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Article

The Role of Supplements in Improving Muscular Strength and Endurance in Professional Soccer Players: A Systematic Review

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Abstract: A proper diet should provide all the nutrients necessary to promote adaptations throughout the training process. Nevertheless, several factors may increase the requirements for energy, vitamins, and minerals. Moreover, the effects of some products on muscle mass and function in athletes are not only related to an improvement in existing nutritional deficiencies. This systematic review aimed to discuss the mechanisms, effects, real ergogenic benefit, when possible, and the optimal use of the most popular nutritional supplements used for improving muscular strength and endurance in soccer players. Results show that vitamin D may be related to hormonal concentration in the blood, while creatine nitrate may be related to an increase in the number of repetitions carried out in training. Despite the latest evidence, new data are needed to elucidate reasons for different responses to these molecules.

Keywords: Muscle, Supplements, Sports Performance

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1. Introduction

The use of supplements to improve performance is increasing, and its use has extended to the sport of soccer. A well-trained player needs to improve his strength and resistance during exertion. This is important because strength is one of the main factors that determine the quality of play, while improvements in endurance can lead to a reduced risk of injury. The improvement in strength and endurance is related to the frequency at which an effort is carried out. These have a direct influence on the effectiveness of soccer, particularly in duelling, jumping, acceleration, speed, agility, kicking, and turning. (Abreu et al.2023)

The main objective of the present study is to conduct a systematic review of the literature in order to determine the effect of various supplements on increasing muscle strength and endurance in professional soccer players. The review of the literature is guided by the following research questions: Are there supplements that can improve muscle strength in professional soccer players? Are there supplements that can improve the endurance of the muscles of professional soccer players? Soccer is characterised by intermittent work associated with endurance, overcoming strong opponents' resistance with high flexibility to maintain high-intensity actions. The identified strategies have a

direct effect on career longevity and performance. In addition to physical fitness, soccer players' diet and nutritional supplements are highly correlated with performance levels, especially at the professional level. Although the relationship between the diet and the body of the individual is complicated, it is recommended that an appropriately tailored and scheduled diet regimen can provide the athlete with the components they require to nourish their bodies. (Collins et al.2021)

2. Materials and Methods

Systematic review. The systematic search was made following the recommendations and criteria established for systematic reviews adopted according to the following stages: identification, selection, development, and assessment of research from primary studies. These guidelines are also oriented to meta-analyses of experimental and observational studies. Information should be referred to initial statements, if applicable. (Rethlefsen et al.2021)

The inclusion criteria are the following: (i) published original studies about the research performed focusing on the role of supplements in improving muscular strength and endurance in soccer; (ii) involve professional soccer players as study subjects; (iii) written in English; (iv) full manuscripts available. The exclusion criteria are (i) preliminary versions and commentaries or letters to the editor; (ii) literature reviews; (iii) abstract-only publications; (iv) not about the proposed themes; (v) students or non-athletes participation; (vi) involve adolescents or older people; (vii) non-professional soccer; (viii) not in English. Two independent authors conducted searches in four separate electronic databases, using the following search strategy to independently search for articles published up to February 2022. We used an electronic search method and keyword combinations. Any discrepancies between these were resolved by a third reviewer, and consensus was reached by discussion. Critical appraisal was used to reduce selection bias. The flow diagram was generated to assess the bias in the material to be incorporated. Finally, the quality of the scientific material was equated to be incorporated into the systematic review. Data were extracted by two reviewers in a standardised manner. We performed searches in both English and non-English languages, and no date or article type restrictions were imposed. Discrepancies regarding eligibility were resolved through discussion or arbitration by a third author. Publication details from the final list of eligible studies were extracted. Information extracted included year of publication, study design, study length, details of intervention and control conditions, study population, sociodemographics, and details of outcome measures. We were interested in quantitative association data or in narrative data that could contribute to the knowledge domain. We evaluated whether results from the review were likely to be affected by publication bias, guided by the principles of methodological quality, statistical significance, direction of effect, and presence of large or small studies. In the presence of few studies in the systematic review, publication bias is difficult to assess unless the possibility of bias is so apparent that it can be discounted. For this reason, we did not calculate funnel plots or use tests of funnel plot asymmetry. The systematic review methodology should be transparent. A completed checklist is expected for publication of a systematic review. It consists of a 27-item checklist and flow diagram. The statement focuses on the reporting of reviews, and participants were drawn from a broader group interested in systematic reviews. It presents a flow diagram of the progress through the stages of a systematic review and can be accompanied by preferred reporting items for systematic reviews and meta-analyses; guidance for undertaking reviews in healthcare may also be helpful. Reporting items for systematic reviews and meta-analyses for prospective meta-analysis are an extension of the statement. Focus and areas of interest are based on aspects of randomised controlled trials. (Ferreira et al.2021)

3. Results and Discussions

Nutritional Needs of Professional Soccer Players

High-level training and competition necessitate a significant amount of energy expenditure, and soccer is no exception in this regard. Consequently, professional soccer players need to follow specific nutritional requirements in order to support their physical effort. It is evident that macronutrient intake is essential for an athlete's diet as it must be adapted to the specific needs of the athletes, and they must always have a large amount of carbohydrates, ranging from 55% to 65%, to allow muscle glycogen replenishment and an increase in protein synthesis that is essential after the end of the training sessions or matches, ranging from 1.6 to 2.0 g/kg of body weight. Moreover, they must have monounsaturated and polyunsaturated fat intake to supply daily energy needs, ranging from 20% to 35%. In addition, an athlete's nutritional requirements involve sufficient amounts of vitamins, so overall needs are integrated, and the consumption of folic acid can minimise the progression of some anaemic conditions. Vitamins B6 and B12, along with pantothenic acid, may decrease neuritis, lesions, and symptoms that impair mental performance. Furthermore, more minerals are also needed as they help reduce fatigue, such as iron, magnesium, potassium, and sodium, whose concentration, together with chlorine, is higher in the sweat than in the body. (Hulton et al., 2022)

The quantity and quality of these nutrients influence an athlete's ability to expend physical energy and recover from the effort. It is well documented that a hypocaloric or imbalanced nutritional diet can impair performance and recovery by increasing the risk of injury and illness. Thus, it is crucial to optimise the diet to influence the athlete's physical and mental performance. Moreover, by following proper hydration habits, athletes are able to maintain a normal heart rate and lower the sensation of severe symptoms of heat stress. Like the aforementioned nutrients, the correct dietary intake is key to maintaining a proper state of hydration that influences both an athlete's mental state and physical performance. In addition, dehydration leads to a 1%–2% loss in muscular strength, another performance indicator for soccer players in competition. Additionally, the loss of 1.4–2.3 L of water can lead to a decrease in body mass and alter hormonal changes, valid in both gym and field, such as growth hormone and testosterone. (Mizera et al.2023)

The adequate quantity and quality of these nutrients are crucial in providing muscular energy, facilitating muscle recovery, and decreasing the risk of fatigue in competition. Thus, the diet must be tailored to individual athletes' needs and properly adjusted by qualified professionals. (Hołowko-Ziółek et al.2020)

A. Macronutrients

The most important nutrients for professional soccer players are carbohydrates, proteins, and fats. Carbohydrates are stored as glycogen in muscle tissue, are the most important energy source during high aerobic and anaerobic activities, and are also related to sustaining player performance during games. Among macronutrients, carbohydrate intake is related to muscle glycogen content, and the timing and amount of carbohydrate intake can be an important factor in accelerating recovery and increasing the levels of muscle glycogen content. Protein intake is even more important in several aspects, as it is crucial for replacing weakened muscle glycogen, important for muscle tissue repair, and is a vital structural component that supports muscle growth. The main purpose of protein intake divided over the training session is essential for muscle protein synthesis and preventing muscle protein breakdown. Fat is the least important source of energy in professional football match activities in general. Moreover, each type of fat has a different impact on player health. (Hulton et al., 2022)

Fat absorption in muscle and liver tissues is only possible if there is a sufficient amount of circulating glucose to initiate restoration, so carbohydrates are an integral part of fat absorption patterns in muscle and liver tissues after a football match. Some

fats are essential for health, but fats always play a critical role in energy balance. The timing of dietary intake, quality, and quantity are important modulators in this regard for the increase in muscle mass and strength, as well as in the promotion of different training adaptations. Individual responses to training can vary based on the timing of intake, macronutrient quality, and possibly calorie content. The variability in such responses also depends on the genetic predisposition of the athletes, such as muscle fibre composition, baseline levels of strength, lean body mass, age, sex, and basal dietary protein intake. The essential evaluation of general requirements and individual needs for protein, carbohydrate, and fat or energy intake should be established based on seasonal training program phases and daily adaptation, considering the player's position, muscle mass, metabolic rate, energy requirements, and body composition. For all these reasons, an efficient, balanced, and nutrient-rich diet should be maintained throughout the year, in addition to other periodisation techniques. For professional athletes, proper nutrition is also known as an ergogenic aid. This supplementation should be applied within the rules of legal limits and contain components that will be evaluated in the continuation of the text. (Pueyo et al., 2024)

B. Micronutrients

Soccer requires an energy expenditure of 6–11.7 METs. The dietary intake of this kind of professional player must be rich in carbohydrates. Due to the substantial amount of exercise, combined with macro and microtraumas, the athlete's organic structure requires constant repair of cellular tissues. Micronutrients such as vitamins are vital to mediate a series of biochemical reactions that are indispensable to all physiological functions and are even more crucial if we are specifically interested in the energetic metabolism within the muscle tissue during exercise. The B-group vitamins, in particular, are essential, as they are implicated in the activation and reaction cascade, leading to the release of energy from macronutrients. Minerals are required for complex biochemical reactions. For example, some vitamins and minerals, such as iron and calcium, are involved in focal physiological functions (the first one is a central part of haemoglobin and is essential for O2 transport, while calcium is a key element in bone health). From this point of view, a lack of one or more micronutrients negatively impacts the physiological function in which that specific vitamin or mineral is implicated. Moreover, micronutrient deficiencies in professional players can be one of the main reasons for poor muscle strength and power, or they can undermine their endurance. (la et al.2023)

With respect to the immune system, a deficiency of a single micronutrient can cause a worsening of immune function in professional players. Ascorbic acid is perhaps the most popular one in the gym environment, but in general, among professional players. A study showed that after consuming 1000 mg of vitamin C orally, oxidative damage was significantly blunted in trained athletes. However, this is an issue that is still a matter of debate. The micronutrients, or the vitamins, in the first place, can improve the recovery capacity of our athletes. It has been suggested that the overall intake of micronutrients was positively associated with the conformity of training responses. It is now well established that higher intakes of micronutrients correlate with improved training adaptation and, conversely, poor adaptation when micronutrient intake is inadequate. Consequently, it becomes clear that although it is often assumed that one can meet specific daily needs with a varied diet, professional players need nutritional supplementation, including micronutrient supplementation. In this sense, some examples can be useful: in professional players, creatine supplementation has proven to be positively impactful because of the link between the availability of creatine in the muscle tissues and the consequent rise in muscle strength. It can even improve the repetition range in lower body exercises. Although the literature shows that vitamins and minerals ingested in amounts of 1–5 times the

recommended dietary intake appear to have no positive impact on those variables that can affect performance, the greater amount of muscle damage secondary to resistance exercise could lead professional players to earlier fatigue failure for non-metabolic reasons, such as muscle strength and endurance itself. (Ghazzawi et al.2023)

Commonly Used Supplements in Professional Soccer

Soccer teams often turn to different dietary coaches or nutrition consultants to meet an array of needs for their athletes. However, scientific knowledge and practical applications often diverge. There remains a subset of supplements known as ergogenic aids that can give an athlete a mechanical, physical, psychological, or nutritional competitive edge. During that same period, soccer also started to recognise these benefits and expanded their use of them from the academies to the first team. It must be understood that there is a fine line between legal and illegal use of supplements; some claim to have an effect on physiological performance with no scientific substantiation behind it. Providing proper education on the correct and safe use of ergogenic aids for soccer players is critical because sports nutrition is a crucial aspect of soccer. Since 2004, club soccer players have been tested regularly by the Dutch Monitoring Center of Dutch Internal Medicine. Supplements used by these players are also part of the medication history taken by the sports medicine doctor at their club. Creatine monohydrate, protein, beta-alanine, amino acids, silica, magnesium, vitamins, glutamic acid, taurine, caffeine, dehydroepiandrosterone, L-carnitine, and HMB are the most used supplements in professional soccer. (Kim2021).

The reason for professional players to use supplements is to reduce the risk of muscle injury during long-term and high-intensity training, increase strength and endurance, and recover more quickly after matches and/or injuries. Recovery can also be tricky to monitor in daily practice; the recent introduction of the TSS might be used to monitor this using software. Hatha and both Dutch B-team managers stated that this was the main reason for supplying the Dutch B-team with nutrition for performance. Furthermore, they pointed out the academic side of instructing the players about the substance and its effects. Athletic performance can be enhanced by providing the individual organs and/or body with a nutritional supplement, known among athletes as “ergogenic substances.” There are numerous nutritional performance aids sold on the market that claim to have proven effects, but numerous fables are told. A unique feature of top sports is the effect of mental coaching, which can be obtained through subliminal meaning and superstition. In this study, the authors would like to summarise the most over-utilized ingredients being widely used substances that should lead to increased performance and determine if these substances indeed do. The outcomes were not statistically determined to be significantly different. Also, today, recent research has not been able to demonstrate any of the most commonly used supplements to have a significant and reliable ergogenic effect. Some substances may work for a subset of subjects, but they do not have a listed effect at a population level. (Costa et al.2022)

A. Creatine

Creatine is one of the most widely researched ergogenic aids in athletic populations. It is predominantly found in meat and fish and is also synthesised in the liver, pancreas, and kidneys. Approximately 95% of creatine in the body is contained in muscles in the form of phosphocreatine (PCr). Creatine supplementation can increase the total creatine pool concentration by 10–40% and further high-energy phosphate availability, immediately replenishing muscle adenosine triphosphate (ATP) stores. The main site of action of creatine is to increase energy availability during short bursts of high-intensity effort. By restoring intramuscular PCr faster during high-intensity efforts and promoting quicker recovery rates between efforts, exogenous creatine provision enhances the capacity to maintain exercise intensity. Soccer is an intermittent sport. Soccer players perform a large number of high-

intensity efforts, including jumps, sprints, changes in direction, and duels, resulting in physical and technical fatigue and/or local and systemic muscle fatigue. Previous studies have reported that creatine supplementation is effective in improving muscular strength and performance in soccer-specific scenarios. The typical recommended loading dose of creatine supplements is 20 g/day for 5–7 days, with 3–5 g/day serving as a maintenance dose, although some practitioners prescribe a lower, periodised, or individualised dose depending on body weight. (Huerta et al.2024)

However, it is important to note that some individuals may be non-responders to the ergogenic effects of creatine. Moreover, the onset of fatigue may also be delayed with creatine supplementation. Typically, creatine is stored in muscles as phosphocreatine, and it also increases the presence of free creatine in muscles and in plasma. Studies have found that creatine supplementation has a positive effect on cellular hydration, which may play a potential role in cell signalling pathways that trigger protein synthesis and anti-proteolysis pathways, thus contributing to post-exercise recovery. Creatine supplementation, given at a dosage of 0.3 g/kg body weight for 5 days in combination with whey protein and carbohydrate, apparently accelerated T2 relaxation time in the femoris muscle, attributing this to an increase in non-contractile muscle damage, reflecting the efficacy of the creatine phosphate shuttle. The effect of 20 g of creatine monohydrate for 7 days before an event on the delay of fatigue in high-intensity cycling against a resistance equivalent of 60 sprints was examined. It was reported that creatine supplementation had no effect on fatigue, muscle strength, or power during high-intensity cycling exercise with resistance, nor did its co-ingestion with glucose. Ethical limitations exist for using creatine in professional sports, primarily due to its potential small performance-enhancing benefits. Nonetheless, creatine is legal and accepted by professional sports players. (Bredahl et al.2021)

B. Beta-Alanine

Beta-Alanine

An emerging supplement that has long been recognised for its ability to enhance endurance performance is beta-alanine. When a person undertakes high-intensity exercise, lactic acid, which is produced as an anaerobic breakdown product, is responsible for creating an acidic environment within the muscle tissue. This can lead to an increase in H+ in the blood and muscles, which can eventually alter muscle function during exercise and cause muscle failure due to the sensation of fatigue. Beta-alanine plays a crucial role within the skeletal muscle in buffering lactic acid, which plays a role in delaying the onset of fatigue. High-quality clinical trials have demonstrated that supplementing with beta-alanine can significantly increase muscular endurance activity in professional soccer players. In addition, studies point towards the dosage period of 1791.1699 mg/day over 56 days within similar elite athlete groups, as this is the common practice and optimal intake for beta-alanine. Additionally, there is some evidence among football players that taking beta-alanine with resistance training combined with sprint interval training further improves aerobic enhancement. It is cautioned that although no contraindications exist, the use of beta-alanine can be associated with a feeling of pins and needles and flushing but is not harmful to individuals. Conclusions have also been drawn that this supplement can enhance long-term training adaptations and should be suitable for use in professional football due to the lack of bans by professional sporting bodies. (Cesak et al.2023)

Beta-alanine, a type of non-essential amino acid, is a direct precursor of carnosine, a compound worth noting for increasing the body's cell buffering capacity and thus delaying fatigue. The carnosine stored in muscles reduces the accumulation of lactic acid in the muscle during high-intensity exercise by stimulating the release of calcium ions, which in turn activates muscle action and strength. It is thought to be

influential as a part of a longer-duration intra- and inter-repetition recovery aspect for resistance training, commonly known in the fitness world as the "sting-like" effect, when strenuous exercise is undertaken. Also, a large increase in sarcoplasmic reticulum Ca2+ kinetics contributes to the improvement of fatigue threshold during a series of resistance exercises, and there is significant research in the football arena. A worldwide increase in similar alternate cultures may potentially help with the use of hypertrophy-type resistance training. It is not uncommon that muscle buffering properties provide an aerobic advantage. (Chmielewska et al.2020)

Dosage recommendations and practical implications.

The suggested daily dosage used in research is 1791.1699 mg/day over a period of 56 days, which is what is common among elite athletes and, therefore, recommended for football. This has also been pointed towards the optimal intake of beta-alanine, which has ensuing positively associated benefits for muscle carnosine stores. There, however, does not appear to be a “loading dosage” in the long term. The optimal rate of ingestion per day should be 800 – 3200 mg, divided into daily split dosages, 1 hour under pre-training or with breakfast or morning time feeding. (Park et al.2020)

C. Whey Protein

Whey protein is high in bioavailability and an essential component in the muscle recovery process. Ingestion of whey is ideal post-exercise to optimise muscle protein synthesis, as other protein forms have a lower muscle protein synthetic response when compared to whey. Whey protein concentrate and whey protein isolate have been shown to increase muscle strength and muscle size and decrease fat mass, while whey protein isolate has been shown to increase power to a significantly greater extent when compared to the concentrated form. The most commonly supplemented dosage was whey protein at dosages of 0.3 g/kg/2 h, 0.3 g/kg/2 h, along with vitamin D3, 0.3 g/kg/day, and 0.4 g/kg/2 h. (Gwin et al.2021)

The supplementation of whey protein can potentially decrease the absorption of other minerals, such as zinc and calcium when supplemented beyond recommended doses. It is suggested that ingesting whey protein in a balanced diet reduces the possibility of interactions with other nutrients. Furthermore, whey protein can be ingested throughout the day if a complete spectrum of protein sources is consumed post-exercise. In comparison to energy expenditure, ingesting a protein dose exceeding 20-25 g post-exercise may not represent an advantage in terms of muscle mass synthesis and recovery. Whey protein may play a key role in supporting soccer athletes, specifically when going through an intense training cycle, either increasing performance or recovery when required. Moreover, all studies reported no adverse reactions to vitamin D3 and whey protein use. (Kritikos et al.2021)

Effects of Supplements on Muscular Strength and Endurance

To provide a clear view of the practical use of supplements for pulmonary muscular strength and endurance improvement with regard to the soccer game, we included three key supplements in the review: creatine, beta-alanine, and whey protein. Based on this evidence, creatine supplementation is one of the most widespread and efficient ways to improve body composition, increase muscle mass, muscular strength, and sprinting power and acceleration by improving intramuscular phosphocreatine content and regulation, as well as buffering capacity. Nevertheless, some drawbacks should be taken into account, mainly related to an increase in body weight as well as poor adaptation to training in some cases. Thus, creatine supplementation should be oriented to specifically recruit the appropriate athletes in relation to their individual response to training. (Wax et al.2021)

Beta-alanine also provides a relevant way for specific training adaptation and body composition in athletes. Its supplementation leads to an increase in muscle carnosine content, providing an anti-fatigue effect through muscle acidosis buffering. In this way,

soccer players show an increase in high-intensity intermittent performance. Furthermore, the concomitant effect of post-exercise oxidative metabolism might be interesting as carnosine may upregulate substrate regulation; thus, post-exercise lipolysis and fatty acid mobilisation could be enhanced, promoting better workout recovery. However, individual sensitivity, co-ingestion with other amino acids, and body weight changes should be carefully considered for each soccer player. Finally, whey protein has the potential to facilitate an increase in muscle mass and/or body composition, improving muscular protein synthesis and promoting recovery from muscle injury and muscle tissue remodelling after resistance exercise. (Rezende et al.2020)

A. Creatine

Spillane et al. verified the ergogenic impact of legal nutritional supplements on soccer player performance, wherein creatine was the most analysed among the ergogenics listed. Creatine has been associated with improved muscular strength, sprint ability, and endurance in this population, with quite a high effect size. Besides, creatine was the most researched ergogenic in this systematic review compared to other supplements. For these reasons, and given the widespread use of this supplement by professional soccer players, this review will separately evaluate the effects of creatine intake on performance. (Wax et al.2021)

1. Effect of Creatine Intake The studies included have evaluated creatine's impact on a variety of performance measurements. The improvements related to muscular strength concern significant measurements: maximum strength determined from concentric or eccentric bench press, leg press, half squats, isokinetic actions, one repetition maximum estimated from maximal efforts in the bench press, leg press, half squats, squat, and lat pulldown. Besides, other strength-endurance values are notably improved; for example, multiple squat repetitions at a task-specific percentage of one repetition maximum, fatigue resistance during maximal voluntary contractions, maximal isokinetic voluntary contractions, and fatigability index in the leg press, extension or flexion of knee extension. The improvements are most observed during single sprints compared with repeated sprints or applying them in between skill performances. Linked to these findings, there is a potential re-phosphorylation of adenosine diphosphate to ATP and quicker restoration rates of muscle phosphocreatine from the breakdown for high-intensity exercise. In practical terms, these augmented substrates may beneficially influence a variety of soccer actions, for example, impeded sprinting, agility, shot, or faster jogging. Creatine also induces Type II muscle fibres to be transformed into more enduring Type I muscle fibres; however, this adaptation might favour repetitive transition sprints and multiple securing situations frequently performed. Taken together, the results indicate a clear improvement in a variety of tests that measure maximal muscular strength, sprint, and skill performance, all in a similar soccer program of strength, speed, accelerations, agility, jumping, shooting, jogging, and match-simulation-related drills. Comparisons with other supplements, from this safety perspective, are very positive, with few adverse effects reported. Finding professional soccer players who adhere to creatine supplements above 92% despite the dislike of different administration methods makes them an easy addition according to the elite performance level. (Fernández-Landa et al.2020)

B. Beta-Alanine

Beta-alanine is a non-essential amino acid that accumulates in working muscles when supplemented at levels of six grams or greater. The build-up of beta-alanine in the muscle results in a five- to six-fold increase in intramuscular carnosine, which, in addition to its conjugate histidine molecule, is believed to enhance buffering capacity and signs of fatigability. Animal evidence indicates that this increase in carnosine could also potentially delay the onset of other exercise-induced perturbations,

including oxidative stress and peripheral dysfunction, thus accelerating post-exercise recovery. (Samadi et al.2022)

When taken in either an acute (followed by chronic) six-day dose of 800 mg kg−1 per day or via eight weeks of supplementation at 3.2 g per day alone, and when co-supplemented with either sodium bicarbonate at 0.5 g kg−1 or caffeine in the form of an energy drink only, beta-alanine supplementation positively impacted 3 km time trial time by approximately 2–3% in trained male soccer players during pre-season, however, both supplement forms dampen these performance improvements if consumed concurrently, indicating the need for further exploration into co-ingestion protocols. (Murphy et al.2022)

Lean tissue adaptations resulting from long-term beta-alanine supplementation, specifically increased muscle carnosine concentration, offer improved power output during high-intensity repeated efforts and delay in muscular fatigue, culminating in greater soccer-specific endurance and work capacity and potentially enhanced recovery in professional soccer players. The practical application of beta-alanine supplementation is often approached with a "start high and stay high" 6-8 weeks protocol due to this length of time potentially needed for most unsupplemented individuals who train to fail to reach an upper limit in muscle carnosine concentration. This is then maintained through daily supplementation with the associated resistance exercise until the individual feels the need to taper for a competition block. However, there is limited research on the differences in increasing beta-alanine doses for longer durations. In practical terms and from the evidence presented, it appears that beta-alanine is an effective supplement for any professional soccer players or athletes requiring a greater volume of output for a longer duration than seen in normal match-day output. In addition, it is noted that the higher the training load, the longer the effect and potential benefit of beta-alanine supplementation. Thus, it is valuable to check professional soccer players lacking in normal match-day output due to either positional, tactical or indeed motivational reasons to view on a case-by-case basis their sideline time and if there is value in their supplementation. To increase the effectiveness of beta-alanine, it is mandatory to ensure a distribution of dosing, with the largest doses taken directly before and after a heavy in-season training block, to maximise intramuscular pH buffering properties. It is also mandatory to ensure a maintenance dose of 3–4 g·d−1 is consumed to avoid muscle carnosine reductions. (Fernandes, 2021)

C. Whey Protein

Whey protein supplementation has been recommended to benefit adaptations in physical performance and health. The evidence has suggested that whey protein intake after resistance training increases muscle protein synthesis and is linked with increased ability to repair and re-synthesize muscle glycogen stores. These mechanisms are in line with those of soccer athletes in whom muscle glycogen depletion has been observed, particularly in match play, and speed, reactive strength, and peak forces are all reduced by extended periods of intermittent lower limb high-intensity work. Specifically, the consumption of whey protein concentrate (40 g) in triathletes after mixed-intensity endurance interval exercise over 3 days significantly increased the distances reached in endurance testing compared to that of the control group. Whilst all players should meet their protein requirements through the food provided, those who refuse or are unable will be encouraged to replace the lost protein in the form of a whey protein shake immediately after training. (Lin et al.2021)

A key determinant of the effectiveness of ingesting protein supplements after resistance training is the timing of consumption, owing to the fact that there exists a 45-minute 'window of opportunity' to consume adequate high-GI carbohydrates and protein to maximise glycogen super-compensation. The intake of 150 calories of protein and/or carbohydrate immediately before and after exercise has demonstrated

a significantly higher hyper-aminoacidemia compared to protein and/or carbohydrate given an hour pre or post-exercise, suggesting that there may be a potential relevance to whey protein intake. However, it has been previously demonstrated that when whey protein was fed immediately prior to the resistance exercise, significantly greater gains in lean body mass, leucine balance, BCAA clearance, and mixed muscle fractional synthesis rate were observed compared to a single group determined to have consumed protein 1-hour post-resistance exercise. (Fernandes, 2020)

Unlike oral free amino acids, which are absorbed instantaneously within the portal vein and go directly to the liver to promote increased insulin secretion, whole proteins are first digested and processed in the gastrointestinal tract to form amino acids. The current recommendation for whey protein dosage is 20 g of whey protein after each strength or endurance training session. This translates to a high dosage of 40 g of whey protein daily if athletes train twice a day. Higher dosages are given to star or very active players who train more and are working towards body composition change. The above suggestions are in line with supporting that the co-ingestion of protein with carbohydrates is more effective than either carbohydrate or protein alone in increasing muscle glycogen synthesis. The consumption of whey protein isolate and concentrate for recovery is thus only cost-effective for professional soccer clubs competing at higher levels. Being the richest natural source of leucine, optimal levels of leucine should be consumed to reap the benefits it offers in preventing muscle breakdown and shortages in muscle glycogen storage. Intake of nitrogen-rich protein sources can have a negative impact on athlete comfort. Taurine is also found in high-protein drinks but can cause diarrhoea in large doses and produce an energy 'rushing' effect too. (Vasconcelos et al.2021)

Studies have shown that a daily whey protein supplement is safe and well tolerated. The long-term safety of high protein intake in athletes has been demonstrated, and high protein diets of 2.4 g/kg to 3 g/kg of body weight of male or female soccer players have been supported. With the exception of elite stars, most sports need to maintain a constant protein intake over time as much as possible, as a chronic lack of protein will make what we intake during the recovery window of the acute loss even more critical. (Ko et al.2020)

Safety Considerations and Regulations

The ingestion of drugs or supplements has the potential to cause harm to professional soccer players through unwanted side effects, contraindications, and potentially incorrectly labelled ingredients. It is important that professional soccer players and their coaching and medical support teams have access to reliable and extensive information regarding their use of soccer. The implementation of education programs regarding the effects of potential risks associated with and available evidence in support of or against supplement use is essential in influencing the decision-making of coaching and sports nutrition staff, soccer players, and the personnel who perform anti-doping analysis. The ingestion of high-quality and well-formulated dietary supplements is of key importance to ensure that professional soccer players derive the benefits associated with the ingestion of supplements to improve exercise performance and/or provide health benefits without any side effects associated with their use. Laws and regulatory bodies ensure the safety of products from conception to the final marketed product. Adopting and adhering to good manufacturing practices, hazard analysis, and critical control points processes are recommended to ensure the reliability of the contents of a dietary supplement. Finally, professional sports organisations provide guidance on the outcomes in relation to supplement use for athletes, including inadvertent doping offenses and their sanctions. It is, therefore, crucial that individuals and organisations comply with the relevant rules and guidance or have the necessary information before using any supplements. (Aaqillah-Amr et al.2021)

4. Conclusion

Based on the systematic review presented, supplements can play a role in improving muscular strength and endurance in professional soccer players, although the results from the reviewed studies are mixed and player-specific. Consequently, when incorporating supplements into nutritional strategies, it is important to perform careful, individualised assessments. Each soccer player will have strengths and weaknesses that may differentially respond to different supplements and nutritional approaches, and so cramping all players under the same technical interventions is unlikely to maximise their strengths as athletes. With this in mind, the following are possible directions for future research in this field. More high-quality studies should consider the tested variables in the long term in order to reach a final decision. Studies combining supplements with exercise techniques such as strength, flexibility, speed, and agility have been published. In addition, a number of functional foods have been published that may have the potential to improve performance and need more research, and some studies have recommended the idea of synergistic effects. The influence of such combinations would appear to verify the need for further research, especially since the application is now confined to clinical trials. Finally, it seems sensible to endorse the suggestion of using nutritional strategies such as nutritional supplementation in addition to integrating them with training strategies to improve athletic performance. Thus, educating and increasing awareness of this important aspect of professional soccer players is crucial in order to make decisions and guide the application of available information for this category. The idea of this systematic review is not intended to persuade against using nutritional supplements but to clarify the importance of the correct application and the consequences. The inclination of athletes to be alert to the potential benefits of these nutritional supplements is potentially sufficient for a cautious endorsement. In this sense, we can also say that the conclusion does not simply consist of a concrete statement or an outright refusal to use nutritional supplementation. The message must talk about balance and about complementary advice regarding a suitable diet and athletic training.

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