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FOOTBALL TASK FORCE

SUPPLEMENTS FOR CONSIDERATION IN FOOTBALL

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KEY POINTS

- Supplements should be consumed to “supplement” a healthy balanced diet, not as a replacement.
- Sports supplements should be safe and legal, have a well-grounded scientific rationale and supporting evidence, and should be consumed alongside a daily diet that is already considered sufficient for both macro- and micro-nutrient content. Supplements should be administered with the strategic aim of improving match-day performance, promoting training adaptations and maximizing recovery.
- Players may experience progressive fatigue during match play, apparent as a graduate decline in the capacity to perform physical and technical skills. To reduce symptoms of progressive fatigue, pre-game caffeine ingestion may improve cognitive, physical and technical performance.
- Players may also experience temporary fatigue during match play, evident as a transient reduction in physical performance in the minutes following a particularly physically demanding period of the game. To improve the capacity to perform repeated bouts of high-intensity activity in close proximity to one another, players may benefit from prior loading with β-alanine, creatine and nitrate.
- Proteins high in leucine consumed post-match and post-training may facilitate recovery and training adaptations by promoting muscle protein synthesis. This can be ingested in a sports nutrition product or as normal foods.
- Vitamin D supplementation is likely necessary during the winter months (to account for the natural reduction in UV-B exposure) so as to promote immune function and bone health as well as potentially maintaining skeletal muscle function.
- Supplements should not be administered as a one-size-fits-all approach, given that many players are training for different goals (e.g., body composition issues, injury rehabilitation, etc.) and have different training loads.
- Players should initially experiment with non-familiar supplement strategies in training or simulated games (so as to evaluate any potential negative side-effects) prior to implementing during elite level competition.

INTRODUCTION

Supplements are a hot topic amongst athletes and coaches and are often used to enhance performance, improve recovery or support general health. It is important to note that there is hardly ever a need for supplements if the diet of the athlete is healthy, varied and balanced. There are exceptions where supplements can help performance or recovery, but in any case they should be consumed to “supplement” a healthy balanced diet, not as a replacement. In this context a supplement is defined as a product intended for ingestion that contains a "dietary ingredient" intended to add further nutritional value to (supplement) the diet (FDA, 2014; Finley et al., 2013). A "dietary ingredient" may be one, or any combination, of the following substances: a vitamin, a mineral, an herb or other botanical, an amino acid or a dietary substance for use by people to supplement the diet by increasing the total dietary intake with a concentrate, metabolite, constituent or extract. Sports nutrition products such as sports drinks and recovery/protein drinks are not considered supplements.

The sports supplement industry is a growing multi-billion dollar business with thousands of commercially available supplements that are all purported to improve muscle strength, power, speed and endurance as well as prevent (and promote recovery from) illness and injury. Given that all of the aforementioned indices of physical fitness are relevant to the professional footballer, it is unsurprising that elite players, coaches and sport science staff are often overwhelmed when faced with the challenge of developing a practical and evidence-based supplement strategy that supports football match play and training. Additionally, the vast majority of sports supplements commonly used by professional players are also commercially driven (as opposed to evidence based). Most importantly, the chosen approach to supplementation should adhere to the World Anti Doping Association (WADA) code of conduct in that all supplements are free from prohibited substances. With this in mind, the present chapter provides an evidence-based review of those supplements that may be considered suitable for practical use for football match play and training.

SUPPLEMENTS FOR MATCH PLAY AND TRAINING

Caffeine

Caffeine (chemical name 1,3,7-trimethylxanthine) is found in a variety of drinks and foodstuffs (e.g., tea, coffee, cola, chocolate, etc.) and is perhaps the most widely studied and research-proven of all ergogenic aids. Indeed, caffeine has been consistently shown to improve both cognitive and physical performance across a range of endurance sports such as running, cycling, rowing, swimming, etc. (see Burke et al., 2013 for a comprehensive review). However, numerous data suggest that caffeine also improves the physical and technical elements of performance that are inherent to football match play. For example, caffeine can enhance repeated sprint and jump performance (Gant et al., 2010), reactive agility (Duvnjak-Zaknich et al., 2011) and passing accuracy (Foskett et al., 2009) during intermittent-type exercise protocols. The ergogenic effects of caffeine are typically achieved with ingestion of 2-6 mg/kg BM (Burke et al., 2013). Given that plasma caffeine levels peak approximately 45-60 min after ingestion (Graham & Spriet, 1995), it is recommended to consume caffeinated drinks, capsules or gels (depending on players' preferences) within the warm-up period prior to kick-off.

Although the precise ergogenic mechanisms are still considered elusive, most researchers agree that the ability of caffeine to modulate the central nervous system (CNS) is the predominant mechanism (Meeusen, 2014). Indeed, caffeine is readily transported across the blood-brain barrier and can act as an adenosine antagonist, thereby opposing the action of adenosine. As such, caffeine can increase concentrations of important neurotransmitters such as dopamine (Fredholm, 1995), the result of which manifests itself as increased motivation (Maridakis et al., 2009) and motor drive (Davis et al., 2003). In addition to its effect on the CNS, recent data suggest that caffeine may also exert its ergogenic influences during high-intensity intermittent exercise through an additional mechanism related to maintenance of muscle excitability. Indeed, Mohr et al. (2011) observed improved performance on Yo-Yo Intermittent Recovery Test 2 (a highly reliable and valid test of football-specific high-intensity exercise performance) following caffeine supplementation that was associated with reduced muscle interstitial accumulation of potassium (K^+) during intense intermittent exercise. The latter observation is consistent with the notion that extra-cellular accumulation of potassium is a contributing cause of fatigue during very high-intensity exercise.

In contrast to match days when specialized caffeine sports products are typically consumed, players may achieve ergogenic effects on training days by consuming caffeine in the form of tea or coffee with their breakfast meal prior to training. Indeed, this strategy seems appropriate given recent evidence that pre-exercise coffee ingestion induces similar performance benefits to that of anhydrous caffeine ingestion (Hodgson et al., 2013). Finally, it has been suggested that post-training caffeine ingestion may help promote recovery and performance during a subsequent training session undertaken on the same day. Indeed, post-exercise muscle glycogen resynthesis was enhanced when caffeine (8 mg/kg administered as 2 x 4 mg/kg doses at 2-h intervals) was co-ingested with post-exercise carbohydrate feeding (Pedersen et al., 2008). Accordingly, high-intensity intermittent running capacity is enhanced during an afternoon training session completed four hours after a morning training session when adopting the same dosing protocol as the previous authors (Taylor et al., 2011). It is noteworthy, however, that not all researchers have observed that post-exercise caffeine ingestion enhances muscle glycogen resynthesis (Beelen et al., 2012).

Despite the substantial evidence base supporting caffeine ingestion for exercise performance, it is highly recommended that players initially experiment with caffeine in training sessions (so as to evaluate any unwanted negative side effects and optimize individual dosing strategy) prior to implementing in competitive games. Indeed, not all individuals display performance enhancements after acute caffeine ingestion, and large doses (i.e., especially > 6 mg/kg BM) may often induce negative symptoms such as increased heart rate, irritability, tremor, confusion, reduced concentration and shortness of breath, etc. (Graham & Spriet, 1995). Furthermore, consuming high doses of caffeine prior to or during night games can also be problematic given that sleep quality can be negatively affected (Drake et al., 2013).

Creatine

In addition to caffeine, creatine is also one of the most widely researched supplements that has a strong supporting evidence base. Creatine is a guanidine compound that it is synthesized in the liver and kidney from the amino acids arginine and glycine. From a dietary perspective, the predominant sources of creatine are fish and red meat. The largest store of creatine in the body is skeletal muscle (Wyss & Kaddurah-Daouk, 2000), where approximately 60-70% is stored as a phosphorylated form known as phosphocreatine (PCr). Creatine supplementation has traditionally been associated with strength and power athletes such as weightlifters and sprinters given the role of PCr hydrolysis in regenerating ATP during the initial seconds of supra-maximal activity. In the context of football, however, creatine supplementation is also of particular reference given that phosphocreatine stores exhibit significant declines during football match play (Krustrup et al., 2006). Accordingly, creatine supplementation improves repeated sprint performance during both short duration (Casey et al., 1996) and prolonged intermittent exercise protocols (Mujika et al., 2000), likely due to increased resting muscle PCr stores as well as improved rates of phosphocreatine resynthesis in the recovery periods between successive sprints (Casey et al., 1996). In addition to augmenting repeated sprint performance, players may also wish to consume creatine with the goal of augmenting training-induced improvements in muscle mass, strength and power (e.g., Branch, 2003).

Harris et al. (1992) provided the initial evidence that creatine supplementation (using a loading protocol of 20 g/d for 5 d) increased (in the magnitude of 20%) both total creatine and PCr stores in skeletal muscle. As such, the conventional creatine dosing strategy is to undertake a loading protocol (usually involving 4 x 5 g doses/d for 5-7 d) followed by a daily maintenance dose of 3-5 g/d (Hultman et al., 1996). However, given that player adherence to such a protocol may be limited, it is noteworthy that daily consumption of a lower dose over a longer period (i.e., 3 g/d for 30 d) will eventually augment muscle creatine to a similar level as that observed with classical loading protocols (Hultman et al., 1996). Upon cessation of supplementation, the elevated muscle creatine stores tend to return towards basal levels within 5-8 weeks (Hultman et al., 1996). To maximize creatine storage to a given dose, it is also recommended that creatine be consumed post-exercise and in conjunction with carbohydrate and/or protein feeding given that contraction and elevated insulin are known to increase muscle creatine uptake (Robinson et al., 1999). In a practical context, this means ensuring creatine provision before and after training periods in conjunction with other sports nutrition products containing carbohydrate (and/or protein) or with whole food provision at the main meals of breakfast, lunch and dinner. Prior loading with creatine may also enhance post-exercise muscle glycogen resynthesis rates (Robinson et al., 1999). Considering the difficulty of replenishing post-game muscle glycogen stores even with sufficient carbohydrate and protein intakes, this strategy appears relevant during those periods of intense fixture schedules when multiple games are played with limited recovery time.

Analogous to caffeine, it is noteworthy that not every individual will respond similarly to creatine supplementation in terms of both augmentation of muscle creatine stores and subsequent improvements in performance. Indeed, the magnitude of elevation of muscle creatine to a given dose of creatine supplementation is highly variable and appears to be largely determined by the initial level of muscle creatine concentration prior to supplementation, the latter likely determined by habitual diet (Hultman et al., 1996). In general, individuals with lower muscle creatine stores exhibit greater increases in total muscle creatine during supplementation compared with those individuals who already exhibit high concentrations of muscle creatine (Hultman et al., 1996). Accordingly, creatine-induced improvements in intermittent exercise performance are greater in those individuals who exhibited larger increases in muscle (especially Type II fibres) creatine and PCr (Casey et al., 1996).

Acute creatine supplementation (i.e., loading) can also induce a 1-1.5 kg gain in body mass, an effect that is greater in men compared with women (Mihic et al., 2000). Such increases in body mass are confined to fat free mass and are likely due to an increase in intra-cellular water accumulation. For this reason, not all players may choose to supplement with creatine given the perception that they feel heavier and slower, an effect that may be especially relevant for those lighter players (such as strikers and wide midfielders) who rely on speed and agility as key physical attributes. Additionally, creatine supplementation is also often perceived to have negative health effects in terms of liver and kidney function. It is noteworthy, however, that prospective studies demonstrate no adverse health effects in healthy individuals who were long-term creatine users (Poortmans & Francaux, 1999). Nevertheless, given that it takes weeks for creatine stores to return towards basal levels upon the cessation of supplementation (hence ergogenic effects should still occur), it may be prudent for players to “cycle” creatine supplementation to specific stages of the season (e.g., pre-season, congested fixture schedules) and/or training goals (e.g., strength / hypertrophy goals).

β-alanine

In skeletal muscle cells, β-alanine combines with L-histidine to form the dipeptide β-alanyl-L-histidine, the latter more commonly known as carnosine. Carnosine is of particular reference for high-intensity exercise performance given that it can act as an intracellular buffer to H+ due to its imidazole ring having a pKa of 6.83 whilst also being present in muscle at fairly high concentrations (e.g. 10-60 mmol/kg d.w) (Hobson et al., 2012). Given the repeated sprint nature of football match play, muscle pH declines to levels that may impair the capacity to generate ATP through glycolytic metabolism (Krustrup et al., 2006). As such, it has become common practice for football players to consume daily β-alanine supplements (as the rate-limiting determinant of carnosine synthesis) so as to increase muscle carnosine stores and hence, potentially improve high-intensity exercise performance. Indeed, in relation to the former, daily β-alanine supplementation has been consistently shown to elevate skeletal muscle carnosine concentration by approximately 50% in both type I and II human skeletal muscle fibres (Hill et al., 2007; Harris et al., 2012). Furthermore, in recent meta-analyses, Hobson et al. (2012) concluded likely ergogenic effects of β-alanine supplementation during high-intensity sports lasting in duration from 1- 6 min such as track and field events, cycling, rowing and swimming.

Unfortunately, investigations evaluating the effects of β-alanine supplementation during high-intensity intermittent exercise protocols that are applicable to football are both limited and conflicting. For example, Saunders et al. (2012a) observed no beneficial effect of four weeks of β-alanine supplementation (6.4 g/d) on sprint performance during the Loughborough Intermittent Shuttle Test, a prolonged field test designed to mimic the activity pattern of team sports. In contrast, the same researchers later observed improved performance during the Yo-Yo Intermittent Recovery Test Level 2 following 12 weeks of daily supplementation with 3.2 g of β-alanine (Saunders et al., 2012b). Unfortunately, both studies did not report changes in muscle carnosine stores following supplementation though it is possible that the enhanced effect observed in the latter study was due to the longer period of supplementation. This hypothesis is especially relevant given that length of β-alanine supplementation is a determinant of increases in muscle carnosine concentration (Hill et al., 2007).

A negative side effect of β-alanine supplementation when administered as single doses >10 mg/kg BM (especially when in solution or as gelatin capsules) is a flushing of the skin and tingly sensation (Harris et al., 2006), a phenomenon known as paraesthesia. To reduce such symptoms, sustained release formulations have been developed that allow two 800 mg doses to be ingested simultaneously without any symptoms (Decombaz et al., 2012). Although the optimal dosing and delivery strategy of β-alanine supplementation is not currently known, it is noteworthy that a significant linear relationship exists between total β-alanine intake (within the range of 1.6-6.4 g/ d) and both relative and absolute increases in muscle carnosine (Stellingwerff et al., 2012a). To this end, Stellingwerff et al. (2012b) observed that four weeks of supplementation with 3.2 g of β-alanine induced 2-fold greater increases in muscle carnosine stores compared with 1.6 g daily.

Moreover, these researchers also observed that subsequent daily doses of 1.6 g/d continued to induce further increases despite already high carnosine stores following the four weeks of higher dose β-alanine supplementation. More recently, Stegen et al. (2014) also observed that following six weeks of 3.2 g β-alanine/d a further daily maintenance dose of 1.2 g/d was required to maintain muscle carnosine content elevated at 30-50% above baseline values. Indeed, upon cessation of supplementation, muscle carnosine stores typically return towards basal levels within 10-20 weeks (Baguet et al., 2009). On the basis of the above background, it is therefore recommended that where muscle carnosine stores are required to be elevated quickly (perhaps during important stages of competition such as intense fixture schedules), loading with larger doses (e.g. 3-6 g/d for 3-4 wks) would be initially beneficial followed by daily maintenance doses >1.2 g. To minimize symptoms of paraesthesia, players may benefit from consuming slow-release formulas in a number of doses spread evenly throughout the day.

Nitrate

In recent years, dietary inorganic nitrate supplementation has received a significant amount of research attention due to the effects of nitric oxide on a variety of physiological functions. Indeed, nitric oxide has well-documented roles in regulating blood flow, muscle glucose uptake and contractile properties of skeletal muscle (Jones, 2014). The traditional pathway of endogenous nitric oxide production is recognized as that of L-arginine oxidation, as facilitated by the enzyme nitric oxide synthase. However, it is now known that dietary ingestion of inorganic nitrate can also be metabolized to nitrite and subsequently, nitric oxide, thereby complementing that produced from the L-arginine pathway (Hord et al., 2009). Identification of this biochemical pathway has therefore led to a series of studies conducted in the last decade evaluating the effects of inorganic nitrate ingestion on exercise performance.

Nitrates are especially high in green leafy vegetables such as beetroot, lettuce and spinach though the exact content can vary considerably based on soil conditions and time of year. As a means to provide a constant dose of nitrate, most researchers have therefore used standard doses of beetroot juice (0.5 L is equivalent to approximately 5 mmol nitrate) so as to elevate nitrate and nitrite availability. Using both chronic (ranging from 3-15 d of 0.5 L beetroot juice per day) and/or acute ingestion 2.5 h before exercise, it was collectively demonstrated that nitrate ingestion reduces blood pressure, lowers oxygen consumption for a given workload or velocity during steady-state exercise as well as improving exercise capacity during short-duration high-intensity cycling or running (Bailey et al., 2009, 2010; Vanhatalo et al., 2010; Lansley et al., 2011a). These initial studies were later supported by experiments demonstrating that acute (Lansley et al., 2011b) and chronic beetroot juice ingestion (Cermak et al., 2012) in trained but sub-elite athletes also improved cycling time trial performance in distances ranging from 4 km to 16.1 km (i.e., approximately 5-30 min of exercise). It is noteworthy, however, that the performance-enhancing effects of nitrate is not readily apparent in elite athletes (Wilkerson et al., 2012), likely due to a combination of underpinning differences in the physiology of elite versus sub-elite athletes that collectively render a trained athlete less sensitive to additional nitric oxide availability, e.g., higher nitric oxide synthase activity, plasma nitrite values, greater muscle capillarization, higher type I fibres (Jones, 2014).

The mechanisms underpinning reduced oxygen cost of exercise and improved capacity/performance are currently thought to be due to improved muscle efficiency and energy metabolism (Jones, 2014). For example, Bailey et al. (2010) observed that reduced oxygen uptake during exercise (following six days of 0.5 L beetroot juice ingestion per day) was associated with reduced PCr degradation and accumulation of ADP and Pi, thus implying a reduced ATP cost of contraction for a given power output and hence reduced signals to stimulate respiration. Using three days of sodium nitrate ingestion (0.1 mmol/kg BM), Larsen et al. (2011) suggested that mitochondrial efficiency in mitochondria might be improved in isolation from human skeletal muscle following supplementation. More recently, Haider and Folland (2014) observed that seven days of nitrate loading in the form of concentrated beetroot juice (9.7 mmol/d) also improved in vivo contractile properties of human skeletal muscle, as evidenced by improved excitation-coupling at low frequencies of stimulation as well as explosive force produced by supra-maximal stimulation.

The optimal loading dose to facilitate the ergogenic effects of nitrate is also not currently well known, especially in relation to whether acute (i.e., 2.5 h before exercise) or chronic (i.e., several days) loading protocols are required. Nevertheless, in the acute context, Wylie et al. (2013a) observed that the improved exercise tolerance (relative to placebo) was not different when 8.4 or 16.8 mmol of nitrate was ingested 2.5 h before exercise. It is noteworthy, however, that the reduction in oxygen cost during exercise associated with nitrate ingestion was greater with the higher dose. Such data suggest that inability to detect physiological effects of nitrate in acute scenarios (especially with elite athletes) may be overcome by using higher pre-exercise dosing strategies and/or longer duration dosing protocols (>3 days).

Despite the data reviewed above, convincing evidence demonstrating ergogenic effects of nitrate ingestion during intermittent exercise protocols relative to football is not yet available. However, using a more aggressive loading dose of concentrated beetroot juice (approximately 30 mmol in a 36 h period), Wylie et al. (2013b) observed significant improvements in the distance run on the Yo-Yo Intermittent Recovery Test Level 1 when compared with placebo supplementation. Interestingly, these researchers observed reduced plasma glucose during exercise in the beetroot trial, suggesting that muscle glucose increased and that improved performance may be due to muscle glycogen sparing. Additionally, improved performance may have been due to maintained muscle membrane excitability given that plasma K^+ was lower during exercise following beetroot juice supplementation. From a practical perspective, the use of an intense 36 h nitrate loading protocol is likely to gain more acceptance amongst football players than the conventional 3-6 day loading approach. Nevertheless, the practical application of nitrate supplementation (even in concentrated form) may be limited due to the taste and palatability issues of the current nitrate products that are commercially available. Given the limited available evidence for football-specific protocols, it is therefore highly recommended that players experiment with nitrate supplementation (perhaps even more so than the supplements reviewed previously) prior to implementing in high-level competition.

Protein

Although protein is not considered ergogenic to exercise performance, protein ingestion in close proximity to the exercise stimulus increases skeletal muscle protein synthesis (MPS), and thereby facilitates post-exercise skeletal muscle remodeling processes. To this end, ingestion of 20-30 g of protein is sufficient to induce maximal rates of MPS (Res, 2014; Moore et al., 2009). Furthermore, because of its rapid rates of digestion and elevated leucine concentration, whey proteins are superior to both soy and casein protein sources (Tang et al., 2009). Given that liquid protein induces higher plasma aminoacidemia than solid protein sources, it is therefore recommended that players have access to whey-based liquid protein immediately after games.

In the context of training days, 20-25 g of protein can be easily consumed through whole foods with the breakfast meal (e.g., milk, eggs, yoghurt, etc.), although occasionally it may be more practical to deliver protein in the form of a protein shake or drink that delivers the exact amount of protein in a convenient form. The training practices of football players usually consist of a pitch-based football-specific session (from 10:30 a.m. to 12 p.m.), immediately followed by 30-45 min of resistance-type training intended to promote a combination of hypertrophy, strength and power. Given that breakfast will have typically been consumed at 9 a.m., it might therefore be beneficial to provide access to high-quality protein sources prior to the gym-based session so as to promote recovery from the pitch-based session but also provide a rapid supply of amino acids for the subsequent resistance-training session. In practice, this can be achieved for example by providing 20 g of whey protein in the form of a flavored ready-to-drink formulation which might also promote player adherence. It is also beneficial for players to consume 30-40 g of casein based protein prior to sleep so as to stimulate MPS and promote overnight recovery (Res et al., 2012).

Vitamin D

Vitamin D is a hormonal precursor that plays a well-documented role in supporting bone health and immune function. However, the discovery of the vitamin D receptor in human skeletal muscle has led to increased research on the potential role of vitamin D in regulating MPS and muscle function, thus having obvious implications for training adaptations. The study of vitamin D is particularly relevant given that many athletes, including professional football players, exhibit vitamin D deficiency in the winter months (Morton et al., 2012; Close et al., 2013a). At this time, there is no UV radiation of appropriate wavelength for cutaneous production of previtamin D_3 to occur (Webb & Holick 1988).

To account for the seasonal variation in ultraviolet-B radiation during winter, it has therefore become common practice to supplement with vitamin D_3 (cholecalciferol) in order to promote vitamin D synthesis. To this end, daily supplementation with 5,000 IU appears a safe and tolerable dose to restore circulating 25 (OH)D concentrations to sufficient levels within six weeks, i.e., approximately 100 nmol/L (Close et al., 2013a). Although not conclusive, preliminary evidence also suggests that vitamin D supplementation in those athletes who exhibit severe deficiency (i.e., 25 (OH)D < 12.5 nmol/L) can improve sprint and jump performance in a cohort of youth professional football players (Close et al., 2013a).

In an attempt to promote training adaptations as well as maintain both bone and immune health, it is therefore recommended that football players correct any deficiency with appropriate supplementation strategies during the winter period when exposure to natural sunlight is likely negated. Furthermore, because of the clinical implications of both vitamin D deficiency but also toxicity, it is highly advised that individuals' baseline serum 25 (OH)D levels are suitably assessed using reliable and valid techniques (such as tandem mass spectrometry) prior to intervening with any supplement strategy. The latter point is particularly pertinent given that the magnitude of increases in serum 25 (OH)D is inversely proportional to basal levels (Close et al., 2013b) and hence, a one-size-fits-all approach to supplementation is not appropriate. Indeed, high dose supplementation in individuals exhibiting high basal levels may also increase the risk of toxicity. Despite uncertainty with optimal dosing strategies, recent data suggests that weekly supplementation of 40,000 IU per week for six weeks is superior to 20,000 IU in terms of magnitude of elevation, though it is noteworthy that six weeks of continued supplementation with 40,000 IU induces no further elevations beyond 100 nmol.L-1 (Close et al., 2013b). At present, daily supplementation of 5,000 IU therefore appears a safe and practically relevant dose though players should also seek medical advice.

PRACTICAL APPLICATIONS

Based on the evidence reviewed above, a number of potential practical supplement strategies are presented below. It should be noted that these recommendations are not intended to be immediately applicable or relevant to every player. Rather, these strategies could be adopted as initial starting points for which to experiment with during non-competitive situations so as to fine-tune individual approaches to supplementation for competition and important phases of training.

- Ingestion of caffeine 30-60 min prior to match play can improve cognitive, physical and technical elements of performance. Ergogenic effects are achieved with 2-6 mg/kg BM in either capsule, fluid or gel format. Pre-training ingestion of caffeine can be readily achieved by coffee ingestion with the breakfast meal.

- Creatine can enhance repeated sprint performance during match play, promote post-exercise muscle glycogen resynthesis and also augment training-induced gains in lean mass, strength and power. To achieve ergogenic effects, players can undertake a five-day loading dose (4 x 5 g per day) followed by a daily maintenance dose (e.g., 3-5 g). Alternatively, a more practically relevant strategy may be to consume 3 g daily though it is noteworthy that longer periods are required (e.g., 30 days) to augment muscle creatine stores.
- Supplementation with β-alanine (1.6-6.4 g/d) augments muscle carnosine stores within several weeks that can subsequently buffer the metabolic acidosis associated with high-intensity exercise, thereby improving repeated sprint performance. To minimize symptoms of paraesthesia (i.e., tingling of the skin) associated with supplementation, players should consume "slow-release" formulas in doses spread evenly throughout the day.
- Pre-match nitrate supplementation (especially using an intense loading dose of 30 mmol in 36 h) may improve repeated sprint performance. This may be achieved by consuming concentrated beetroot juice in the day before match day as well as in the hours before the game.
- Post-match and post-training ingestion of 20-30 g of whey protein can induce maximal rates of MPS, thereby promoting recovery and training adaptation. To promote overnight recovery, players may consume 30-40 g of casein protein prior to sleeping.
- Daily consumption of 5,000 IU vitamin D during the winter months can restore any seasonal decline in vitamin D to levels deemed as sufficient, thus promoting immune and bone function and potentially improving training adaptations through modulation of MPS.

SUMMARY

Professional football players typically train 5-6 days per week, which consists of both pitch-based training to promote football-specific fitness and resistance training that is intended to increase muscle strength and power. These diverse training stimuli are usually in close proximity of one another with minimal recovery between successive sessions. Given the concurrent training demands as well as the requirement to participate in up to three games per week, the cumulative weekly physiological loading is complex and recovery time is limited. In addition to ensuring a daily energy intake that is sufficient in both macro- and micronutrient quantities, it is therefore common practice for sports science support staff to implement a supplement policy in an attempt to maximize training adaptations, match-day performance and recovery. It is noteworthy, however, that the evidence base in favor of the many popular supplements reviewed herein has typically been derived from endurance-type or high-intensity exercise protocols as opposed to the high-intensity "intermittent" exercise stimulus that is characteristic of football match play and training. Furthermore, much of the sports supplement research has used recreationally active or sub-elite participants and hence there is a definitive need for further high-quality research utilizing both highly trained athletes and football-specific exercise protocols. Additionally, players should initially experiment with non-familiar supplement strategies in training or simulated games (so as to evaluate any potential negative side-effects) prior to implementing during elite level competition.

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