk indicators[56]. A crossover study with cyclists after 2-weeks of pistachio or no pistachio supplementation found a reduction in the performance of cyclists. It reduced 75-km cycling time trial performance by 4.8% compared to the control group[57]

4.3.4. Yohimbine

The only study that studied Yohimbine found no association[41]. For many years, people have used Yohimbine as a stimulant and aphrodisiac. Yohimbine is a phytochemical affecting the central and peripheral nervous systems by blocking pre- and postsynaptic α2-adrenergic receptors and binding to other monoaminergic receptors. These include α-2 NE, 5HT-1A, 5HT-1B, 1-D, D3, and D2 receptors. Researchers have suggested that Yohimbine's pharmacological activity makes it worth exploring for treating conditions such as erectile dysfunction, myocardial dysfunction, inflammatory disorders, and cancer[58]. In addition to these uses, Yohimbine has also been investigated for its potential to enhance athletic performance[59,60]. Athletes in soccer and other sports have used creatine as a supplement to increase energy and reduce fatigue. The ability of creatine to enhance blood flow and oxygen delivery to muscles is a possible explanation for these effects. In 2007, an incident occurred with the World Anti-Doping Agency (WADA) in which an athlete tested positive for the banned substance 19-nor androsterone after reportedly ingesting Yohimbine before a sporting event[61]. Yohimbine, found in energy drinks, pre-workout supplements, or fat burners[62], was not classified as a prohibited substance by WADA at the time[63]. Furthermore, the agency had not yet confirmed whether Yohimbine consumption could elevate the body's natural levels of anabolic steroids, specifically 19-nor androstenedione and testosterone.

4.3.5. Tart Cherry

The findings of the tart cherry clinical trial are consistent with the bibliography. Tart cherry juice from Montmorency cherries contains phytochemicals like anthocyanins and flavonoids with antioxidant and anti-inflammatory effects[64,65]. It has lowered the risk of diabetes and cardiovascular diseases[66]. The anti-inflammatory effects of tart cherry juice maintain the inflammatory response and redox balance and help to improve recovery after strenuous exercise[67,68]. Several studies have examined the effect of tart cherry juice on exercise-induced muscle damage (EIMD) and delayed onset muscle soreness (DOMS). Some studies have reported positive effects on muscle strength, inflammation, and oxidative stress markers, while others have found no significant impact[69,70]. The effectiveness of tart cherry juice on recovery may vary depending on factors such as sport, training, and individual differences. Tart cherry juice positively affects soccer players' performance in laboratory conditions, but the effects have not been detected in professional soccer players under normal game conditions[71].

4.3.6. Creatine

A crossover study and three clinical trials investigated creatine's effects, with intervention durations ranging from 6 to 14 days [37][38,45]. Doses varied from 5g four times a day to 0.03g/kg/day of creatine monohydrate. Findings included significant differences in repeated sprints, agility runs, muscle activation, and power outputs. One trial also examined the combination of bicarbonate and creatine, observing significant differences in sprint performance [17]. It detected significant differences in the sprint.

Creatine, a widely researched ergogenic aid, is popular among athletes and weightlifters for enhancing performance, promoting exercise adaptations, and reducing recovery time. Its benefits are observed in short-duration, high-intensity exercises, and training adaptations[72]. Numerous studies have consistently shown that taking a creatine supplement raises the creatine concentration in the muscles, which may explain the improvements in high-intensity exercise performance observed in these studies. These improvements can lead to more pronounced training adaptations.[73]. The International Society of Sports Nutrition (ISSN) claims that healthy people can take creatine supplements for short and extended periods (up to 30 g per day for five years)[74]. Creatine occasionally causes adverse side effects, including weight gain due to water retention, nausea, diarrhea, cramps, and heat sensitivity. There is evidence that creatine monohydrate supplementation can enhance short-term high-intensity exercise in athletes[75]. However, a meta-analysis found no effects on aerobic activities[76].

4.3.7. Betaine.

A double-blind clinical trial found that daily ingestion affected player strength.*[40]*. Foods like sugar beets, wheat bran, spinach, and shrimp contain betaine, a byproduct of choline metabolism*[77]*. Betaine is a methyl donor in the metabolic process of transmethylation of homocysteine to methionine and aids in cell volume regulation, stabilizing native protein structure, preventing degradation under stressful conditions, and may improve anaerobic performance by reducing cellular acidosis*[78]*. Studies have demonstrated that betaine improves body composition results and performance when individuals use it with a resistance training program.*[79–82]*

4.3.8. Isoprotein Ketogenic Diet.

A clinical trial in this systematic review found no differences in physical performance tests, such as CMJ and Yo-Yo Intermittent Recovery, when comparing the ketogenic diet with the Mediterranean diet*[42]*. These results are compatible with other studies that did not find any effect on the performance of cross-fit athletes using a Ketogenic Diet*[83]*. Furthermore, a crossover study found that a Low-carbohydrate, ketogenic diet impaired anaerobic exercise performance in exercise-trained women and men*[84]*.

4.3.9. Symbiotic

This clinical review trial with a symbiotic found a significant increase in Kcal/week and Mets measured by accelerometry*[43]*. Probiotics and prebiotics combined constitute synbiotics, which can improve the host's health, for example, by modifying the gut microbiota. A clinical trial has studied the effects of long-term prebiotic and synbiotic supplementations on the immunosuppression of male football players*[85,86]*.

4.3.10. High carbohydrate diet

One clinical trial included in this systematic review found that a high-carbohydrate diet increased the distance covered by soccer players *[44]*. Research suggests that soccer players consume enough protein, but carbohydrate intake might be flawed or excessive. Optimal nutrition during the competitive season is crucial for peak performance. A study on the diet, energy expenditure, and dietary intake of professional football players in the Dutch Premier League concluded that increasing daily carbohydrate intake maximizes performance and recovery. *[87]*. Also, a meta-analysis found a lousy low in the small carbohydrate*[88]*.

While the diverse range of outcome measures employed in these 15 studies offers a comprehensive assessment of the effects of nutritional interventions on soccer performance and recovery, the heterogeneity of these measures presents challenges in comparing and synthesizing the findings. Future research could benefit from standardizing outcome measures and adopting a more consistent approach to assessing performance and recovery variables. This would facilitate the comparison of results across studies and help provide a clearer understanding of the overall effectiveness of nutritional interventions for soccer players.

It is necessary to design randomized double clinical trials with significant sample and factorial designs that study the combination of a High carbohydrate diet and bicarbonate drinks with supplements such as creatine, betaine, and tart cherry.

5. Conclusions

The performance of professional soccer players can be increased by ingesting a high carbohydrate diet in the weeks before the soccer matches, drinking bicarbonate and minerals solutions, and using several supplements such as creatine and betaine, and Tart cherry. So far, no nutritional interventions can accelerate or improve the recovery period in professional soccer players.

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