Nutrition in Soccer: A brief review of the issues and solutions

Caruana Bonnici, D. [1], Greig, M.[1], Akubat, I. [2], Sparks, S.A. [1], Bentley, D. [3], and Mc Naughton, L.R. [1]

1 Department of Sport and Physical Activity, Edge Hill University, Ormskirk, L39 4QP, UK doriannecaruanabonnici@gmail.com Greigm@edgehill.ac.uk, Sparksa@edgehill.ac.uk, lars.mcnaughton@edgehill.ac.uk

2 Faculty of Arts, Society and Professional Studies, Newman University, B32 3NT, Birmingham, UK Ibrahim.Akubat@newman.ac.uk

3 College of Nursing and Health Science, Flinders University, Adelaide 5001, South Australia, Australia david.bentley@flinders.edu.au

Corresponding Author:

Professor Lars R Mc Naughton
Department of Sport and Physical Activity,
Edge Hill University,
Ormskirk,
L39 4QP, UK
lars.mcnaughton@edgehill.ac.uk

Abstract

This review examines the issues surrounding soccer nutrition, including the nature of the game, training, and how nutrition can play a significant role in improving player performance and recovery. In soccer match-play, a total distance covered of up to 13 km is characterised by an acyclical and intermittent activity profile. The aerobic system is highly taxed, with average heart rates of ~85% of maximal values, and the finite muscle glycogen stores represent a key aspect of the interface between training, performance and nutritional support. Diets with high CHO content can optimise muscle glycogen, reduce net glycogen depletion, delay the onset of fatigue and improve soccer performance. It is more common however, for players to consume an excessive amount of protein in their daily diet perpetuating the popular belief that additional protein increases strength and enhances performance. More comprehensive recommendations suggest that soccer players should consume a high CHO diet from nutrient-rich complex CHO food sources that ranges from a minimum of 7 $g \cdot kg^{-1}$ BM to 10 $g \cdot kg^{-1}$ BM and up to 12 $g \cdot kg^{-1}$ BM on match or heavy training days. Unfortunately, players often have a low energy intake which can lead to negative energy balance, especially at times of schedule congestion. In many cases soccer players often consume diets that are not very different from those of the general public. Therefore, despite a clear understanding of the physiological demands of soccer, and the association between nutritional preparation and performance, the dietary habits of soccer players are often characterised by a lack of education and mis-informed sporting traditions. This review discusses the potential barriers and various nutritional phases that need to be considered for training, pre, on the day of, and post-match to enable players and coaches to be more aware of the need to achieve more optimal macronutrient nutrition.

Introduction

In soccer match-play, a total distance covered of up to 13 km (Mascio and Bradley 2013) is characterised by an acyclical, and intermittent activity profile (Williams 2012; Mohr, et al. 2005) that challenges a variety of physiological systems (Alghannam 2013; Bangsbo 2014). During 90 min of a match ~90% of activity is performed at a low to moderate intensity (Bangsbo 2014). This is usually characterised as movement ≤15 km.h^{-1} in elite players (Mohr et al. 2003). In this case the primary energy pathway might be presumed as glycogenolysis and glucose oxidation (Stolen et al. 2005). The aerobic system is highly taxed, with average and peak heart rates of ~85 and 98% of maximal values respectively (Bangsbo 2006; Krustrup et al. 2005), corresponding to an average oxygen uptake of around 70% of maximum (Andrzejewski et al. 2012). The ratio of low-to-high intensity exercise (where low, moderate and high are 4-12, 15-17, >18 km.h^{-1} respectively), has previously been reported as ~ 2.5:1 in terms of distance, or ~ 7:1 in time (Reilly 2007).

While constituting a small proportion of the total distance covered, the high-intensity efforts, characterised as high running speeds (>18 km.h^{-1}) or sprinting (~30 km.h^{-1}) (Mohr et al. 2003) are a crucial element in elite soccer performance (Bangsbo 2014; Di Salvo et al. 2009), since the most decisive actions in a match are often performed in this category (Stolen et al. 2005; Mohr, Krustrup et al. 2005). High-intensity activities require use of the anaerobic systems which fuel actions such as tackling, jumping, sprinting (Aziz, Chia and Teh 2000), and ball possession (Reilly 2007; Aziz et al. 2000). Elite players complete around 150 to 250 high intensity bouts (FIFA 2016; Mohr et al. 2005), of up to 4 seconds duration (O'Donoghue et al. 2001) which may occur every 40 to 70 s (Bradley et al. 2010; Reilly, 1994b), but 98% of these bouts are under 10 s in duration (O'Donoghue 2002).

The intensity profile of match-play therefore has implications for energy expenditure and the nutritional strategies required to support these energy demands. Many factors contribute to success, with nutrition playing a small, but vital part, relative to the influence of genetic endowment, skill, training, motivation and others (Maughan and Shirreffs 2007a). Nonetheless, a carefully-planned nutritional strategy that meets overall energy expenditure demands, should optimise energy stores, reduce fatigue, support training, achieve and maintain optimal body mass and physical condition, promote rapid recovery, and supply adequate hydration. This can offer additional related benefits and provide a competitive advantage. The aim of this review is therefore, to consider and evaluate the nutritional demands and dietary habits of elite soccer players, and to provide evidence-based recommendations for macronutrient and fluid intake.

Nutrition and Soccer Performance

Carbohydrate

Carbohydrate (CHO) is a vital macronutrient for both soccer training and performance. It is an essential fuel for high intensity long duration activity, but storage of these carbohydrates is limited, and it can easily become depleted (Shephard and Leatt 1987; Zehnder et al 2001). When CHO stores are inadequate to meet the energy needs of the players' training requirements, several physical, technical and cognitive parameters are at stake, jeopardising training/playing capacity (Burke, Loucks and Broad 2006; Bangsbo, Mohr and Krustrup 2006). A common feature, which is often experienced during prolonged sessions of ≥90 min of submaximal or intermittent high-intensity activity, is fatigue. Noakes (2000) and Nybo (2003) reported that such fatigue may be experienced in the skeletal muscles (peripheral fatigue) and/or in the central nervous system (central fatigue), both of which will negatively impact performance by reducing either skeletal muscle contraction or central drive.

Conversely, a chronic excessive macronutrient intake may alter the players' body composition (Clark 1994). Early work by Sherman et al. (1981), suggested that an upper limit of around 600 $g.day^{-1}$, (or 8 $g.kg^{-1}$) beyond which additional CHO does not contribute significantly to muscle glycogen storage and performance. Thereafter, the loading intake suggestions were revised to include high CHO intake in the two or three days before competition (Hawley, Dennis and Noakes 1994) to maximise muscle and liver glycogen reserves (Little et al. 2010) and enhance prolonged intermittent exercise performance. Balsom et al. (1999) observed a 38% increase in muscle glycogen concentrations following 48 h of high CHO intake, which is likely to result in more high intensity running (Bangsbo et al. 1992). Other researchers have also demonstrated the important contribution of pre-match meals such as breakfast, which has been shown to increase muscle glycogen content by up to 10% (Chryssanthopoulos et al. 2004). What is also now clear, is that such loading strategies are not required for every day, and fuelling should be specifically targeted to address the needs of session that players are preparing for a practice session or game (Anderson et al., 2016).

Nicholas et al. (1999) reported that CHO ingestion during exercise, normally in the form of fluid which enables absorption, has been found to improve soccer-specific exercise capacity. Fluid CHO ingestion has been associated with spared glycogen (Williams 2012; Nicholas et al. 1999), reduced risk of hypoglycaemia, maintained plasma glucose concentrations and improved running time to fatigue (Foskett et al. 2008). In a previous review Phillips, Sproule and Turner (2011) concluded that studies are almost unanimous in supporting the consumption of CHO-electrolyte solutions during prolonged intermittent exercise for maintaining and/or improving exercise performance and capacity.

Adequate post-exercise CHO intake has been shown to maximise recovery of muscle glycogen stores allowing for more frequent and higher-quality training sessions (Maughan and Shirreffs 2007b; Ranchordas et al., 2017), recovery between matches, and enhanced training adaptation (Ono et al. 2012). This strategy produces an increased rate of muscle glycogen re-synthesis (Ivy et al. 1988) compared to a normal mixed diet (Burke et al. 2004). Failure to consume CHO in the immediate phase of post-exercise recovery leads to very low rates of glycogen restoration and can impair performance (Williams 2012). The appropriately timed intake of such ingestion is paramount because it provides an immediate source of substrate to the muscle cell to start effective recovery (Ivy et al. 1988). The type of CHO provided is also important, CHO-rich foods with a moderate or high glycaemic index (GI) appear to have some advantages in promoting glycogen synthesis (Burke et al. 1993). Fluid versus solid CHO does not appear to affect glycogen synthesis (Keizer et al. 1986). The pattern of food intake does not appear to affect glycogen storage in overall daily recovery so long as the total CHO needs are met (Burke et al. 2011), but when exercise is likely to occur again within 8 h, CHO should be consumed as soon as possible to maximise the rate of glycogen resynthesis (Burke 2004). Therefore, planning strategies which include consuming CHO before, during and in the recovery period between exercise bouts is of great importance for the player (Drobnic et al., 2016). The player's eating and drinking plan must therefore provide enough CHO to fuel their training programme and to optimize the recovery of muscle glycogen stores between workouts and demanding matches. In addition to these acute manipulations, more recently, researchers and practitioners have attempted to further enhance training adaptations by periodising nutritional intake (Anderson et al. 2017).

Protein

In comparison to CHO, there are only a few studies which have investigated the effects of protein ingestion in soccer (Maughan and Shirreffs 2007b; Hawley, Tipton and Millard-Stafford 2006; Tipton and Wolfe 2004). Protein ingestion near the time of exercise may promote a positive nitrogen balance across the active muscles and facilitate a more effective adaptation to training. If players delay protein supplementation after a match or training, net protein balance will remain negative which is likely to result in a decrease in muscle mass; a vital component in soccer performance. Data from Levenhagen et al. (2001) show that delayed feeding of just three hours reduces the whole-body protein synthetic rate by 12% (based on the rates of appearance of endogenous leucine of 2.69 ± 0.13 $mg.kg^{-1}.min^{-1}$ and 2.40 ± 0.11 $mg.kg^{-1}.min^{-1}$ for early and delayed feeding respectively). In addition, eccentric contractions caused by deceleration associated with soccer movement patterns and well as contact between players, causes skeletal muscle damage (Res, 2014). There is however a considerable volume of research which has investigated a wide variety of protein ingestion strategies for the promotion of training adaptations and recovery from damaging exercise (Phillips et al. 2015). Therefore, in the absence of studies which have directly used soccer as an exercise model, much of the recommendations are based on work examining other participant populations and exercise protocols (Cockburn et al., 2008; Moore et al., 2009; Sollie at al., 2018;).

Protein supplementation has been shown to expedite skeletal muscle protein turnover by upregulating muscle protein synthetic rate under conditions of increased physiological stress that would otherwise favour negative protein balance, such as those applied during a congested soccer schedule (Pasaikos, Liebermann and McLellan, 2014; Draganidis et al., 2013). In a recent study, Poulios (2018), provided evidence that protein feeding may be advantageous for eccentric and concentric lower limb muscle strength and high-speed running performance, whilst also allowing faster recovery of protein and lipid peroxidation during a congested schedule. Other studies suggest that, recovery from injury typically requires additional protein (Medina, Lizarraga, & Drobnic, 2014), gelatin or hydrolysed collagen (Close et al., 2019). Protein therefore is a key macronutrient, required to optimise recovery after matches and hard training sessions (Res, 2014).

Evidence suggests that the inclusion of 3-4 g of whey protein with CHO may be beneficial to performance in intermittent exercise (Highton et al. 2013). Adding protein to a CHO supplement increased endurance running capacity towards the end of a simulated soccer match by 43% when compared to a CHO solution with equal energy content alone (Alghannam 2011). Where a lower amount of CHO is consumed, the co-ingestion of protein (0.4 $g{\cdot}kg^{-1}h^{-1}$) could be useful for increasing post-exercise muscle glycogen synthesis rates, as it may stimulate insulin secretion and muscle glycogen synthase, which have previously been shown to be key determinants of glucose disposal and uptake (Ebling et al. 1993). Further research investigating the precise type and amount of each nutrient required to optimise training and competition in soccer is warranted, since even elite players may not be ingesting optimal nutrients for the volume and type of training they are undertaking (Anderson et al 2017; Brinkmans et al. 2019).

Nutritional Demands of Soccer Players

Carbohydrate requirements

Players should be aware of issues relating to quantity, quality and timing of their CHO intake (FIFA 2016). Considering the heavy reliance on endogenous CHO stores in soccer, and the fact that only enough CHO to last for a single day of hard training can be stored (Coyle 1991), the primary need for players is to consume sufficient CHO nutrient-rich complex food sources. Diets with high CHO content can optimise muscle glycogen, reduce net glycogen depletion, delay the onset of fatigue and improve soccer performance (Williams and Rollo 2015). Such a strategy will enable training load and intensity to be sustained, as well as to facilitate recovery between games (Zehnder et al. 2001; Rico-Sanz, et al. 1999). The CHO recommendations for soccer players suggests between 60 to 70% (FIFA 2016) of total daily energy intake (TDEI). More comprehensive specific recommendations suggest that soccer players should consume a high CHO diet from nutrient-rich complex CHO food sources that ranges from a minimum of 7 $g \cdot kg^{-1}$ BM daily (Burke et al. 2006; Hawley, Tipton and Millard-Stafford 2006) to 10 $g \cdot kg^{-1}$ BM daily (Hawley, Dennis and Noakes 1994), and up to a maximum of 12 $g \cdot kg^{-1}$ BM daily for intensive training or maximum glycogen refuelling (Burke et al. 2004). The majority of CHO intake should come from nutrient-dense CHO-rich or complex foods, rather than simple CHO foods containing refined sugars that are not particularly nutrient-rich (Deakin 1994).

Carbohydrates are classified according to their postprandial glycaemic response (Burke et al. 2001), relating to how quickly CHO raises blood glucose concentrations following ingestion (Burke et al. 2001). High GI (≥70) foods are rapidly digested and absorbed and characterised by a rapid increase in blood glucose and muscle glycogen, making them particularly useful for recovery between training session in the same day (Burke et al. 2004). Foods in this category include white bread, white rice, sports drinks, many soft drinks, sugar, jam, and honey among others (Williams 2012). Low GI (≤ 55) foods are digested and absorbed slowly, resulting in a lower rise in circulating glucose (Williams 2012) and insulin (Jenkins et al. 1981), and include beans, brown pasta and rice, and nuts. Ingestion of these CHO foods may have long-term health benefits and usually increase fibre intake compared to HGI alternatives. However, whilst HGI pre-exercise meal may increase muscle glycogen more than an LGI isocaloric meal (Wee et al. 2005), the potential performance benefits are equivocal (Hulton et al., 2012; Wu et al. 2006).

Protein requirements

Amino acids from proteins are essential for the production of the hormones and enzymes that regulate metabolism and other body functions (Wolfe 2006). The metabolism of amino acids can also serve as an auxiliary fuel source during the intense prolonged phases of a soccer match (Hawley, Tipton and Millard-Stafford 2006; Burke et al. 2004), typically when glycogen stores are severely depleted (Williams 2012), but this auxiliary fuel source is estimated at only 3% of total energy metabolism (Wagenmakers et al. 1989). Protein also plays a key role in the adaptations that take place in response to training (FIFA 2016; Lemon 1994). The intake of small amounts (20-25 g) of high-quality protein that includes leucine, particularly after exercise (Phillips et al., 2005), enhances protein synthesis, promotes the remodelling of both muscle tissue (Moore et al., 2009; 2015), and brain vasculature (Ho et al. 2018) as well as enhancing endothelial renewal (Yang et al. 2018).

Despite the extensive research on many aspects of protein intake, few studies have specifically evaluated the protein requirements of soccer players (Garcia-Roves et al. 2014), but Packer et al., (2017) showed that the daily protein requirements were increased in trained males following a soccer match simulation. Several other studies have suggested that these athletes typically ingest adequate amounts, sometimes at the expense of CHO (Anderson et al., 2017; Brinkmans, et al., 2019). Becoming prematurely CHO depleted, may increase the reliance of protein as an energy source, so players should aim for a daily protein intake of between 1.3 to 1.75 $g \cdot kg^{-1}$ BM, rising to ~2.0 $g \cdot kg^{-1}$ BM during periods of intense training (Burke et al. 2016). These recommendations are based on intakes of 0.25-0.40 $g.kg^{-1}.meal^{-1}$ (Moore et al. 2015) and pre sleep intakes of 0.55 $g.kg^{-1}$ (Res et al. 2012). As some protein-rich foods are also high in saturated fat, players need to choose lean meat, and low-fat milk and dairy products while ensuring that meals are prepared with minimal added fat. Fish is considered the best choice of protein from the animals, but other sources such as vegetables, breakfast cereal, soy milk, nuts, seeds, tofu, legumes and lentils should also be consumed to meet requirements and add dietary variety (Deakin 1994).

Lipid requirements

Fat is a necessary nutrient that assists in a number of bodily functions including the preservation of body heat, cushioning of vital organs, and the provision of valuable energy storage and supply. While fat is not the primary source of energy in soccer, it is necessary during low-intensity aerobic activities (Bangsbo et al. 2006) and during recovery from high intensity exercise during match-play or training (Bangsbo et al., 2007; Bangsbo et al., 2006; Krustrup et al. 2006). Clarke et al. (2008) demonstrated that during simulated soccer performance, fat oxidation rates increase from 0.25 to 0.35 $g.min^{-1}$ over the course of a 90-minute treadmill protocol. These authors also demonstrated that the rate of fat oxidation was inversely related to the intake of CHO during exercise. Interestingly, in both the CHO and placebo ingestion trials, plasma non-esterified fatty acids and glycerol increased during the course of the match simulations. Plasma free fatty acids have also been shown to increase from 433 ± 77 $\mu Mol.L^{-1}$, by 1.5 and 3 times after the first and second halves respectively, these data suggest that lipolysis and fat oxidation play a role in overall energy provision during a game (Krustrup et al. 2006) especially if CHO is not ingested during the match (Clarke et al 2008).

Historically, soccer players were advised to consume less than 30% of their TDEI from fat (FIFA 2016), with a distribution of 7% from saturated fat, 10% from polyunsaturated fats, and 13% from mono-unsaturated fats (Kreider et al. 2010). Food containing omega-3 fatty acids, such as the oily fish, salmon, mackerel, sardines may also be beneficial in reducing post-exercise inflammation and delayed onset muscle soreness (Jouris et al. 2011). Whilst this may be a useful addition to the diet, even the leanest players will have adequate fat available as an energy substrate during exercise, so players should focus on achieving appropriate protein and CHO daily targets.

Dietary habits of soccer players

Despite the reported benefits of optimal nutrition in soccer performance (Ono et al. 2012; Rico-Sanz et al. 1998), research among soccer players reveals many nutrition concerns. Players often have a low TDEI (Anderson et al. 2017; Brinkmans et al. 2019; Garcia-Roves et al. 2014). Soccer players also consume diets that are not very different from those of the general public (Garcia-Roves et al. 2014), which may result in a suboptimal distribution of energy with respect to the basic energy-producing nutrients, namely in levels of fat and protein that are too high when compared to evidence-based recommendations, and CHO volumes that are too low. Inadequate CHO intake is likely due to low consumption of the main sources of dietary CHO such as breads, cereals, fruits and vegetables, especially at dinner time (Ruiz et al. 2005). Unlike CHO intake, nutritional assessment of soccer players generally reveals that protein consumption is sufficient to accommodate even the highest estimates of protein requirements (Anderson et al. 2017; Brinkmans et al. 2019), but with additional concerns regarding the suboptimal timing and quality of intake (Alghannam 2013).

Hyper-ingestion of fat has been reported among soccer players, although in contrast to protein this excessive ingestion is normally involuntary. Fat is the most proportionally over-consumed macronutrient (Garcia-Roves et al. 2014; Ruiz et al. 2005). This is however unlikely to pose problems for the body composition of players, because they often do not attain their energy intake target (Anderson et al. 2017; Brinkmans et al. 2019), and this will likely be exacerbated during a congested match schedule. In such a scenario, this may also restrict muscle and liver CHO storage capacity (Williams 2012) and reduce the rate of muscle protein synthesis (Stephens et al. 2015). Most concerning of all is the evidence of under-reporting energy intake when using self-report food diaries, and photographic confirmation of food portion sizes (Anderson et al. 2017), as this makes accurate assessment of TDEI potentially inaccurate for some players.

Barriers for optimal nutrition in soccer

The dietary habits of soccer players are often not compatible with peak physical performance (Rico-Sanz et al. 1998). Deficits in nutritional knowledge by professional staff and players (Shifflett et al. 2002) represent a barrier to change. Nutrition information is often obtained by athletes from diverse sources including coaches, teammates, athletic trainers, fitness trainers, parents, supplement manufacturers, and the media (Blennerhassett et al. 2018). A bias or lack of awareness can add to the myths surrounding nutrition that may ultimately adversely affect players' diets (Burns et al. 2004). This is particularly common among coaches, many of whom are former players possessing knowledge of nutrition limited to what they learnt throughout their own professional careers (Ono et al. 2012). This may lead to the adoption of practices that are not evidence-based and the reduced likelihood of consulting with qualified nutritional professionals (Ono et al. 2012; Rosenbloom et al. 2002). This is problematic since for many players, the coach remains a primary source of nutrition education, whose knowledge is often regarded to be accurate and complete (Walsh et al. 2011; Juzwiak and Ancona-Lopez 2004; Shifflett et al. 2002). Soccer players tend to acquire and internalise such knowledge as soccer habitus, and unconsciously embody it throughout their career span just as their coaches did before them (Bourdieu 2001), resulting in many false beliefs and misconceptions. Players should understand that improvements in performance and fitness occur as a result of long-term changes in diet and effective training, and not via quick-fix solutions as marketing efforts by nutritional product manufacturers might suggest (Williams 2012; Rosenbloom et al. 2002).

A common barrier to effective nutritional practice among players is the tendency toward infrequent meals (Jonnalagadda et al. 2001), which may promote muscle catabolism, fat synthesis and overall undesirable changes in body composition, such as reductions in muscle mass (Benardot et al. 2005). Ruiz et al. (2005) noted that as players get older (>20 years), they also tend to skip meals or substitute the items they eat, especially in the case of breakfast and snacks (Casey et al. 2000). Cultural issues can also influence dietary habits (Flatt, 1995), with implications for a culturally diverse team. Ono et al. (2012) showed that professional players' personal eating habits were influenced predominantly by their social class and national habitus. Eating habits are likely to be related to players' upbringing and influenced by the food culture and environment established by parents and guardians, (Ono et al. 2012).

Nutritional planning

Soccer training and competition must be accompanied by an increased energy intake to maintain performance capacity and prevent the development of excessive fatigue (William 2012; Bangsbo 1994; Lemon 1994). Various nutritional challenges emerge as a result of a busy training and competition schedule; players may lose their appetites after training, eat poorly or regularly miss meals, or become ravenous and resort to take-away or fast foods (Caruana Bonnici et al., 2018).

The typical daily energy demand for senior male players has been estimated between 3500 and 4000 kcal on training days (Rico-Sanz et al. 1998). The estimated energy expenditure of soccer match-play has been reported at ~1700 kcal (Shephard 1992; Stolen et al. 2005). Influencing factors such as training volume and intensity, physical status, and phase of the season must be taken into consideration in estimating total energy requirements and planning a successful nutritional strategy (Garcia-Roves et al. 2014). The energetic and metabolic demands of soccer training and match play will also vary as a result of environmental influences, standard of competition, patterns of play and their playing position (Shephard 1999; Di Salvo and Pigozzi, 1998). Indeed, Anderson et al. (2018) recently used the doubly labelled water technique to determine that the daily energy intake of goalkeepers in the English Premier League (EPL), may be ~600 $kcal.day^{-1}$ lower than outfield players. Nutritional demands are further influenced by temporal variations in basal metabolic rate, thermic effect of food and thermic effect of activity.

Historically, guidelines of 55-65% CHO, 12-15% protein, and less than 30% fat were provided by Clark (1994) and FIFA (2016). Expressing daily requirements as a percentage of TDEI may however be misleading and is difficult for athletes to attain such targets in real-time. The use of percentage targets is wholly discouraged for CHO and protein and instead, researchers and practitioners now prefer to express recommended intake in terms of $g \cdot kg^{-1}$ BM. These options might be used simultaneously in order to provide a more complete overview of macronutrient intake recommendation for soccer players (Garcia-Roves et al. 2014). The provision of generic guidelines is also made more complex with the observation that some practitioners in elite club settings, are now using a periodised approach to facilitate fuelling for and recovery from specific training sessions and matches (Anderson et al. 2017). This approach highlights the large daily variations in energy intake previously observed in EPL players on match (3789 ± 532 kcal) and training days (2956 ± 374 kcal) using the photographic, and 24 h recall method (Anderson et al. 2017).

Nutrition on match-day

Menu planning on match-day is traditionally considered a nutritional priority by many soccer players and technical staff (Holway and Spriet 2011). Burke et al., (2006) suggested that soccer players traditionally attach more importance to pre- and post-match meals than to the daily diet. The main goals of a pre-match meal are to; support and maintain euglycemia, maintain glycogen stores (Rollo 2014) and hydration (Res 2014). Failure to do so will lead to early losses of glycogen, which can lead to hypoglycaemia, fatigue and impaired performance (FIFA 2016; Coyle 1991). According to Jentjens and Jeukendrup (2003), glycogen synthesis is affected by the amount of CHO consumed, with the optimal intake for glycogen storage reported at 7-10 $g \cdot kg^{-1}$ $BM \cdot day^{-1}$ (Drobnic et al. 2016). If the match begins in the afternoon, players will typically have a light breakfast followed by a main meal around midday. If the match is played in the evening, players will have a late breakfast followed by a light lunch and a pre-match meal during the late afternoon. Players should start a match on an almost empty stomach, so they are generally advised to focus on CHO-rich foods to provide a total of at least 1.0 $g \cdot kg^{-1}$ BM during the 3-4 h period before kick-off (Briggs et al. 2017). Protein intake is not considered to be a nutrient of utmost importance at this particular time. The meal should contain low-GI, complex CHO-rich foods, for long-term stable blood glucose concentrations and general feelings of satiety (Stevenson et al. 2005), especially when adequate CHO has been ingested in the previous 24-36 h before the match, as the GI of the meal is likely to have less of an effect on muscle glycogen content (Wee et al. 20015). Players should avoid inappropriate foods such as those containing large quantities of fibre, or those representing high protein sources that inadvertently also contain high concentrations of fats, such as ground beef and dairy products. Such protein-rich sources take longer to digest and absorb, and are therefore inappropriate for consumption prior to long duration high intensity exercise (de Oliveira et al. 2014).

A pre-match snack with a small amount of CHO that is rapidly digested and absorbed, such as dried fruit or CHO energy bars (Deakin 1994) administered within an hour prior to kick-off may help to spare liver and muscle glycogen and maintain blood glucose (Shephard and Leatt 1987). The closer the ingestion of CHO occurs to kick-off, the greater the reliance should be on liquid-form CHO, such as a fruit smoothie, yogurt drink, fresh or tinned fruit (Deakin 1994), or sports drinks (Coombes and Hamilton 2000).

Table 1. Pre-match carbohydrate (CHO), protein (PRO) and fluid intake recommendations.

Timing	Pre-match intake
Daily intake	7 to 10 and up to 12 g·kg^{-1} BM of CHO
	1.3 to 1.75 up to 2.0 g·kg^{-1} BM of PRO
3-4 h before kick-off	1 to 4 g·kg^{-1} BM of CHO
	1 g·kg^{-1} BM or PRO
2 h before kick-off	6 to 8 mL·kg^{-1} BM of fluid
1 h before kick-off	25-30g of CHO
15 min before kick-off	300-600 mL of fluid

Inter-match CHO intake

The primary purpose of inter-match nutrition is to maintain sufficient concentrations of blood glucose and muscle glycogen in order to sustain a high rate of energy production and delay fatigue as much as possible (Mohr et al 2003). This is achieved by consuming adequate fluids that can move through the stomach and into the bloodstream without causing any form of distress to the player during the match.

The best opportunity for the player to replenish some of the fluid and CHO lost during the match is during the half-time interval. In this regard, the most effective and convenient way to consume a combination of fluids, CHO and electrolytes is to ingest a well-formulated isotonic sports drink containing 6 to 8% CHO (Burke 2010; Williams 2012) or CHO supplementation of 30-60 $g.h^{-1}$ (Drobnic et al., 2016). This choice of intake is easily digested and absorbed, helps maintain hydration status, provides substrate to delay fatigue, and maintains skill and cognitive function to minimise diminishing performance towards the end of a match. Other sources may include diluted fruit juices, high-CHO energy bars, fruit, water and gels, although they are less recommended due to their association with gastrointestinal discomfort unless the players have specifically trained their gut to be familiar with this strategy (Jeukendrup 2017). Smith et al. (2015) highlighted the importance of isotonic hydration in the case of prolonged training lasting more than one hour, due to the substantial increases in energy demands. Such supplementation was shown to permit the preservation of energy throughout the entire session by promoting glycogen storage.

Post-match nutrition

The restoration of muscle and liver glycogen is a fundamental goal of recovery between training sessions or competitive events, especially when the athlete must undergo multiple workouts within a condensed time period (Burke et al. 2011). The main goal for recovery nutrition in soccer is therefore to replenish glycogen stores and repair muscle damage, ensuring recovery in time for the next match or training session, given the highly congested schedules that typically characterise soccer at any level (Burke et al. 2006). Timing of intake is crucial to ensure rapid recovery at this stage (Williams et al. 2003). While complete recovery in soccer is likely to take more than five days (Souglis et al. 2018), recovery nutrition in the fifteen minutes to four hours after the match is considered the most critical time-frame when training is scheduled the following day. Souglis et al. (2018) observed that both male and female players had elevated blood uric acid and creatine kinase concentrations 4-5 days after competitive soccer matches. Therefore, nutrition strategies should also target recovery from muscle damage sustained during training or match play (Poulios et al. 2018).

One of the key nutritional ingestion strategies to enhance recovery is to consume protein which can be absorbed rapidly. Some research suggests that the timing, rather than the overall quantity of daily protein may be of more importance to soccer players (Res, 2014). Immediately after exercise, whey protein is likely to be the best choice of protein to consume as it can be quickly absorbed and contains high amounts of leucine (Drobnic et al., 2016), which is believed to be an important in the optimisation of the mTOR muscle protein synthesis pathway (van Loon et al., 2012). Another important aspect of recovery, is that the quantity and quality of protein required in the diet to both maintain and increase body protein deposits, is closely related to the amount of energy consumed (Butterfield, 1991; Phillips, 2002; Tarnopolsky, 2006). Animal protein, which is believed to be a main trigger for increases in muscle protein synthesis, contains more leucine (van Loon, 2012), while whey protein is rapidly digestible and been shown to be superior in terms of muscle protein synthesis compared to soy or casein, when taken in isocaloric amounts (Tang et al. 2009). Optimal myofibrillar protein synthesis rates may also be reduced by up to 24% during recovery from exercise when alcohol is co-ingested with protein, compared to only consuming protein (Parr et al. 2014), so players should avoid drinking alcohol during the recovery period. An effective recovery strategy should therefore include both CHO (Burke et al. 2006; Ivy et al. 2002) and protein (Berardi et al. 2006) for the restoration of nutrients and energy stores, with the aim of an efficient return to normal physiological function, lessening of muscle soreness, and the disappearance of the psychological symptoms associated with extreme fatigue, thereby reducing the risk of injury (Nedelec et al. 2013). The co-ingestion of milk-based protein and CHO has previously been shown to reduce blood myoglobin, creatine kinase, and increase peak muscle torque 48 h after a damaging exercise bout, compared to CHO alone (Cockburn et al. 2008). More recently Sollie at al. (2018), also demonstrated that CHO and protein co-ingestion (0.8 and 0.4 $g.kg^{-1}.h^{-1}$ respectively) was more effective at promoting anabolism compared to the ingestion of 1.2 $g.kg^{-1}.h^{-1}$ CHO following exhaustive aerobic exercise. Furthermore, the CHO and protein strategy also improved sprint performance by 3.7% and time trial performance by 8.5%, 18 h after the exhaustive exercise bout.

An immediate recovery strategy that involves ingesting of 1.0 to 1.2 $g·kg^{-1}$ BM· h^{-1} (Burke et al. 2006) of CHO perhaps in a series of small snacks every 15 to 30 min (Jentjens and Jeukendrup 2003) for up to four hours after a match is necessary to provide an immediate source of substrate to muscle cells to initiate effective recovery (Burke et al. 2004; Karp et al. 2006). This strategy aims to enhance glycogen restoration, stimulate insulin secretion, increasing glucose uptake and muscle glycogen synthase (Jentjens and Jeukendrup 2003), and reducing overall muscle soreness (Millard-Stafford et al. 2005). There may also be a role of providing CHO for the improvement of skeletal muscle function, which has previously been glycogen depleted. Gejl et al. (2014) showed that calcium release from muscle sarcoplasmic reticulum was impaired in a glycogen depleted state when insufficient CHO was consumed in the recovery period.

Therefore, post-exercise nutrient intake should should, according to Williams (1994) consist of a high GI CHO source such as a serving of fresh fruit or juice, breakfast cereal, oats, or CHO based sports nutritional supplements in solid or liquid form (Deakin 1994). Adding a dose of protein provides added benefits as it helps to upregulate muscle protein synthesis for training adaptation and the repair of damaged muscle (Cockburn et al. 2008; Moore et al. 2009; Res 2014; Sollie et al. 2018). The ideal amount of protein to maximally stimulate muscle protein synthesis is likely to be at least 20-25 g or ~0.3 $g·kg^{-1}$ BM (Moore et al., 2009), but may be as high as 40 g in some individuals, depending on the quality of the protein and the age of the athlete (for a more detailed review of these factors, readers are directed to Phillips et al. 2016). In view of this, Nedelec et al. (2013) suggested that the timely co-ingestion of a CHO to PRO ratio of approximately 3:1, such as flavoured milk combined with a chicken/honey/peanut butter sandwich. A post-match meal consumed within four hours of the final whistle should comprise a low-fat PRO source such as chicken, combined with potatoes and vegetables to satisfy recommended co-ingestion ratios (Nedelec et al. 2013; Harvey et al. 2008), when the primary goal is recovery and refuelling.

Table 2. Post-match and training nutritional intake recommendations.

Timing	Intake guidelines
Within 15 min of exercise	1 $g \cdot kg^{-1}$ BM of CHO 20-40 g high quality protein containing 2-3 g of leucine
Up until 4 h after exercise	1.0 to 2.4 $g \cdot kg^{-1}$ BM of CHO 0.3 $g \cdot kg^{-1}$ BM of PRO Fluid with electrolytes replacement - 150% of BM losses

Summary

Despite a clear understanding of the physiological demands of soccer, and the association between nutritional preparation and performance, the dietary habits of soccer players are often characterised by a lack of education and mis-informed sporting traditions. The onus is often on the player and relevant support staff to better monitor and support players' nutritional strategies and find effective implementation strategies. This review provides clear evidence-based recommendations for macronutrient and fluid intake for heavy training and match days, so that more optimal nutrition might be achieved.

References

1. Anderson. L., Close, G.L., Morgans, R., Hambly, C., Speakman, J.R., Drust, B., Morton, J.P. (2018). Case Study: Assessment of Energy Expenditure of a Professional Goalkeeper From the English Premier League Using the Doubly Labeled Water Method. *International Journal of Sports Physiology and Performance,* 2018 Nov 14:1-13. [Epub ahead of print].
2. Anderson, L., Orme, P., Di Michele, R., Close, G.L., Morgans, R., Drust, B., Morton, J.P. (2016). Quantification of training load during one-, two- and three-game week schedules in professional soccer players from the English Premier League: implications for carbohydrate periodisation. *Journal of Sports Sciences*, 34(13):1250-9.
3. Anderson. L., Orme, P., Naughton, R.J., Close, G.L., Milsom, J., Rydings, D., O'Boyle, A., Di Michele, R., Louis, J., Hambly, C., Speakman, J.R., Morgans, R., Drust, B., Morton, J.P. (2017). Energy Intake and Expenditure of Professional Soccer Players of the English Premier League: Evidence of Carbohydrate Periodization. *International Journal of Sports Nutrition and Exercise Metabolism*, 27(3):228-238.
4. Alghannam, A.F. (2012) Metabolic Limitations of Performance and Fatigue in Football. *Asian Journal of Sports Medicine,* 3(2), 65-73.
5. Alghannam, A.F. (2013) Physiology of soccer: The role of nutrition in performance. *Novel Physiotherapists,* 1-5.
6. Andrzejewski, M., Chmura, J., Dybek, T. and Pluta, B. (2012) Sport exercise capacity of soccer players at different levels of performance. *Biology of Sport,* 29, 185-191.
7. Aziz, A., Chia, M. and Teh, K. (2000) The relationship between maximal oxygen uptake and repeated sprint performance indices in field hockey and soccer players. *Journal of Sports Medicine and Physical Fitness,* 40, 195-200.
8. Balsom, P., Gaitanos, G., Soderlund, K. and Ekblom, B. (1999) High-intensity exercise and muscle glycogen availability in humans. *Acta Physiologica Scandinavica,* 165, 337-345.

9. Bangsbo, J. (1994) The physiology of soccer with special reference to intense intermittent exercise. *Acta Physiologica Scandinivaca,* 619, 1-155.

10. Bangsbo, J. (2014) Physiological demands of football. *Football Task Force*, 27(125), 1-6.

11. Bangsbo, J., Graham, T., Kiens, B. and Saltin, B. (1992) Elevated muscle glycogen and anaerobic energy production during exhaustive exercise in man. *Journal of Physiology,* 451, 205-227.

12. Bangsbo, J., Iaia, F. and Krustrup, P. (2007) Metabolic response and fatigue in soccer. *International Journal of Sports, Physiology and Performance,* 2, 111-127.

13. Bangsbo, J., Mohr, M. and Krustrup, P. (2006) Physical and metabolic demands of training and match-play in the elite football player. *Journal of Sports Sciences,* 24, 665-674.

14. Berardi, J.M., Price, T.B., Noreen, E.E., Lemon, P.W. (2006). Postexercise muscle glycogen recovery enhanced with a carbohydrate-protein supplement. Medicine and Science in Sports and Exercise, 38(6), 1106-13.

15. Blennerhassett, C., McNaughton, L.R., Cronin, C., and Sparks, S.A. (2018). Development and implementation of a nutrition knowledge questionnaire for ultra-endurance athletes. *International Journal of Sports Nutrition and Exercise Metabolism*, Oct 17:1-7. doi: 10.1123/ijsnem.2017-0322. [Epub ahead of print].

16. Bradley, P.S., Di Mascio, M., Peart, D., Olsen, P. and Sheldon, B. (2010) High-intensity activity profiles of elite soccer players at different performance levels. *Journal of Strength and Conditioning Research,* 24(9), 2343-2351.

17. Briggs, M.A., Harper, L.D., McNamee, G., Cockburn, E., Rumbold, P.L.S., Stevenson, E.J., Russell, M. (2017). The effects of an increased calorie breakfast consumed prior to simulated match-play in Academy soccer players. *European Journal of Sport Science*, 17(7), 858-866.

18. Brinkmans, N.Y.J., Iedema, N., Plasqui, G., Wouters, L., Saris, W.H.M., van Loon, L.J.C., van Dijk, J.W. Energy expenditure and dietary intake in professional football

players in the Dutch Premier League: Implications for nutritional counselling. *Journal of Sports Sciences*, 2019 Feb 16:1-9. doi: 10.1080/02640414.2019.1576256. [Epub ahead of print].

19. Burke, L. (2001) Energy needs of athletes. *Canadian Journal of Applied Physiology,* 26, 202-219.
20. Burke, L. (2010) Fuelling strategies to optimise performance: training high or training low? *Scandinavian Journal of Medicine and Science in Sports,* 20(2), 48-58.
21. Burke, L., Bell, L., Cort, M., Cox, G., Farthing, L., Greenaway., Minehan, M., Petrunoff, N. and Wood, C. (2016) Current concepts in Sports Nutrition. *Australian Institute of Sport,* 1-56.
22. Burke, L., Collier, G. and Hargreaves, M. (1993) Muscle glycogen storage after prolonged exercise: effect of the glycaemic index of carbohydrate feeding. *Journal of Applied Physiology,* 75(2), 1019-1023.
23. Burke, L.., Cox, G.R., Cummings, N.K. and Desbrow, B. (2001) Guidelines for daily carbohydrate intake: Do athletes achieve them. *Sports Medicine,* 31(4), 267-299.
24. Burke, l., Hawley, J., Wong, S. and Jeukendrup, A. (2011) Carbohydrates for training and competition. *Journal of Sports Sciences,* 29(1), 17-27.
25. Burke, L., Kiens, B. and Ivy, J. (2004) Carbohydrates and fat for training and recovery. *Journal of Sports Sciences,* 22, 15-30.
26. Burns, R.D., Schiller, M., Merrick, M.A. and Wolf, K.N. (2004) Intercollegiate student athlete use of nutritional supplements and the role of athletic trainers and dieticians in nutrition counseling. *Journal of the American Dietetic Association*, 104(2), 246-249.
27. Caruana Bonnici, D.C., Akubat, I., Sparks, S.A., Greig, M., & Mc Naughton, L.R. (2018) Dietary habits and energy balance in an under 21 male international soccer team, *Research in Sports Medicine,* 26(2):168-177. DOI: 10.1080/15438627.2018.1431537
28. Clark, K. (1994) Nutritional guidance to soccer players for training and competition. *Journal of Sports Sciences,* 12, 43-50.

29. Clarke, N.D., Drust, B., Maclaren, D.P., Reilly, T. (2008) Fluid provision and metabolic responses to soccer-specific exercise. *European Journal of Applied Physiology*, 104(6), 1069-77.

30. Close, G.L., Sale, C., Baar, K., Bermon, S. (2019). Nutrition for the Prevention and Treatment of Injuries in Track and Field Athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, 2019 Jan 24:1-26. DOI: 10.1123/ijsnem.2018-0290. [Epub ahead of print].

31. Cockburn, E., Hayes, P.R., French, D.N., Stevenson, E., St Clair Gibson, A. (2008). Acute milk-based protein-CHO supplementation attenuates exercise induced muscle damage. *Applied Physiology, Nutrition and Metabolism*, 33(4): 775-783.

32. Coombes, J. and Hamilton, K. (2000) The effectiveness of commercially available sports drinks. *Sports Medicine,* 29(3), 181-209.

33. Coyle, E. (1991) Timing and method of increased carbohdyrate intake to cope with heavy training, competition and recovery. *Journal of Sports Sciences,* 9, 29-52.

34. Deakin, V. (1994) *Training nutrition,* University of Canberra and the Australian Institute of Sport: National Sports Research Centre.

35. de Oliveira, E.P., Burini, R.C., Jeukendrup, A. (2014). Gastrointestinal complaints during exercise: prevalence, etiology, and nutritional recommendations. *Sports Medicine*, 44, Suppl 1, S79-85.

36. Di Salvo, V. and Pigozzi, F. (1998) Physical training of football players based on their positional roles in the team. *Journal of Sports Medicine and Physical Fitness,* 38, 294-297.

37. Di Salvo, V., Gregson, W., Atkinson, G., Tordoff, P. and Drust, B. (2009) Analysis of high intensity activity in Premier League soccer. *International Journal of Sports Medicine,* 30(3), 205-212.

38. Ebeling, P., Bourey, R., Koranyi, L., Tuominen, J.A., Groop, L.C., Henriksson, J., Mueckler, M., Sovijärvi, A., Koivisto, V.A. (1993) Mechanism of enhanced insulin sensitivity in athletes. Increased blood flow, muscle glucose transport protein (GLUT-4)

concentration, and glycogen synthase activity. *Journal of Clinical Investigation*, 92(4), 1623-31.

39. FIFA, 2016. *www.fifa.com.* [Online] Available at: http://www.fifa.com [Accessed 20 August 2018].

40. Foskett, A., Williams, C., Boobis, L. and Tsintzas, K. (2008) Carbohydrate availability and muscle energy metabolism during intermittent running. *Medicine and Science in Sports and Exercise,* 40(1), 96-103.

41. Garcia-Roves, P., Garcia-Zapico, P., Patterson, A. and Iglesias-Gutierrez, E. (2014) Nutrient intake and food habits of soccer players: Analysing the correlates of eating practice. *Nutrients,* 6, 2697-2717.

42. Gejl, K.D., Hvid, L.G., Frandsen, U., Jensen, K., Sahlin, K., Ortenblad, N. (2014). Muscle glycogen content modifies SR Ca^{2+} release rate in elite endurance athletes. *Medicine and Science in Sports and Exercise*, 46, 496–505.

43. Hawley, J., Dennis, S. and Noakes, T. (1994) Carbohydrate, fluid, and electrolyte requirements of the soccer player: a review. *International Journal of Sport Nutrition,* 4, 221-236.

44. Hawley, J., Tipton, K. and Millard-Stafford, M. (2006) Promoting training adaptations through nutritional interventions. *Journal of Sports Sciences,* 24, 709-721.

45. Highton, J., Twist, C., Lamb, K. and Nicholas, C. (2013) Carbohydrate-protein co-ingestion improves multiple-sprint running performance. *Journal of Sports Science,* 31, 361-369.

46. Ho, C.F., Jiao, Y., Wei, B., Yang, Z., Wang, H.Y., Wu, Y.Y., Yang, C., Tseng, K.W., Huang, C.Y., Chen, C.Y., Kuo, C.H. (2018) Protein supplementation enhances cerebral oxygenation during exercise in elite basketball players. *Nutrition*, 53, 34-37.

47. Holway, F. and Spriet, L. (2011) Sport-specific nutrition: Practical strategies for team sports. *Journal of Sports Science,* 29, 115-125.

48. Hulton, A.T., Gregson, W., Maclaren, D., Doran, D.A. (2012). Effects of GI meals on intermittent exercise. *International Journal of Sports Medicine*, 33(9):756-62.

49. Ivy, J.L., Katz, A.L., Cutler, C.L., Sherman, W.M. and Coyle, E.F. (1988) Muscle glycogen synthesis after exercise: Effect of time of carbohydrate ingestion. *Journal of Applied Physiology,* 64, 1480-1485.

50. Jentjens, R. and Jeukendrup, A. (2003) Determinants of post-exercise glycogen synthesis during short-term recovery. *Sports Medicine,* 33(2), 117-144.

51. Jonnalagadda, S., Rosenbloom, C. and Skinner, R. (2001) Dietary practices, attitudes, and physiological status of collegiate freshman football players. *Journal of Strength and Conditioning Research,* 15, 507-513.

52. Jouris, k.B., McDaniel, J.L., Weiss, E.P. (2011). The effect of Omega-3 fatty acid supplementation on the inflammatory response to eccentric exercise. *Journal of Science and Medicine in Sport*, 10(3), 432-438.

53. Juzwiak, C. and Ancona-Lopez, F. (2004) Evaluation of nutrition knowledge and dietary recommendations by coaches of adolescent Brazilian athletes. *International Journal of Sport Nutrition and Exercise Metabolism,* 14, 222-235.

54. Keizer, H., Kuipers, H., Van Kranenburg, G. and Guerten, P. (1986) Influence of fluid and solid meals on muscle glycogen re-synthesis, plasma fuel hormone response, and maximal physical working capacity. *International Journal of Sports Medicine,* 8, 99-104.

55. Krustrup, P., Mohr, M., Amstrup, T., Rysgaard, T., Johansen, J., Steensberg, A., Pederson, P.K. and Bangsbo, J (2003) The yo-yo intermittent recovery test: physiological response, reliability, and validity. *Medicine and Science in Sports and Exercise,* 35(4), 697-705.

56. Krustrup, P., Mohr, M., Ellingsgaard, H. and Bangsbo, J. (2005) Physical demands during an elite female soccer game: importance of training status. *Medicine and Science in Sports and Exercise,* 37, 1242-1248.

57. Krustrup, P., Mohr, M., Steensberg, A., Bencke, J., Kjaer, M. and Bangsbo, J. (2006). Muscle and blood metabolites during a soccer game: implications for sprint performance. *Medicine and Science in Sports and Exercise,* 38(6), 1165-1174.

58. Lemon, P. (1994) Protein requirements for soccer. *Journal of Sports Sciences,* 12, pp. 17-22.

59. Levenhagen, D.K., Gresham, J.D., Carlson, M.G., Maron, D.J., Borel, M.J., Flakoll, P.J. (2001) Postexercise nutrient intake timing in humans is critical to recovery of leg glucose and protein homeostasis. *American Journal of Physiology Endocrinology and Metabolism*, 280(6), E982-93.

60. Little, J.P., Chilibeck, P.D., Ciona, D., Forbes, S., Rees, H., Vanderberg, A. and Zello, G.A. (2010) Effect of low- and high-glycaemic index meals on metabolism and performance during high intermittent exercise. *International Journal of Sports Nutrition and Exercise Metabolism,* 20(6), 447-456.

61. Mascio, M. and Bradley, P. (2013) Evaluation of the most intense high-intensity running period in English FA premier league soccer matches. *Journal of Strength and Conditioning Research,* 27(4), 909-915.

62. Maughan, R. (1997) Energy and macronutrient intakes of professional football (soccer) players. *British Journal of Sports Medicine,* 31, 45-47.

63. Maughan, R. and Shirreffs, S. (2007a). Nutrition and hydration concerns of the female football player. *British Journal of Sports Medicine,* 41, 60-63.

64. Maughan, R. and Shirreffs, S. (2007b) Nutrition for Soccer players. *Current Sports Medicine Reports,* 6, 279-280.

65. Mohr, M., Krustrup, P. and Bangsbo, J. (2003) Match performance of high-standard soccer players with special reference to development of fatigue. *Journal of Sports Science,* 21, 519-528.

66. Mohr, M., Krustrup, P. and Bangsbo, J. (2005) Fatigue in soccer: a brief review. *Journal of Sports Sciences,* 23, 593-599.

67. Moore, D.R., Churchward-Venne, T.A., Witard, O., Breen, L., Burd, N.A.,Tipton, K.D., and Phillips, S.M. (2015) Protein ingestion to stimulate myofibrillar protein synthesis requires greater relative protein intakes in healthy older versus younger men. *The*

Journals of Gerontology, Series A, Biological Sciences and Medical Science, 70(1), 57–62.

68. Moore, D.R., Tang, J.E., Burd, N.A., Rerecich, T., Tarnopolsky, M.A., Phillips, S.M. (2009). Differential stimulation of myofibrillar and sarcoplasmic protein synthesis with protein ingestion at rest and after resistance exercise. *Journal of Physiology*, 587(Pt 4), 897-904.

69. Nedelec, M., McCall, A., Carling, C., Legall, F., Berthoin, S. and Dupont, G. (2013) Recovery in Soccer: Part 2: Recovery Strategies. *Sports Medicine,* 43(1), 9-22.

70. Nicholas, C., Tsintzas, K., Boobis, L. and Williams, C. (1999) Carbohydrate-electrolyte ingestion during intermittent high-intensity running. *Medicine and Science in Sports and Exercise,* 31, 1280-1286.

71. O'Donoghue, P., Boyd, M., Lawlor, J. and Bleakley, E. (2001) Time-motion analysis of elite, semi-professional and amateur soccer competition. *Journal of Human Movement Studies,* 41, 1-12.

72. Ono, M., Kennedy, E., Reeves, S. and Cronin, L. (2012) Nutrition and Culture in professional football. A mixed method approach. *Appetite,* 58, 98-104.

73. Packer, J.E., Wooding, D.J., Kato, H., Courtney-Martin, G., Pencharz, P.B., Moore D.R. (2017). Variable-Intensity Simulated Team-Sport Exercise Increases Daily Protein Requirements in Active Males. *Frontiers in Nutrition*. Dec 21, 4:64.

74. Parr, E.B., Camera, D.M., Areta, J.L., Burke, L.M., Phillips, S.M., Hawley, J.A., Coffey, V.G. (2014). Alcohol ingestion impairs maximal post-exercise rates of myofibrillar protein synthesis following a single bout of concurrent training. *PLoS One*, 9(2), e88384.

75. Phillips, S.M., Chevalier, S., Leidy, H.J. (2016) Protein "requirements" beyond the RDA: implications for optimizing health. *Applied Physiology Nutrition and Metabolism*, 41(5), 565-72.

76. Phillips, S.M, Hartman, J.W., Wilkinson, S.B. (2015). Dietary protein to support anabolism with resistance exercise in young men. *Journal of the American College of Nutrition*, 24(2), 134S-139S.

77. Phillips, S., Sproule, J. and Turner, A. (2011) Carbohydrate Ingestion during Team Games Exercise. *Sports Medicine,* 41(7), 559-585.

78. Poulios A, Fatouros IG, Mohr M, Draganidis D, Deli CK, Papanikolaou K, Sovatzidis, A., Nakopoulou, T., Ermidis, G., Tzatzakis, T., Laschou, V. C., Georgakouli, K., Koulouris, A., Tsimeas, P., Chatzinikolaou, A., Karagounis, L. G., Batsilas, D., Krustrup, P., Jamurtas, A. Z. (2018). Post-game high protein intake may improve recovery of football-specific performance during a congested game fixture: results from the PRO-FOOTBALL study. *Nutrients* (2018) DOI: 10.3390/nu10040494.

79. Ranchordas, M.K., Dawson, J.T., Russell, M. (2017). Practical nutritional recovery strategies for elite soccer players when limited time separates repeated matches. *Journal of the International Society of Sports Nutrition*, 12;14:35.

80. Reilly, T. (1994b) Physiological profile of the player. In: *Football (soccer).* London: Blackwell.

81. Reilly, T. (2007) *The Science of Training - Soccer.* London: Routledge.

82. Res, P. (2014) Recovery nutrition for football players. *Sports Science Exchange,* 27(129), 1-5.

83. Res, P.T., Groen, B., Pennings, B., Beelen, M., Wallis, G.A., Gijsen, A.P., Senden, J.M., van Loon, L.J. (2012) Protein ingestion before sleep improves postexercise overnight recovery. *Medicine and Science in Sports and Exercise*, 44(8), 1560-1569.

84. Rico-Sanz, J., Frontera, W.R., Mole, P.A., Rivera, M.A., Rivera-Brown, A. and Meredith, C.N. (1998) Dietary and performance assessment of elite soccer players during a period of intense training. *International Journal of Sports Nutrition,* 8(8), 230-241.

85. Rico-Sanz, J., Zehnder, M., Buchli, R., Dambach, M. and Boutellier, U. (1999) Muscle glycogen degradation during simulation of a fatiguing soccer match in elite soccer players examined non-invasively by C-MRS. *Medicine and Science in Sports and Exercise,* 31(11), pp. 1587-1593.

86. Rollo, I. (2014) Carbohydrate: The football fuel. *Sports Exchange Science,* 27(127), 1-8.

87. Rosenbloom, C.A., Jonnalagadda, S.S. and Skinner, R. (2002) Nutrition knowledge of collegiate athletes in a division I national collegiate athletic association institution. *Journal of the American Dietetic Association,* 102(3), 418-420.

88. Ruiz, F., Irazusta, A., Gil, S., Irazusta., J., Casis, L. and Gil, J. (2005) Nutritional intake in soccer players of different ages. *Journal of Sports Sciences,* 23(3), 235-242.

89. Shephard, R. (1992) The energy needs of the soccer player. *Clinical Journal of Sports Medicine,* 2, 62-70.

90. Shephard, R. (1999) Biology and medicine in soccer: an update. *Journal of Sports Science,* 17, 757-786.

91. Shephard, R. and Leatt, P. (1987) Carbohydrate and fluid needs of the soccer player. *Sports Medicine,* 164-176.

92. Sherman, W., Costill, D., Fink, W. and Miller, J. (1981) Effect of exercise-diet manipulation on muscle glycogen and its subsequent utilisation during performance. *International Journal of Sports Medicine,* 2(2), 114-118.

93. Shifflett, B., Timm, C. and Kahanov, L. (2002) Understanding of Athletes' nutritional needs among athletes, coaches, and athletic trainers. *Research Quarterly for Exercise and Sport,* 73(3), 357-362.

94. Smith, J.W., Holmes, M.E., McAllister, M.J. (2015). Nutritional Considerations for Performance in Young Athletes. *Journal of Sports Medicine,* 2015:734649. doi: 10.1155/2015/734649.

95. Sollie, O., Jeppesen, P.B., Tangen, D.S., Jernerén, F., Nellemann, B., Valsdottir, D., Madsen, K., Turner, C., Refsum, H., Skålhegg, B.S., Ivy, J.L., Jensen, J. (2018). Protein intake in the early recovery period after exhaustive exercise improves performance the following day. *Journal of Applied Physiology*, 2018 Sep 13. doi: 10.1152/japplphysiol.01132.2017. [Epub ahead of print].

96. Souglis, A., Bogdanis, G.C., Chryssanthopoulos, C., Apostolidis, N., Geladas, N.D. (2018). Time Course of Oxidative Stress, Inflammation, and Muscle Damage Markers

for 5 Days After a Soccer Match: Effects of Sex and Playing Position. *Journal of Strength and Conditioning Research*, 32(7):2045-2054.

97. Stephens, F.B., Chee, C., Wall, B.T., Murton, A.J., Shannon, C.E., van Loon, L.J., Tsintzas, K. (2015). Lipid-induced insulin resistance is associated with an impaired skeletal muscle protein synthetic response to amino acid ingestion in healthy young men. *Diabetes*, 64(5), 1615-1620.

98. Stevenson, E., Williams, C., and Nute, M. (2005) The influence of glycaemic index of breakfast and lunch on substrate utilisation during postprandial periods and subsequent exercise. *British Journal of Nutrition,* 93, 885-893.

99. Stolen, T., Chamari, K., Castagna, C. and Wisloff, U. (2005) Physiology of soccer: an update. *Sports Medicine,* 35, 501-536.

100. Tipton, K. and Wolfe, R. (2004) Protein and amino acids for athletes. *Journal of Sports Science,* 22, 65-79.

101. van Loon, L.J. (2012). Leucine as a pharmaconutrient in health and disease. *Current Opinions in Clinical Nutrition and Metabolic Care*, 15(1):71–77. DOI: 10.1097/MCO.0b013e32834d617a

102. Walsh, M., Cartwright, L., Corish, C., Sugrue, S. and Wood-Martin, R. (2011) The body composition, nutritional knowledge, attitudes, behaviours, and future education need of senior school-boy rugby players in Ireland. *International Journal of Sport Nutrition and Exercise Metabolism,* 21(5), 365-376.

103. Wee, S., Williams, C., Tsintzas, K., and Boobis, L. (2005). Ingestion of a high-glycemic index meal increases muscle glycogen storage at rest but augments its utilization during subsequent exercise. *Journal of Applied Physiology*, 99,707–14.

104. Williams, J.H. (2012). *The Science behind Soccer Nutrition, (*2nd ed), Charleston, USA, CreateSpace.

105. Williams, M., Raven, P.B., Fogt, D.L., Ivy, J.L. (2003). Effects of recovery beverages on glycogen restoration and exercise performance. Journal of Strength and Conditioning Research, 17, 12-19.

106. Williams, C., and Rollo, I. (2015). Carbohydrate nutrition and team sports. *Sports Medicine*, Suppl 1, S13-S22.

107. Wu, C-L., Williams, C. (2006). A low glycemic index meal before exercise improves running capacity in man. *International Journal of Sports Nutrition and Exercise Metabolism*, 16:510–27.

108. Yang, C., Jiao, Y., Wei, B., Yang, Z., Wu, J.F., Jensen, J., Jean, W.H., Huang, C.Y., Kuo, C.H. (2018) Aged cells in human skeletal muscle after resistance exercise. *Aging*, 10(6), 1356-1365.

109. Zehnder, M., Rico-Sanz, J., Kuhne, G. and Boutellier, U. (2001) Re-synthesis of muscle glycogen after soccer specific performance examined by 13C-magnetic resonance spectroscopy in elite players. *European Journal of Applied Physiology,* 84, 443-447.