SSE #227

Sports Science Exchange (2022) Vol. 35, No. 227, 1-7

# SPORTS NUTRITION RECOMMENDATIONS FOR ELITE FEMALE SOCCER PLAYERS

**Samantha L. Moss, PhD[1,2] and Rebecca K. Randell, PhD[2]**

[1]Department of Sport and Exercise Sciences, University of Chester, Chester, UK

[2]Gatorade Sports Science Institute, PepsiCo R&D Life Sciences, Leicester, UK

## KEY POINTS

- Low energy availability could be problematic for a considerable number of elite female soccer players, especially in competitive periods when exercise demands are high.
- Daily carbohydrate intake (3-5.5 g·kg$^{-1}$·day$^{-1}$) could be insufficient to support the demands of high-intensity training and matches.
- Players fail to periodize carbohydrate intake to account for different exercise demands over a competition week.
- Sufficient total daily protein (≥ 1.2 g·kg$^{-1}$·day$^{-1}$) is consumed, but little is known about the quality or distribution of protein intakes around exercise.
- Player sweat rates, body mass losses, and sweat sodium ($Na^+$) losses are higher in match-play than in training. The large between-player variability underlines the need for individualized hydration strategies to avoid negative consequences to performance and health.
- There are a few dietary supplements that could provide small but important benefits to health and performance, but more studies on elite female soccer players are needed.

## INTRODUCTION

Participation in women's soccer continues to grow, with strategies from global governing bodies such as the Union of European Football Association (UEFA) and the Fédération Internationale de Football Association (FIFA) driving improvements in playing standards and professionalism (FIFA, 2021; UEFA, 2019). Interest from media and fans is also increasing exponentially, with major tournaments attracting record match attendances and viewing figures (FIFA, 2019b; UEFA, 2022). Increased match demands and frequent fixtures now characterize the women's game (FIFA, 2019a). An elite team competing in domestic and international league competitions will typically play a match every three to seven days, with four to six training sessions and one rest day per week. Therefore, elite players are required to repeatedly optimize their preparation and recovery within a limited time period throughout the competitive season, in addition to any international tournaments.

Nutrition can make a valuable contribution to the performance, health, and well-being of female soccer players (Collins et al., 2021; Randell et al., 2021). However, the lack of research in women has meant that female players have long been reliant on nutritional advice based on studies performed in males, despite physiological differences that might warrant sex-specific guidance. This Sports Science Exchange (SSE) article attempts to translate the current evidence into practical recommendations to support the female soccer player in the areas of energy intake, macronutrients, hydration, and supplements.

## ENERGY REQUIREMENTS AND ENERGY AVAILABILITY

Players need to consume sufficient energy to fuel for, recover from, and adapt to the demands of training and matches. Average in-season daily energy expenditures are estimated to be between 2,400 and 2,753 kcal·day$^{-1}$ (Dobrowolski et al., 2020; Morehen et al., 2022). Energy expenditure from training (300 – 1.069 kcal·day$^{-1}$) (Morehen et al., 2022; Moss et al., 2021) and matches (~881 kcal·day$^{-1}$) (Moss et al., 2021) makes up a considerable proportion of the total energy expenditure, with resting metabolic rates reported to be ~1,500 kcal·day$^{-1}$ (Moss et al., 2021). Average daily energy intakes are reportedly somewhat lower than expenditures, in the region of 1,548 to 2,400 kcal·day$^{-1}$ based on three- to five-day food diaries (Dobrowolski et al., 2020; Morehen et al., 2022; Moss et al., 2021; Reed et al., 2013). Interpretation of these findings warrants acknowledgement of issues and errors associated with the measurement of energy intake and expenditure (Burke et al., 2018). Moreover, studies measuring both energy intake and energy expenditure simultaneously are limited. In one such example, Morehen et al. (2022) used doubly-labeled water and weighed food analysis to show an average energy deficit of 825 kcal·day$^{-1}$ (± 419 kcal·day$^{-1}$) over a 4-day national training camp in 24 players (n = 3 goalkeepers), where training was completed daily. However, no changes in body mass were apparent during the monitoring period. Taken collectively, data indicate that some elite players are likely to be in an energy deficit during the season.

Energy deficiency can lead to low energy availability (EA) with subsequent impairments in body systems and functions. Energy availability can be defined as the amount of dietary energy available for normal physiological function after the energy expended during exercise has been accounted for, (expressed relative to lean body mass)

(Loucks et al., 2011). Energy availability status can be estimated using an equation (energy intake – energy expenditure during exercise / fat-free mass (FFM)) with a guideline threshold representative of low EA (< 30 kcal·kg $FFM^{-1}·day^{-1}$) (Loucks et al., 2011). An in-depth discussion concerning the negative impact of low EA on health and performance is available (De Souza et al., 2022). In elite soccer, 8 – 19% of players report menstrual dysfunction (Moss et al., 2021; Prather et al., 2016; Sundgot-Borgen & Torstveit, 2007) and 9 – 13% report previous stress fractures (Prather et al., 2016; Sundgot-Borgen & Torstveit, 2007), both of which are symptoms of low EA. Despite debate around the optimal EA status required for congested training and match periods, maintaining an energy intake within a range of 30 to 52 kcal·kg $FFM^{-1}·day^{-1}$ is recommended (De Sousa et al., 2022).

Studies in elite female players demonstrate that between 23% and 89% classify as having low EA (Dobrowolski et al., 2020; Morehen et al., 2022; Moss et al., 2021), with the lower and upper ranges representative of players competing in the top division of the English Women's Super League (Moss et al., 2021) and the England international squad (Morehen et al., 2022), respectively. As most studies have monitored EA over three to five days at a single time point during the season, these data provide a snapshot of practices and cannot be extrapolated to indicate EA over medium (weeks to months) or long (years) term. However, insight via the use of repeated assessment points showed that players were in low EA during pre-season (26.3%), in-season (33.3%), and post-season (11.8%) in a Division I US soccer squad (Reed et al., 2013). Therefore, EA could be a cause for concern for some players throughout the sporting calendar, with the in-season period being a challenge for the most players.

The changing day-to-day exercise demands during the season (i.e., matches, single or double training sessions, and rest days) require the elite player to alter energy intake to maintain adequate EA. However, within the season, players find it more difficult to maintain sufficient EA as the exercise demands increase. For example, an assessment of EA during a typical in-season week revealed that a greater proportion of players were in low EA on match day (54%) and heavy training days (double exercise session, 69%) in comparison with light (single exercise session, 38%) or rest days (0%) (Moss et al., 2021). Considering that exercise demands change daily, support for players is required to ensure that energy needs are met. Specifically, delivery of education around fuelling and maximizing opportunities for energy intake relative to match and heavy training days could help to prevent a chronic sub-optimal EA (Morehen et al., 2022; Moss et al., 2021). Support staff could have the most impact by providing varied menus and food choices that cater for the needs and eating habits of all players (Burke et al., 2006). In addition, increasing the focus on achieving sufficient energy intake at lunch and evening meals could be worthwhile, as low EA status of players was reportedly due to lower intakes at these mealtimes during the season (Reed et al., 2013).

## CARBOHYDRATE REQUIREMENTS

The capacity for carbohydrate storage (as glycogen) is limited within the body. A recent study by Krustrup et al. (2022) reported that 80% of type I fibres and 69% of type II fibres were almost empty or completely empty of glycogen following a 90-minute soccer match in female players. The decline in glycogen concentrations was associated with reduced repeated sprint performance. Therefore, ensuring the implementation of appropriate fuelling strategies before, during and after training and matches is important to ensure that glycogen does not limit performance (Kerksick et al., 2018).

It is recommended that carbohydrate intake is adjusted in accordance with daily training loads, total daily energy expenditure, and individualized goals (Thomas et al., 2016). The UEFA consensus statement proposes that daily carbohydrate guidelines should be applied on a sliding scale between 3 and 8 g·$kg^{-1}$, with congested fixture periods (i.e., matches every 3 – 4 days) warranting higher intakes (6 – 8 g·$kg^{-1}$) compared with single match weeks (3 – 8 g·$kg^{-1}$), pre-season training (4 – 8 g·$kg^{-1}$) and off-season training (< 4 g·$kg^{-1}$) (Collins et al., 2021). Although these recommendations were proposed as suitable for both males and females (Collins et al., 2021), further soccer-specific carbohydrate ingestion intervention studies in female players are needed before recommendations can be revisited.

Female soccer players do not normally achieve sufficient carbohydrate intakes during the season. Research spanning two decades shows that average in-season intakes in elite female soccer players are in the region of ~3 – 5.5 g·$kg^{-1}·day^{-1}$ (Morehen et al., 2022; Santos et al., 2016; Sousa et al., 2022), which is within the lower recommended range for soccer players (Collins et al., 2021) and athletes completing moderate training (~1 h per day, 5 – 7 g·$kg^{-1}$) (Thomas et al., 2016). Moreover, female players typically do not periodize their carbohydrate intake according to the changing exercise demands during match weeks (Morehen et al., 2022; Moss et al., 2021). A substantial number of top-division players reported intakes < 3 g·$kg^{-1}$ on a double-session day (62%) and match day (39%) (Moss et al., 2021), which is likely to result in insufficient glycogen availability and reduced performance in training and matches.

### Carbohydrate Intake Before Training and Matches

High carbohydrate ingestion (6 – 8 g·$kg^{-1}·day^{-1}$) is recommended the day before high-intensity training sessions and matches (i.e., the day before a match (match day – 1)) as higher pre-exercise glycogen stores have been found to enhance the capacity for repeated bouts of exercise in professional male players (Bangsbo et al., 1992). A recent review found that the capacity to load muscle glycogen is not sex dependent, provided that high carbohydrate intakes (i.e., > 8 g·$kg^{-1}·day^{-1}$) are ingested (Moore et al., 2022). However, for a female consuming 2,000 kcal·$day^{-1}$, a carbohydrate intake of 8 – 10 g·kg·$day^{-1}$ would equate to approximately 93 – 120% of habitual energy intake (assuming a body mass of 60 kg). Clearly, it can be impractical for females to consume a diet with this proportion of carbohydrates. There is some research to support that resting glycogen concentrations are lower in the mid-follicular phase of the menstrual cycle (Hackney, 1990; McLay at al., 2007; Nicklas et al., 1989), but the consensus is that these differences can also be overcome via a high carbohydrate intake (i.e., > 8 $g \cdot kg^{-1} \cdot day^{-1}$) (McLay et al., 2007). Practically, players should aim to ingest the upper limits of recommendations (~ 8 g·kg–1·$day^{-1}$) before high-intensity training and matches and pay particular attention to doing so when in the mid-follicular phase of their menstrual cycle (Moore et al., 2022). However, achieving this goal requires a coordinated effort between players, medical staff, and nutritionists or dieticians to properly identify menstrual cycle phase and implement the accompanying nutritional strategy.

On the day of a match or high-intensity training, consuming a carbohydrate-rich meal (1 – 3 $g \cdot kg^{-1}$) 3 – 4 h before commencement can further promote glycogen stores, which is important considering that liver glycogen is reduced by ~30 – 35% following an overnight fast (Rothman et al., 1991).When choosing a suitable meal, players should consider opting for high glycaemic index (GI) carbohydrates, which offer some advantages over low GI carbohydrates for promoting glycogen synthesis (Burke et al., 1993). In addition, avoiding foods high in fibre, fat, and protein and ensuring that all fuelling strategies are practiced well in advance of competition could reduce the potential for stomach discomfort (Burke et al., 2006; Thomas et al., 2016).

### Carbohydrate Intake During Training and Matches

During exercise, ingestion of ~30-60 $g \cdot h^{-1}$ of carbohydrate corresponds with performance benefits, as documented in simulated soccer matches (Rodriguez-Giustiniani et al., 2019). The warm-up and breaks for half-time, extra-time, and stoppages in play (e.g., injuries) provide opportunities to “top up” carbohydrate stores which serves to increase carbohydrate availability in the later stages of a match. Offering practical suggestions that can deliver carbohydrate quickly is essential in the limited time available. Rodriguez-Giustiniani et al. (2019) reported that ingesting 30 g of carbohydrate via a sports beverage before each half improved high-intensity running capacity and retained passing performance. Although the studies within this section were completed in male participants, recommendations are also considered applicable to females because the within-gender variability in carbohydrate requirement is greater than the between-gender differences (Collins et al., 2021).

### Carbohydrate Intake Post–Training and Matches

After high-intensity training and matches, restoration of glycogen stores via carbohydrate ingestion is a key objective. Although the carbohydrate requirements of official match-play are not yet known, an elite female friendly match resulted in muscle glycogen depletion (Krustrup et al., 2022). Replacing carbohydrates immediately after exercise with ~1 $g \cdot kg^{-1} \cdot h$ for 4 h can maximize the rate of muscle glycogen restoration, which is necessary when there are multiple exercise bouts within a relatively short period of time on the same day (e.g., 4 – 8 h recovery time) (Burke et al., 2017a).

The consumption of a specially formulated sports nutrition product immediately post-exercise followed by a more substantial carbohydrate-rich meal is recommended to assist players in replenishing carbohydrate stores and achieving individual target intake following intense exercise days. Although immediate refuelling might be less essential when recovery times are longer (> 8 h), applying this strategy regardless of recovery time could offer a specified feeding opportunity for the many players who find it difficult to achieve sufficient daily carbohydrate intakes. Indeed, the total carbohydrate intake is considered to be more important than the type, form, and pattern of intake for resynthesis of glycogen (Burke et al., 2006).

## PROTEIN REQUIREMENTS

Dietary protein provides the vital building blocks for remodelling muscle and connective tissue following exercise. The daily protein requirement, as well as the timing, quality, and digestibility of protein, are fundamental considerations for the female player. Total daily self-reported in-season protein intakes average between 1.2 and 2.0 g·kg·day–1 (Morehen et al., 2022; Sousa et al., 2022). These intakes are consistent with recommendations for athletes involved in moderate amounts of intense training (1.2 – 2.0 g·kg·day–1) (for a review see Kerksick et al., 2018). Female athletes have similar protein requirements per kg body mass to their male counterparts, eliminating the need for sex-specific recommendations (Moore et al., 2022).

Provided that total protein intake is sufficient, an even distribution of protein intake every 3 – 4 h can maximize total daily muscle protein synthesis (MPS), which is important for adaptation and recovery (Areta et al., 2013). It is currently unclear how female players distribute protein intake over the course of a day but based on an average intake of 1.6 $g \cdot kg^{-1} \cdot day^{-1}$, an ideal distribution of at least ~0.4 $g \cdot kg^{-1}$ per meal, to total four meals was suggested in the UEFA consensus statement (Collins et al., 2021). Similarly, Moore et al. (2022) recommended that female athletes consume ~0.3 $g \cdot kg^{-1}$ per meal, split over four to five equally spaced servings. For a player weighing 65 kg, this equates to ~20 – 26 g protein per meal, which can easily be achieved via food or, in certain circumstances, via specially formulated sports nutrition products. Indeed, many reasons and scenarios exist for protein supplementation including convenience and ease of digestion, although this practice is not a necessary requirement for enhanced performance and adaptation (Kerksick et al., 2018).

Selecting high-quality protein (i.e., foods supplying high availability of amino acids) such as chicken, fish, eggs, lean beef, and milk enhances acute MPS compared with low-quality protein sources (Pasiakos & Howard, 2021). While plant-based proteins have less favourable amino acid profiles and lower digestibility than animal proteins, it is still possible to achieve sufficient intakes of all amino acids with effective dietary planning (Hoffman & Falvo, 2004). Ensuring ~2.5 g of leucine is ingested at each feeding opportunity could promote protein remodelling for enhanced recovery between training and matches. Foods high in leucine include whey protein, chicken breast, eggs, and soya (Collins et al., 2020).

### Protein Intake Post–Training and Matches

On training and match days, players should attempt to follow the aforementioned guidlines for evenly distributing protein intake. Though on a practical level, with the match day focus on carbohydrate fuelling, the best-case scenario between protein feedings could be ~5 h, based on a match kick-off time of 1 pm, with a pre-match meal at 10 am (~3 h before) and earliest match completion at ~3 pm. With this in mind, players might choose to have sports nutrition protein products (e.g., shakes, bars) immediately after the match, followed by a post-match meal containing high-quality protein in the hours after. Ingesting protein in casein form (e.g., yoghurt, cottage cheese, milk) prior to sleep could continue to benefit MPS rates overnight and support the skeletal muscle adaptive response to exercise (Snijders et al., 2019).

It is important for players to not expect post-exercise protein intake to ameliorate muscle soreness or improve recovery of muscle function in the short-term (i.e., between matches and training) (Pasiakos et al., 2014). Although some evidence points to beneficial effects of protein supplementation on muscle soreness and function in team sports (Poulios et al., 2019), the empirical strength of the findings is reduced by poor study designs, large variability in muscle damage markers, and limited sample sizes (Pasiakos et al., 2014). Players should be aware that protein accretion and adaptation is the result of a repeated process that takes time.

## FAT REQUIREMENTS

Although not a specific focus for training and matches, a consistent dietary intake of fat equating to approximately 20 - 30% of total caloric intake is recommended for replenishing intramuscular triacylglycerol stores, delivering essential fatty acids, absorbing fat-soluble vitamins, and providing an energy source for athletes (Kerksick et al., 2018; Thomas et al., 2016). Sufficient fat intakes are generally achieved by elite female players (Morehen et al., 2022; Sousa et al., 2022).

Unless recommended for medical reasons, there is a lack of evidence to suggest female players should adhere to a low-fat (< 15 – 20%) or high-fat diet (> 35%). Low-fat diets commonly restrict many foods, which could significantly decrease overall dietary quality. High-fat diets (e.g., ketogenic diet) often require the reduction of carbohydrate, and to some extent, protein, which could have negative implications for performance, adaptation and recovery (Burke et al., 2017b). High-intensity performance in elite endurance athletes is impaired and there is a greater oxygen requirement for a given speed when following a high-fat diet that restricts carbohydrate compared with a high-carbohydrate diet with recommended fat intakes (Burke et al., 2017b).

## HYDRATION AND FLUID REQUIREMENTS

The International Federation of Association Football recognizes that limited drinking opportunities during match play could impact player maintenance of fluid balance and, as such, permit water breaks in hot environments (32 °C) (FIFA, 2017). Hypohydration (a body water deficit) can occur when body sweat losses are not replaced via sufficient fluid intake (Sawka et al., 2007), with impairments to cognition, technical skill, and physical performance in team sports, likely to occur when body mass losses reach 3 – 4% under conditions of heat stress (Nuccio et al., 2017). The hormonal fluctuations that exist in menstruating females influence thermoregulation and volume regulatory responses, such that females might warrant different hydration strategies according to the menstrual cycle phase (Giersch et al., 2020). However, current understanding is not yet advanced enough to warrant sex-specific hydration guidelines. Drinking recommendations for each player during training and matches will depend on their sweat rate, initial hydration status, and heat acclimation status, as well as the exercise intensity and environmental conditions (Sawka et al., 2007).

### Fluid Intake Before Training and Matches

To maintain performance and minimize the thermoregulatory and physiological strain that occurs with hypohydration, it is important for players to commence training and matches in a euhydrated state (Nuccio et al., 2017). Many female soccer players require support with fluid intake before exercise, as demonstrated by a systematic review showing that ~47% of players were hypohydrated (urine specific gravity measurement) prior to matches and training (Chapelle et al., 2020). Euhydration can be achieved by ingesting 5 – 10 ml·kg$^{-1}$ (0.17 – 0.34 fl oz) of fluid in the 2 – 4 h prior to training or matches (Thomas et al., 2016). It could be instrumental to emphasize guidelines when players are exercising in hot and humid environmental conditions and when drinking time is limited due to morning training or matches.

### Fluid Intake During Training and Matches

Few studies have assessed body mass losses and sweat rates in elite female soccer players during training and matches. Such assessments are necessary to develop individualized hydration strategies that can be tailored to meet specific exercise demands and environmental conditions. Weighing players pre- and post-exercise (and accounting for fluid intake) represents a simple and accurate method for assessing fluid requirements in different scenarios (Armstrong et al., 2007). Compared with training, match play induces significantly greater body mass losses (difference 0.83%), sweat rates (difference 0.36 L·h$^{-1}$), and $Na^+$ losses (Tarnowski et al., unpublished observations). During competitive matches, two studies showed that mean body mass losses were between 0.9% and 1.1%, with sweat rates between 0.8 and 0.9 L·h$^{-1}$ in hot (25 °C) and normal (14.8 °C) conditions, respectively (Broad et al., 1996; Tarnowski et al., unpublished observations). Recently, Krustrup et al. (2022) reported greater body mass losses of 2.0% after a friendly match played at 17 – 19 °C. The high individual variability in body mass losses (range: 0.2 – 2.3%, Tarnowski et al., unpublished observations) (range: 0.7 – 5.9%, Krustrup et al., 2022) and sweat $Na^+$ losses (Tarnowski et al., unpublished observations) highlights the importance of providing players with individualized hydration strategies. Clear instructions that specify personalized fluid volumes and time-points (i.e., after the warm-up, half-time, before extra-time) for drinking could be helpful for players. As the later stages of a match (i.e., > 90 min) can pose a significant challenge to fluid regulation and fuel availability (Kerksick et al., 2018), consuming a 6 – 8% carbohydrate-electrolyte solution that provides 30 – 60 $g \cdot h^{-1}$ before each half could help to preserve performance during the later stages of a match [*see Carbohydrate Requirements section*].

### Fluid Intake Post Training and Matches

Timely replacement of any fluid deficit after training or matches can usually be achieved via plain water, combined with meals and snacks containing sufficient sodium to replace electrolyte losses (Sawka et al., 2007). Sports drinks can be helpful when recovery times are limited as they enable immediate replenishment of water and electrolytes and promote fast glycogen resynthesis [*see Carbohydrate Requirements section*]. The volume of fluid replacement should range from 1 to ~1.5 L (~34 – 51 fl oz) for each kilogram of body weight lost, depending on how quickly rehydration must be achieved (Sawka et al., 2007). The upper range will account for the increased urine production accompanying the ingestion of large volumes of fluid when recovery time is limited (Shirreffs & Maughan, 1998).

## SUPPLEMENTS

Elite female soccer players use supplements frequently, with the primary motives to stay healthy, accelerate recovery and to increase energy/ reduce fatigue (Oliveira et al., 2022). Micronutrient supplementation can improve a player's health when a nutrient deficiency has been identified. Iron, calcium, and vitamin D are the micronutrients most often requiring dietary supplementation in athletes (Maughan et al., 2018).

Few supplements have good evidence of performance advantages (e.g., caffeine, creatine, dietary nitrate) that are relevant to soccer in men (Maughan et al., 2018) (Table 1). Limited investigation exists in elite female players, although two studies found creatine supplementation to enhance intermittent running capacity (Cox et al., 2002) and strength (Larson-Meyer et al., 2000). More research is required to understand the impact of other dietary supplements relative to performance (i.e., sodium bicarbonate, beta-alanine) and recovery (i.e., antioxidants) in elite players. The decision to supplement should be evaluated using dietary assessment, biochemical testing to assess for sufficiency/insufficiency, medical and nutritional history, and anthropometry (Larson-Meyer et al., 2018). Therefore, ad-hoc intake of any supplement is not advised.

| Supplement | Recommended intake | Potential benefit to soccer | Side effects and notes |
|---|---|---|---|
| Creatine | ~20 g for 5-7 days (loading phase), then 2-3 g daily (maintenance phase) | Explosive movements (e.g., sprinting, jumping)<br><br>Weight gain (~1%) could be beneficial during contact play | Weight gain (~1%) due to water retention, which might offset any improvements from supplementation |
| Caffeine | 3-6 mg·kg-1<br><br>Timing for pre-exercise ingestion is dependent on form:<br>• 30 min prior for drink/ specially formulated sports shot<br>• 45 min prior for gel<br>• 5-10 min prior and at breaks in play > 5 min for gum | Endurance<br><br>Repeated explosive movements | Nausea, headache, anxiety and gastro-intestinal distress can occur when recommended dose is exceeded |
| Dietary nitrate | ~8 mmol nitrate via nitrate salt or foods | Possible improvement in repeated explosive movements | Ergogenic effect less likely in players with high aerobic capacity |

**Table 1:** Supplements that could aid soccer performance and recovery in females, including dose and possible side effects

## PRACTICAL APPLICATIONS

- Provision of individualized nutrition strategies that target fuelling, protein intake, hydration and supplements could promote health and performance for the elite female soccer player.
- Many players require support to achieve and periodize sufficient energy and carbohydrate intakes throughout a competition week. Both education and environmental changes are necessary to ensure that players are appropriately fuelled for the demands of training and matches.
- Individualized hydration strategies for pre, during and post exercise that account for the variability in sweat and electrolyte losses are recommended.
- The decision to supplement should be based on a comprehensive needs analysis that weighs up the player's requirement against any potential side effects.

## CONCLUSION

The application of sound nutritional guidance is necessary to support player health and performance. Based on findings in elite female soccer players, there is scope to improve nutritional practices relative to energy intake, fuelling, hydration, and supplement use. However, provision of best dietary practice will benefit from further high-quality research that includes elite female players as participants.

Rebecca K. Randell is employed by PepsiCo R&D. Samantha L. Moss has received consulting fees from PepsiCo R&D. The views expressed are those of the authors and do not necessarily reflect the position or policy of PepsiCo, Inc.

## REFERENCES

Areta, J.L., L.M. Burke, M.L. Ross, D.M. Camera, D.W.D West, E.M. Broad, N.A. Jeacocke, D.R. Moore, T. Stellingwerff, S.M. Phillips, J.A. Hawley, and V.G. Coffey (2013). Timing and distribution of protein ingestion during prolonged recovery from resistance exercise alters myofibrillar protein synthesis. J. Physiol. 591:2319-2331.

Armstrong, L.E., D.J. Casa, M. Millard-Stafford, D.S. Moran, S.W. Pyne, and W.O. Roberts (2007). American College of Sports Medicine position stand. Exertional heat illness during training and competition. Med. Sci. Sports Exerc. 39:556-572.

Bangsbo, J., L. Norregaard, and F. Thorsoe (1992). The effect of carbohydrate diet on intermittent exercise performance. Int. J. Sports Med. 13:152-157.

Broad, E.M., L.M. Burke, G.R. Cox, P. Heeley, and M. Riley (1996). Body weight changes and voluntary fluid intakes during training and competition sessions in team sports. Int. J. Sport Nutr. 6:307-320.

Burke, L.M., G.R. Collier, and M. Hargreaves (1993). Muscle glycogen storage after prolonged exercise: Effect of the glycemic index of carbohydrate feedings. J. Appl. Physiol. 75:1019-1023.

Burke, L.M., A.B. Loucks, and N. Broad (2006). Energy and carbohydrate for training and recovery. J. Sports Sci. 24:675-685.

Burke, L.M., L.J.C. van Loon, and J.A. Hawley (2017a). Postexercise muscle glycogen resynthesis in humans. J. Appl. Physiol. 122:1055–1067.

Burke, L.M., M.L. Ross, L.A. Garvican-Lewis, M. Welvaert, I.A. Heikura, S.G. Forbes, J.G. Mirtschin, L.E. Cato, N. Strobel, A.P. Sharma, and J.A. Hawley (2017b). Low carbohydrate, high fat diet impairs exercise economy and negates the performance benefit from intensified training in elite race walkers. J. Physiol. 595:2785-2807.

Burke, L.M., B. Lundy, I.L. Fahrenholtz, and A.K. Melin (2018). Pitfalls of conducting and interpreting estimates of energy availability in free-living athletes. Int. J. Sport Nutr. Exerc. Metab. 28:350–363.

Chapelle, L., B. Tassignon, N. Rommers, E. Mertens, P. Mullie, and P. Clarys (2020). Pre-exercise hypohydration prevalence in soccer players: A quantitative systematic review. Eur. J. Sport Sci. 20: 744-755.

Collins, J., R.J. Maughan, M. Gleeson, J. Bilsborough, A. Jeukendrup, J.P. Morton, S.M. Phillips, L. Armstrong, L.M. Burke, G.L. Close, R. Duffield, E. Larson-Meyer, J. Louis, D. Medina, F. Meyer, I. Rollo, J. Sundgot-Borgen, B.T. Wall, B. Boullosa, G. Dupont, A. Lizarraga, P. Res, M. Bizzini, C. Castagna, C.M. Cowiw, M. D'Hooghe, H. Geyer, T. Meyer, N. Papadimitriou, M. Vouillamoz, and A. McCall (2021). UEFA expert group statement on nutrition in elite football. current evidence to inform practical recommendations and guide future research. Br. J. Sports Med. 55:416.

Cox, G., I. Mujika, D. Tumilty, and L. Burke (2002). Acute creatine supplementation and performance during a field test simulating match play in elite female soccer players. Int. J. Sport Nutr. Exerc. Metab. 12:33-46.

De Souza, M.J., N.C.A. Strock, E.A. Ricker, K.J. Koltun, M. Barrack, E. Joy, A. Nattiv, M. Hutchinson, M. Misra, and N.I. Williams (2022). The path towards progress: A critical review to advance the science of the female and male athlete triad and relative energy deficiency in sport. Sports Med. 52:13-23.

Dobrowolski, H., A. Karczemna, and D. Włodarek (2020). Nutrition for female soccer players—recommendations. Medicina 56:28-45.

Fédération Internationale de Football Association (FIFA) 2017—Football Emergency Medical Manual [WWW Document]. https://schoolsfootball.org/wp-content/uploads/2021/07/football-emergency-medicine-manual-2nd-edition-2015-2674609.pdf

Fédération Internationale de Football Association (FIFA). Physical analysis of the FIFA women's world cup France 2019. (2019a) [WWW Document]. https://digitalhub.fifa.com/m/4f40a98140d305e2/original/zijqly4oednqa5gffgaz-pdf.pdf Accessed 15.05.22

Fédération Internationale de Football Association (FIFA). Women's World Cup. 2019TM. News – FIFA Women's World Cup. 2019TM watched by more than 1 billion. (2019b). [WWW Document] https://www.fifa.com/tournaments/womens/womensworldcup/france2019/news/fifa-women-s-world-cup-2019tm-watched-by-more-than-1-billion Accessed 15.05.22

Fédération Internationale de Football Association (FIFA). Women's Football Strategy (2021). [WWW Document]. https://digitalhub.fifa.com/m/baafcb84f1b54a8/original/z7w21ghir8jb9tguvbcq-pdf.pdf Accessed 15.05.22

Giersch, G.E.W., N. Charkoudian, R.L. Stearns, and D.J. Casa (2020). Fluid balance and hydration considerations for women: Review and future directions. Sports Med. 50:253-261.

Hackney, A.C. (1990). Effects of the menstrual cycle on resting muscle glycogen content. Horm. Metab. Res. 22:647.

Hoffman, J.R., and M.J. Falvo (2004). Protein—which is best? J. Sports Sci. Med. 3:118-130.

Kerksick, C.M., C.D. Wilborn, M.D. Roberts, A. Smith-Ryan, S.M. Kleiner, R. Jäger, R. Collins, M. Cooke, J.N. Davis, E. Galvan, M. Greenwood, L.M. Lowery, R. Wildman, J. Antonio, and R.B. Kreider (2018). ISSN exercise & sports nutrition review update: Research & recommendations. J. Int. Soc. Sports Nutr. 15:38.

Krustrup, P., M. Mohr, L. Nybo, D. Draganidis, M.B. Randers, G. Ermidis, C. Ørntoft, L. Røddik, D. Batsilas, A. Poulios, N. Ørtenblad, G. Loules, C.K. Deli, A. Batrakoulis, J.L. Nielsen, A.Z. Jamurtas, and I.G. Fatouros (2022). Muscle metabolism and impaired sprint performance in an elite women's football game. Scand. J. Med. Sci. Sports 32:27-38.

Larson-Meyer, D.E., K. Woolf, and L. Burke (2018). Assessment of nutrient status in athletes and the need for supplementation. Int. J. Sport Nutr. Exerc. Metab. 28:139-158.

Larson-Meyer, D.E., G. Hunter, C.A. Trowbridge, J.C. Turk, J. Ernest, S.L. Torman, and P. Harbin (2000). The effect of creatine supplementation on muscle strength and body composition during off season training in female soccer players. J. Strength Cond. Res. 14:434-442.

Loucks, A.B., R. Kiens, and H.H. Wright (2011). Energy availability in athletes. J. Sports Sci. 29:7-15.

Maughan, R.J., L.M. Burke, J. Dvorak, D.E. Larson-Meyer, P. Peeling, S.M. Phillips, E.S. Rawson, N.P. Walsh, I. Garthe, H. Geyer, R. Meeusen, L.J.C. van Loon, S.M. Shirreffs, L.L. Spriet, M. Stuart, A. Vernec, K. Currell, V.M. Ali, R.G. Budgett, A. Ljungqvist, M. Mountjoy, Y.P. Pitsiladis, S. Torbjørn, U. Erdener, and L. Engebretsen (2018). IOC consensus statement: Dietary supplements and the high-performance athlete. Br. J. Sports Med. 52: 439-455.

McLay, R.T., C.D. Thomson, S.M. Williams, and N.J. Rehrer (2007). Carbohydrate loading and female endurance athletes: Effect of menstrual-cycle phase. Int. J. Sport Nutr. Exerc. Metab. 17:189–205.

Moore, D.R., J. Sygo and J.P. Morton (2022). Fuelling the female athlete: Carbohydrate and protein recommendations. Eur. J. Sport Sci. 22:684-696.

Morehen, J.C., C. Rosimus, B.P. Cavanagh, C. Hambly, J.R. Speakman, K.J. Elliot-Sale, M.P. Hannon, and J.P. Morton (2022). Energy expenditure of female international standard soccer players. Med. Sci. Sports Exerc. 54:769-779.

Moss, S.L., R.K. Randell, D. Burgess, S. Ridley, C. ÓCairealláin, R. Allison, and I. Rollo (2021). Assessment of energy availability and associated risk factors in professional female soccer players. Eur. J. Sport Sci. 21:861-870.

Nicklas, B.J., A.C. Hackney, and R.L. Sharp (1989). The menstrual cycle and exercise: Performance, muscle glycogen, and substrate responses. Int. J. Sports Med. 10:264-269.

Nuccio, R.P., K.A. Barnes, J.M. Carter, and L.B. Baker. (2017). Fluid balance in team sport athletes and the effect of hypohydration on cognitive, technical, and physical performance. Sports Med. 47:1951-1982.

Oliveira, C.B., M. Sousa, R. Abreu, A. Ferreira, P. Figueiredo, V. Rago, V.H. Teixeira, and J. Brito (2022). Dietary supplements usage by elite female football players: An exploration of current practices. Scand. J. Med. Sci. Sports 32:73-80.

Pasiakos, S.M., H.R. Lieberman, and T.M. McLellan (2014). Effects of protein supplements on muscle damage, soreness and recovery of muscle function and physical performance: A systematic review. Sports Med. 44:655-670.

Pasiakos, S.M., and E.E. Howard (2021). High-quality supplemental protein enhances acute muscle protein synthesis and long-term strength adaptations to resistance training in young and old adults. J. Nutr. 151,1677-1679.

Poulios, A., K. Georgakouli, D. Draganidis, C.K. Deli, P.D. Tsimeas, A. Chatzinikolaou, K. Papanikolaou, A. Batrakoulis, M. Mohr, A.Z. Jamurtas, and I.G. Fatouros (2019). Protein-based supplementation to enhance recovery in team sports: What is the evidence? J. Sports Sci. Med. 18:523-536.

Prather, H., D. Hunt, K. McKeon, S. Simpson, E.B. Meyer, T. Yemm, and R. Brophy (2016). Are elite female soccer athletes at risk for disordered eating attitudes, menstrual dysfunction, and stress fractures? PM R 8:208-213.

Randell, R.K., T. Clifford, B. Drust, S.L. Moss, V.B. Unnithan, M.B.A. De Ste Croix, B.A. Mark, N. Datson, D. Martin, H. Mayho, J.M. Carter, and I. Rollo (2021). Physiological characteristics of female soccer players and health and performance considerations: A narrative review. Sports Med. 51:1377-1399.

Reed, J.L., M.J. De Souza, and N.I. Williams. (2013). Changes in energy availability across the season in Division I female soccer players. J. Sports Sci. 31:314-324.

Rodriguez-Giustiniani, P., I. Rollo, O.C. Witard, and S.D.R. Galloway (2019). Ingesting a 12% carbohydrate-electrolyte beverage before each half of a soccer match simulation facilitates retention of passing performance and improves high-intensity running capacity in academy players. Int. J. Sport Nutr. Exerc. Metab. 29:1-9.

Rothman, D.L., I. Magnusson, L.D. Katz, R.G. Shulman, and G.I. Shulman (1991). Quantitation of hepatic glycogenolysis and gluconeogenesis in fasting humans with 13C NMR. Science 254:573-576.

Santos, D.D., J.Q.D. Silveira, and T.B. Cesar (2016). Nutritional intake and overall diet quality of female soccer players before the competition period. Rev. de Nutr. 29:555-565.

Sawka, M.N., L.M. Burke, E.R. Eichner, R.J. Maughan, S.J. Montain, and N.S. Stachenfeld (2007). Exercise and fluid replacement. Med. Sci. Sports Exerc. 39:377-390.

Shirreffs, S.M., and R.J. Maughan (1998). Urine osmolality and conductivity as indices of hydration status in athletes in the heat. Med. Sci. Sports Exerc. 30:1598-1602.

Snijders, T., J. Trommelen, I.W.K. Kouw, A.M. Holwerda, L.B. Verdijk, and L.J.C. van Loon (2019). The impact of pre-sleep protein ingestion on the skeletal muscle adaptive response to exercise in humans: An update. Front. Nutr. 6:1-8.

Sousa, M.V., A. Lundsgaard, P.M. Christensen, L. Christensen, M.B. Randers, M. Mohr, L. Nybo, B. Kiens, and A.M. Fritzen (2022). Nutritional optimization for female elite football players—topical review. Scand. J. Med. Sci. Sports. 32:81-104.

Sundgot-Borgen, J., M.K. and Torstveit, (2007). The female football player, disordered eating, menstrual function and bone health. Br. J. Sports Med. 41:68–72.

Tarnowski, C., Rollo, I., Carter, J.M., Lizarraga-Dallo, M.A., Porta Oliva, M., Clifford, T., James, L.J., and Randell, R.K. Fluid balance and carbohydrate intake of elite female soccer players during training and competition. (In Preparation).

Thomas, D.T., K.A. Erdman, and L. Burke (2017). Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and athletic performance. J Acad. Nutr. Diet. 117:146-146.

Union of European Football Association (UEFA) (2019). Women's Football Strategy 2019-24. [WWW Document]. https://www.uefa.com/MultimediaFiles/Download/uefaorg/Womensfootball/02/60/51/38/2605138_DOWNLOAD.pdf Accessed 15.05.22

Union of European Football Association (UEFA) (2022). Surging numbers bear out success of revamped UEFA Women's Champions League. https://www.uefa.com/womenschampionsleague/news/0275-15308525fcc1-a7e0ee6fef86-1000--surging-numbers-bear-out-success-of-revamped-uefa-women-s-champ/ Accessed 21.05.22