Sports Medicine
https://doi.org/10.1007/s40279-026-02413-8

CURRENT OPINION

Fueling Women's Football: Evidence-Informed Practical Nutrition Strategies for Performance and Health

Abbie E. Smith-Ryan[1] · Sam R. Moore[1] · Michelle Arent[2] · Elena Cantu[1] · Lissette Cornejo[3] · Anthony C. Hackney[1] · Johanna K. Ihalainen[4,5] · Ritva S. Mikkonen[5] · Georgie Bruinvels[6]

Accepted: 23 February 2026

Abstract
This paper synthesizes current research on women's football to develop comprehensive, evidence-informed nutritional strategies tailored to the specific demands of the sport. Four key themes are addressed: (1) energy requirements in women's football; (2) macronutrient and nutrient-timing applications around training and match play, including an illustrative case study; (3) supporting a player with inadequate energy intake, including an illustrative case study; and (4) nutritional considerations relating to fluctuations in female sex hormones. Rather than providing another descriptive narrative review, this synthesis translates research findings into practical strategies for implementation in real-world performance environments. Adequate energy availability is identified as a fundamental nutritional priority. Carbohydrate and protein intake are emphasized as essential for sustaining training quality, supporting recovery, and maximizing match performance. Nutrient timing is highlighted as a critical determinant of in-season performance and effective match preparation. Consideration is also given to the influence of hormonal fluctuations on thermoregulation and menstrual cycle–related symptoms, alongside nutritional strategies to mitigate these effects. This synthesis underscores the importance of individualized nutritional strategies to optimize health, performance, and return-to-play outcomes in women footballers.

1 Introduction

Nearly two decades ago, Maughan and Shirreffs [1] described nutrition and hydration concerns of women football players, highlighting evidence that women footballers often do not meet the energy demands, optimal hydration status, and micronutrient needs of their sport. More recently, the Union of European Football Associations published evidence-informed nutrition guidance for elite footballers [2],

Key Points

Nutrition can contribute to the maintenance of optimal training and performance levels, while supporting health. The appropriate application of nutritional strategies can support player availability, maintain optimal performance, and reduce the risk of fatigue and injury. Nutrition plans should be football specific and tailored to each player's individual needs, considering factors such as playing position, training volume, goals, training age, and menstrual status (e.g., fluctuations in female sex hormones).

To maintain or improve performance and health, women footballers should prioritize adequate energy intake, with careful attention given to the timing of intake around training and matches. Ideally, preparation for a match begins a few days in advance by increasing carbohydrate intake. On match day, a focus on easily digestible carbohydrate before and during the match helps to maintain energy levels while avoiding gastrointestinal distress. Immediately after the match, consuming carbohydrates and proteins can support recovery. Nutrient timing is also key to maintaining menstrual health.

✉ Abbie E. Smith-Ryan
abbiesmith@unc.edu

1 Department of Exercise and Sport Science, Department of Nutrition, University of North Carolina, Chapel Hill, NC 27713, USA

2 Department of Athletics, University of South Carolina, Columbia, SC, USA

3 Lissette Cornejo Nutrition, LLC, Orlando, FL, USA

4 Faculty of Sport and Health Sciences, University of Jyväskylä, Jyväskylä, Finland

5 Finnish Institute of High Performance Sport KIHU, Jyväskylä, Finland

6 Department of Targeted Intervention, University College London, London, UK

Published online: 18 March 2026

providing comprehensive nutrition guidance for match day nutrition, training day nutrition, dietary supplements, body composition, and rehabilitation [2, 3]. Around the same time, other comprehensive reviews provided detailed summaries of women footballers' or women athletes' nutritional needs [4–7]. Meanwhile, new original research studies have emerged focusing on women's football.

It is imperative that nutrition research in women's football is easily translated into practical guidance that is modifiable across individuals, positions, teams, levels of play (i.e., professional to recreational), and global application. The aim of this paper is not to provide another narrative review of women's football nutrition needs, but to provide practical nutritional recommendations through evidence-informed cases modified from real athletes, for women football athletes and support staff. This will be achieved via four themed sections, each with an evidence-informed overview to enhance the understanding and implementation of sport nutrition in this population. Theme 1 considers the energy (caloric) needs of women footballers. Theme 2 considers nutrient timing and match day needs, including hydration with an illustrative case study. Theme 3 considers how to support a player deemed to have inadequate energy intake and includes an illustrative case study. Theme 4 provides considerations for the menstrual status of a woman football player. The largest physical demands come at the elite level, with many of the themes anchored in elite football needs but with many tenets included that can be applied to competitive and pre-professional pathways.

2 Theme 1: Estimating Women's Football Energy (Caloric) Needs

This section outlines the factors contributing to a player's total energy requirement. It should be used to inform periodization of overall macronutrient intake. In real-world training and competition settings, multiple variables must be considered when estimating total caloric needs, including the specific demands of football, which varies by day, playing position, and the body composition of the player.

2.1 Football-Specific Sport Demands

A comprehensive approach, accounting for the physical and mental loads of football, should be used when planning effective nutritional strategies to support athletes. The physical demands of match play were comprehensively reviewed by Harkness-Armstrong et al. [8]. Briefly, women's football matches are characterized by 5–11 km of repeated high-intensity efforts, with sprints occurring approximately every 150 s over a typical 90-min match [6]. Congested match play, total distance covered, maximum speed, number of accelerations and decelerations, number of total high-speed runs, physical contact (heading, tackling, collisions), and cognitive demand (alertness, accuracy) are all variables contributing to the physiological load that footballers experience. Multiple additional factors should be considered when estimating energy and nutrient needs for each athlete, including level of play (youth vs professional), player position [8], and point in the season (varied training load/training periodization) [9, 10]. Initial energy requirement estimations should be considered and re-evaluated. Tracking body composition, i.e., both fat mass and lean mass, can support initial caloric assessments, and can be used as a surrogate for energy availability (EA), providing an indirect but robust means of assessing dietary sufficiency. A variety of methods for assessing whole body composition have been developed to better evaluate each individual's health status, but technology is improving in order to better estimate body tissues [11]. The frequency of measurement should depend on the sensitivity/reliability of the device, with more sensitive devices providing an ability to detect a smaller change, such as a multi-compartment model. At a minimum, pre- and post-season is a good starting point for measurement frequency. Additional measurements around surgery/injury and return to play, as well as before and after key training periodization or seasons that may specifically target body composition (i.e., hypertrophy), could provide value.

2.2 Women's Footballer Body Composition

Regular body composition assessments can provide dietitians and sports nutritionists with data to inform nutritional targets and to assess whether an athlete is meeting caloric requirements. This is important for peak performance and injury risk reduction, as it helps in fine-tuning fueling strategies to ensure adequate nutrient intake, supporting muscle mass and bone density. Body composition is a dynamic and responsive indicator of an athlete's nutritional status and training adaptations. Changes in body fat and fat-free mass (FFM) can serve as early markers of low energy availability (LEA), often preceding more serious consequences such as hormonal disruptions, impaired recovery, and bone health deterioration [12, 13]. A significant loss of body fat or FFM, particularly when not aligned with training goals or training periodization, may signal inadequate energy intake. Regular monitoring of body composition allows practitioners to detect these shifts early, enabling timely adjustments to nutritional strategies before more severe outcomes—like injury or compromised bone density—develop [14, 15].

Importantly, some fluctuations in body composition are expected across a competitive season or training cycle, and individual responses vary widely. Therefore, establishing a personalized tracking profile for each athlete is essential [14]. This individualized approach supports more precise and proactive nutrition planning, helping dietitians and sports nutritionists tailor caloric and macronutrient targets to match training demands. Routine assessments not only inform whether athletes are meeting energy requirements but also serve as a practical tool to fine-tune fueling strategies that support optimal performance, preserve muscle mass, and support skeletal integrity. Ultimately, aligning changes in body fat and FFM with training volume and goals enhances both performance outcomes and injury prevention.

Women's footballer anthropometrics vary according to individual and contextual factors such as training age, level of competition [16, 17], season phase [18–21], and playing position [17, 20, 22]. One 'optimal' body composition across all women's football athletes does not exist. Table 1 provides data to illustrate differences by playing position based on available research, highlighting the range of anthropometrics in this population.

Body composition measurement and individualized goals should be communicated to the athletes from the nutrition professional rather than from the sport coach. Body composition is a tool for understanding energy and macronutrient needs, monitoring changes in muscle and/or bone over time, and for tracking limb asymmetries and FFM changes for injury prevention/return to play [23]. When evaluating the rate of change in body composition over time, it is important to consider that the response of an individual athlete is likely influenced by the athlete's physical and psychological status, as well as the specific training stimulus and nutrition strategy applied.

The menstrual cycle can influence the accuracy of body composition measurements, specifically when the selected technique relies on total body water measurements (i.e., bioelectrical impedance analysis) [24, 25]. Best practice guidelines for body composition assessments dictate that (1) measurements should be taken with an appropriate frequency (e.g., 6 weeks between measures), (2) device measurement error is taken into account when interpreting change (varies by technique), and (3) standardized pretesting protocols are followed (e.g., euhydrated state, no exercise or food within a minimum of 2-h prior). Various published guidelines and recommendations exist [15, 26], and there is no universal standard. Utilizing methods that can provide segmental FFM may have more utility for injury prevention and sport-specific tracking [27]. Furthermore, some measurement methods are sensitive to fluid and hormonal alterations across the menstrual cycle [24], while dual energy x-ray absorptiometry (DXA), ultrasound, and skinfolds are not likely impacted by the menstrual cycle and therefore can be used without timing restrictions [28, 29]. More accessible field-based methods, such as skinfolds and circumferences, can be used and should be completed by individuals with extensive practice and/or certification [30].

Fat-free mass index (FFMI) has been used as a sensitive indicator for women's athletes in terms of injury risk reduction, monitoring body composition, and setting optimal muscle targets based on sport and player-position normative data [31, 32]. FFMI provides a measure of muscle mass relative to height, which provides insight into an athlete's muscular development and potential for future FFM accrual. By regularly monitoring FFMI, strength coaches, dietitians, and athletes can monitor changes over time, ensuring that training and nutrition programs are effectively supporting muscle growth and maintenance. This is particularly important for injury risk reduction, since muscle mass helps protect athlete's joints and bones [33, 34].

Table 1 Average body composition values from elite female football players measured by skinfolds (A) [19, 93] and bioelectrical impedance (B) for goalkeepers (GK), defenders (DF), midfielders (MF), and forwards (FW) [94]

Position	Age (years)	Height (cm)	Weight (kg)	Fat-free mass (kg)	Fat mass (kg)	Percent body fat (%)
(A)						
GK	22.7 ± 5.4	176.8 ± 5.8	72.4 ± 8.6	23.3 ± 2.7	12.6 ± 6.0	18.9 ± 4.9
DF	25.0 ± 3.7	170.4 ± 4.7	64.2 ± 4.4	22.9 ± 2.5	9.5 ± 2.0	21.3 ± 3.3
MF	25.3 ± 3.0	168.9 ± 5.7	63.8 ± 5.6	23.0 ± 2.1	10.7 ± 3.5	21.8 ± 3.4
FW	23.6 ± 5.2	168.3 ± 4.6	64.7 ± 5.9	23.9 ± 3.1	9.9 ± 2.6	20.8 ± 3.6
(B)						
GK	20.7 ± 4.5	171.7 ± 8.3	64.5 ± 13.9	45.2 ± 5.5	16.9 ± 8.6	25.3 ± 6.9
DF	23.1 ± 3.1	164.1 ± 4.4	56.8 ± 4.3	42.1 ± 1.6	12.5 ± 3.2	21.7 ± 4.0
MF	25.0 ± 3.5	161.9 ± 5.5	57.9 ± 6.4	42.3 ± 2.7	13.4 ± 4.8	22.6 ± 6.1
FW	22.3 ± 5.6	163.8 ± 5.9	58.8 ± 6.5	42.6 ± 2.5	14.0 ± 4.3	23.3 ± 4.7

Understanding position-specific demands and establishing individual needs is imperative. While average values may provide a description of position-specific player characteristics, the values themselves should not be used as a specific goal. Additionally, body composition varies globally. These values are based on current published data; more research is needed in various environments, ethnicities, and levels of play. Body composition assessment should be considered when evaluating position-specific normative values

2.3 Energy and Macronutrient Needs

Adequate daily energy intake is fundamental to athlete health and performance, yet many women athletes fail to consume sufficient energy [35–37]. It should be noted that most evidence to date comes from studies conducted in Europe, North America, Australia, and New Zealand [37], which may limit the generalizability to women footballers in other countries. Estimating energy requirements in women footballers is complex due to variability between players (see Sect. 2.2). However, estimating energy requirements can help to guide each player's energy intake. The doubly-labeled water technique and indirect calorimetry methods are considered gold standard for estimating energy expenditure. Total daily energy expenditure (TDEE) estimation typically begins with resting metabolic rate (RMR) assessment [38] in the laboratory, which is not practical in most football settings. Validated RMR prediction equations can be used as an alternative method. Among these, the Cunningham equation [RMR (kcal/day) = 500 + 22 × FFM (kg)] had the lowest error for women athletes (mean difference 110 kcal) [39], which may be optimal for tracking changes. A systematic review of RMR prediction equations for athletes found the Ten-Haaf 2014 equation (Fig. 1) to be the most precise, predicting within ± 10% of measured RMR values [40], which may be best for single-point-in-time evaluations. However, no equations sufficiently account for factors such as ethnicity, nutritional or hormonal status, or environmental conditions, which limit their precision for women athletes. Figure 1 provides a tool to help practitioners to navigate methods for estimating RMR and TDEE to establish starting caloric intake recommendations.

2.4 Energy Availability

Another approach to determining energy needs is to consider EA, defined as the remaining dietary energy available after subtracting exercise energy expenditure from energy intake. This is viewed as the energy available to sustain resting physiological functions and is expressed relative to an individual's FFM. Existing literature suggests women athletes with an EA of at least 45 kcal/kg FFM per day should have adequate energy available to meet daily physiological energy demands [41, 42]. An EA of 30–45 kcal/kg FFM is considered 'reduced'; short periods of reduced EA may occur without serious side effects when implemented with oversight from a nutrition professional. EA < 30 kcal/kg FFM is associated with an increased risk of suboptimal health and performance for women athletes. However, these guidelines are only approximations. The recent International Olympic Committee's (IOC) consensus statement on Relative Energy Deficiency in Sport (REDs) explains that 'problematic' LEA, which may result in REDs development, is highly variable between individual athletes [42]. While these EA thresholds make for easy targets in conversations with athletes and medical personnel charged with athlete well-being, they rely on body composition data being available as well as accurate estimation of energy intake and exercise energy expenditure, all of which have limitations [43]. Further, these thresholds were not intended or designed as hard cutoffs, but rather as more of a guide as hormonal perturbations and physiological effects have been observed at varied levels of EA [42].

A detailed description of carbohydrate, protein, and fat requirements in footballers is not included here since this would duplicate other comprehensive reviews [6, 37, 44]. To help with practical translation into a football setting, Fig. 2 provides an example of a timeline with specific examples of meals and snacks to achieve adequate energy and nutrients for a woman center midfielder, during a typical training day.

3 Theme 2: Nutrient Timing and Match Day Needs (with Case Study Example)

Nutrient timing is the strategic and purposeful consumption of nutrients in and around training bouts to enhance recovery and adaptation including performance and health. Figure 3 provides a case study with a timeline for nutritional intake leading up to and following a match as a general guide for practitioners to adapt as needed for different athletes. Specific foods and supplement choices have not been included here since these vary widely across the globe, independent of player sex, with sources of variation including local culinary traditions, availability of specific foods, climate, and culture. Furthermore, existing guidelines are largely based on Western diets [2]. There is an obvious need for research that provides specific nutritional guidance that accommodates these variables, but this is beyond the scope of the present review.

Nutritional preparation for a match should not wait until 'match day − 1' (the day before the match). Recommendations of carbohydrate intakes of 7–12 g/kg body mass per day [38] may be advantageous 72–48 h before the match. This is especially important in times of congested schedules when there is a maximum of 2–3 days between matches as a return to pre-match muscle glycogen levels in footballers may take 72 h [6, 45]. To the knowledge of the authors, there are no published data available specifically for women footballers; however, other women's athlete research suggests there is no difference between men and women for carbohydrate intakes, rather, intake is driven by exercise intensity and duration [46]. Due to the frequent acceleration/deceleration patterns inherent in football, adequate protein intake of at least 1.6–2.2 g/kg per day should be consumed. Reported protein intakes of youth and adult women football

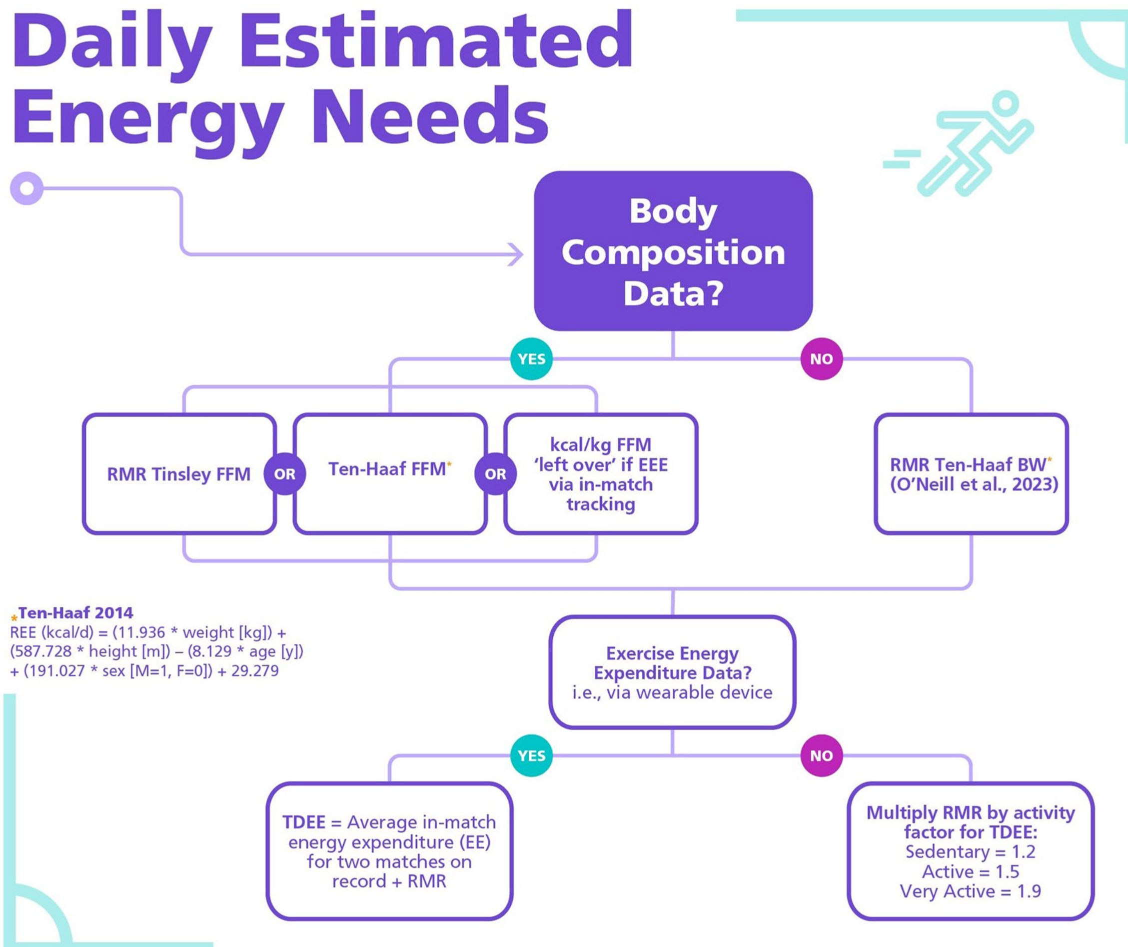

Fig. 1 A proposed tool for estimating resting metabolic rate (RMR) and total daily energy expenditure (TDEE) as a foundation for establishing macronutrient goals. When available, calculations that incorporate fat-free mass (FFM) are preferred. If possible, including data from wearable technology (internal and external load) or through session perceived exertion can help further inform daily energy needs. *BW* body weight, *EE* energy expenditure, *EEE* exercise energy expenditure, *REE* resting energy expenditure

athletes range from 0.96 to 2.0 g/kg [37], aligning with current recommendations [2]. Higher intakes (2.0–4.0 g/kg) are advised during periods of increased muscle damage, illness, injury, surgery, and energy deficits [2]. Fat is also critical to support athlete health and performance. In addition to aiding in meeting daily energy needs, fat may also serve as a fuel substrate during exercise at lower intensities and during periods of recovery between higher intensity bouts of exercise, particularly in women athletes. Dietary fat intakes below 20% of total daily energy needs may not provide adequate amounts of essential fatty acids such as omega 3 [2].

3.1 *Match Day – 1*

On the day prior to the game, the aim is to ensure muscle glycogen stores are full and other energy stores are adequate. Anecdotally, in football, it is common to taper for a game by reducing training volume, which might mislead athletes into eating less the day before a game. However, this reduction in volume can also come with an increase in intensity. Maintaining caloric intake at this time is a strategy to ensure players go into a game with full muscle glycogen stores.

3.2 *Match Day*

For match day, adequate energy and carbohydrate intake remain key priorities. Regardless of game time, significantly increasing intake of easily digestible carbohydrate is crucial to improve glucose availability and minimize gastrointestinal (GI) distress. Carbohydrate intake may be tapered as kickoff approaches, with recommendations of 1–4 g/kg consumed 1–4 h prior to prepare the athlete for optimal performance while allowing for adequate digestion and GI comfort [38]. Consuming small amounts of fat, fiber, and fructose in the hours before and during play can aid in topping off muscle glycogen stores and avoiding any GI discomfort.

Fig. 2 Accounting for estimated total daily energy expenditure for a female center midfielder (~3000 kcals) following the steps proposed in Fig. 1, with recommended macronutrient consumption targets of 6 g/kg of body mass (BM) of carbohydrate (CHO), 2 g/kg of BM of protein (PRO), and 1.4 g/kg of BM of fat. This figure provides a timeline with specific examples of meals and snacks that provide adequate energy and nutrients to meet the recommendations for this player

Due to the high energy demand and glycogen utilization in football, half-time nutrition is vital to sustain muscle glycogen and energy levels. Half-time nutrition should focus on easily digestible carbohydrate with minimal fiber content, aiming for 30–60 g per hour or 60 g before each half [2], along with a source of essential amino acids to facilitate recovery. Athletes with high sweat rates might also consider pre-game and half-time electrolyte consumption like sports electrolyte mix or pickle juice [47]. Post-game is an important window to initiate recovery via nutrition. It is generally well established in research with men and women athletes that consuming carbohydrate and protein as soon as possible after training/match completion can begin to replenish glycogen stores [48], support the immune system [46], and may help to accelerate recovery [49]. For athletes who struggle eating post-match, liquid forms of carbohydrate and protein may be better tolerated as they require less work to digest than solid foods. Additionally, incorporating foods high in electrolytes, such as sports drinks or salty snacks, can help with rehydration. A pre-bed, easy-to-drink protein option, such as a protein shake or a glass of chocolate milk, can aid in meeting calorie needs and support overnight recovery and muscle repair, although the scientific evidence for milk is mixed [50]. There is stronger evidence for a pre-bed intake of > 40 g casein, a constituent of milk, to aid recovery [51].

3.3 *Match Day + 1*

The focus of the day following the match should be on recovery; this should begin immediately post-match with carbohydrates to help refuel and restore glycogen levels and protein to help repair and recover muscle damage. ‘Match day + 1’ is often a day off or an easy recovery day with low-intensity activities, but remains an important fueling window to recover and replenish from match day,

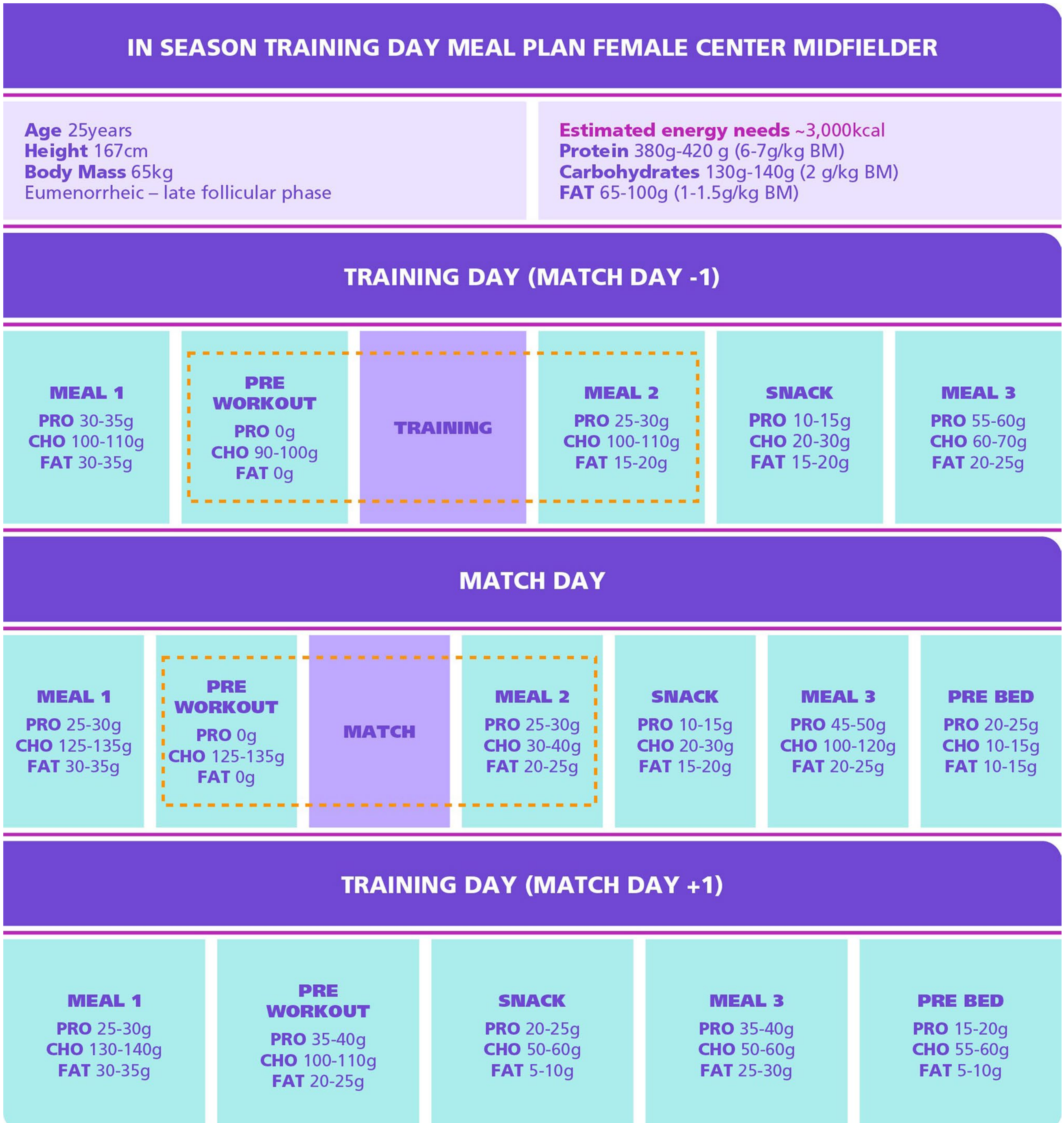

Fig. 3 A case-based approach for nutrient timing around match day with specific examples to optimize performance and recovery for a female center midfielder (25 years, 167 cm, 65 kg). *BM* body mass, *CHO* carbohydrate, *PRO* protein

as well as to prepare for the next training session. Protein consumption immediately following training/match play (0.4 g/kg) and at regular intervals thereafter (~ 3 h) has been shown to improve muscle recovery and high-speed running distances in subsequent match play [44, 52]. Prioritizing energy intake and nutrient-dense foods on this day is vital to support the body's natural repair processes through nutrition. There is a body of research describing the importance of antioxidant and anti-inflammatory foods in recovery from exercise-induced muscle damage [53, 54] (see Table 2 for food sources). Practical translation of this research would imply the necessity for antioxidant and anti-inflammatory rich fruits and vegetables like berries, cherries, citrus fruits, root vegetables, and dark leafy greens, with more carbohydrate-dense foods like potatoes, quinoa, rice, pasta, and breads helping to provide athletes with carbohydrates to aid in glycogen replenishment and micronutrients for recovery. Hydration continues to be important due to the likely increased fluid loss on match day.

3.4 Hydration

Typically, an adult woman athlete can lose several liters of water per day via sweat, varying considerably within and between individuals [55]. It is well established that sweat rate is influenced by environmental temperature and humidity, as well as the clothing worn by an athlete, and can easily reach 1–3 L/h. Sweat loss is not only dependent upon the environment, but also on fitness level, baseline fluid intake, daily physical activity, endogenous and exogenous reproductive hormones, and pregnancy status [7], pointing to an individualized approach to athlete support. Tarnowski et al. [56] also reported a higher sweat rate during matches than in training in women's football athletes. A general template for fluid and electrolyte consumption before, during, and after training and matches is provided in Table 3, based on a woman goalkeeper. This should be adjusted according to individual and environmental factors.

The strengths and weaknesses of various hydration monitoring approaches have been comprehensively reviewed [57]. To monitor fluid loss during a football match or training session, assessing body weight before and after training/matches, in minimal clothing, can be informative. By monitoring weight loss, the amount of fluid recommended for consumption during recovery can be easily determined. For each pound (~ 0.45 kg) lost, consume 20–24 oz (600–720 mL) of fluid with electrolytes within the 2–3 h after training/match [1]. If weight cannot be monitored, the frequency of urination and color of urine may serve as surrogate indicators of hydration status. The validity of monitoring urine color is generally supported by research [58]; however, all methods are subject to error. While water is often the major fluid consumed by athletes, sports drinks can be advantageous due to their electrolyte and carbohydrate content. Beverages such as milk, juices, herbal teas, and coffee, as well as fruits and vegetables, can provide a significant portion of fluid and electrolyte requirements, which may contribute to overall daily fluid needs. Practically, drinking and eating strategies and choices during training and match play should be tailored to the individual player's needs and preferences. This will involve some degree of trial and error on the part of the athlete, as well as the dietitian and coach/trainer staff, and should be addressed well in advance of critical matches. It is important to recognize that some commercial drinks may contain ingredients that increase GI distress or may not include adequate electrolytes and carbohydrates to optimize rehydration.

4 Theme 3: Supporting an Athlete with Inadequate Energy Intake (Case Study)

LEA results when energy intake is inadequate relative to an athlete's daily activity energy expenditure including training/match physical activity. The concern with LEA is that it can place the athlete at risk for developing the Female Athlete Triad [59] and/or REDs [42], with negative consequences on performance and health. In women, the development of the Triad and/or REDs is associated with suppressed menstrual function, including but not limited to amenorrhea (lack of a menstrual cycle) and bone demineralization, which increases the occurrence of bone stress injuries. These changes are brought about by reductions in the female sex hormones and subsequent disruption(s) of hormonal regulatory axes [60]. Although REDs sequelae are often only discussed in the context of LEA in general, it is important to note that adequate total energy intake in the presence of low carbohydrate availability may result in similar hormonal and systemic dysfunctions [61]. While menstrual cycle dysfunction/disruption and impaired bone health are considered major health consequences of LEA, it can also be associated with a compromised immune system, hematological, cardiovascular, metabolic, and GI

Table 2 Including foods and nutrients that naturally modulate inflammation can be beneficial to accelerate recovery, around match day and match day + 1. These may also be beneficial in reducing inflammation and menstrual-related side effects during the luteal phase and through menstruation when inflammation may be elevated

Anti-inflammatory nutrients	Sources (examples)
Anthocyanin	Found in foods that are red, blue, and purple: blackberries, blueberries, cherries, strawberries, eggplant, raspberries, red cabbage
Vitamins A, K, C	Dark leafy greens, avocados, berries, tomatoes, carrots, citrus fruits, broccoli, squash, sweet potatoes, and bell peppers
Vitamin D	Salmon, egg yolks, dairy products
Omega 3	Mackerel, salmon, herring, flax seeds, walnuts, chia seeds
Spices	Garlic, ginger, turmeric, basil, and rosemary

Table 3 Match day hydration and rehydration beverage options for a female goalkeeper: age 20 years; height 173 cm; body mass 72 kg; sweat rate ~ 1.75 L/h. Game time is 6:00 pm at 75 °F (24 °C)

Time	Fluid goals	Sport product option
09:00	20 oz (590 mL)	Water
12:00	20 oz (590 mL)	Water + milk
14:00–16:00	16–24 oz (473–709 mL) + CHO (6–8%) + electrolytes	Isotonic energy drink
17:00–18:00 Warm up	10–16 oz (295–473 mL) + CHO (6–8%) + electrolytes	Isotonic energy drink
18:00 During game	Sip CHO (6–8%) + electrolytes as play permits	Isotonic energy drink
Half time	10–16 oz (295–709 mL) CHO (6–8%) + electrolytes + amino acids	Isotonic energy drink + amino acids scoop
20:00 Post-game	40 oz (1182 mL) (based on 4.5 lb/2 kg bodyweight loss)	Isotonic energy drink + milk
21:00	32 oz (946 mL) CHO (6–8%) + electrolytes	Water + electrolytes
Pre-bedtime	32 oz (946 mL) CHO (6–8%) + electrolytes	Water + electrolytes

This table represents an example of splitting fluid and electrolytes around game day. Where electrolytes are not included in the beverage, a pinch of table salt is comparable

CHO carbohydrate

functions [60, 62]. It is important for a woman footballer to eat throughout the day and around their training and avoid trying to consume all their energy in one large meal. Having prolonged periods of time (e.g., more than 3–4 h) during the day without energy intake increases the risk of developing LEA [63]. Additionally, there are challenges in increasing calories all at once.

Applying tools described previously (Fig. 1), Fig. 4 provides an evidence-informed case study that describes an approach where energy intake was progressively increased in a player identified with LEA, leading to improvements in player performance. Broadly, this case study example demonstrates the ability of the athlete to attain adequate energy intake achieved with incremental recommendations; making smaller, more achievable goals as the athlete gained confidence and comfort with increased intake.

5 Theme 4: Considerations for the Impact of Hormonal Status in Women Footballers

Female sex hormones have physiological effects beyond reproduction, which may impact metabolism and fuel utilization around exercise [64]. This section provides general guidance concerning the effects of hormonal fluctuations on thermoregulation, metabolism, and associated nutritional considerations intended for a football context. It should be noted that there is a need for considerably more ecologically valid research to support recommendations in football. Figure 5 provides an overview of hormonal changes occurring through a natural menstrual cycle, and the potential impact.

5.1 Thermoregulation and Hydration

The hormonal milieu is known to impact thermoregulation, with expected individual variability [65, 66], and potential to impact upon hydration requirements. Importantly, menstrual cycle phase and hormonal contraceptive (HC) use may also influence thermoregulation [67, 68]. Furthermore, there are sex differences in heat acclimation, even though both sexes appear to have adaptative response [69, 70]. Women appear to need longer exposure to acclimate [70], and thermoregulatory responses to acclimation might differ between sexes (e.g., changes in blood flow and the number of active sweat glands) [69]. In general, estrogens tend to promote lower body temperatures by augmenting heat dissipation, while progesterone tends to promote higher body temperatures [71]. In addition, higher concentrations of endogenous or exogenous estrogen and progesterone are associated with water retention in the late luteal phase (LP) [72]. During the LP, sweat rate may increase for a given exercise stimulus; when adequate fluids are consumed to match sweat rate, the menstrual cycle does not have a significant impact on hydration status [73]. An athlete's awareness of their needs is likely important in matching their needs with intake. This highlights the importance of discussing the impact of the menstrual cycle, climate, and individual sweat rates on hydration status with women footballers.

5.2 Hormones, Energy, and Inflammation

Within a normal menstrual cycle, the early follicular phase (FP) has been associated with lower muscle glycogen levels, as a result of increased carbohydrate utilization and

CENTERBACK ENERGY INTAKE CASE STUDY

	JANUARY 2024	FEBRUARY 2024	APRIL 2024
	Body Mass 78.7kg **Fat-Free Mass** 55.9kg **Percent Body Fat** 28.9% **RMR** 1757 kcal **Energy Availability** 22.4 kcal/kg **Daily Intake 1505kcal** **Carbohydrate** 212g **Protein** 99g **Fat** 28g		**Body Mass** 77.4kg **Fat-Free Mass** 59.1kg **Percent Body Fat** 23.6% **RMR** 1827 kcal **Energy Availability** 44.8 kcal/kg **Daily Intake 2900kcal** **Carbohydrate** 380g **Protein** 130g **Fat** 95g
ATHLETE	Athlete reported feeling tired and slow at practice, difficulty concentrating in class, and low appetite (did not feel hungry). She was unhappy with her body composition at the time and fearful increasing calories would negatively affect her body composition and weight. Eumenorrheic, struggling with abdominal cramping and cravings for high sugar foods.	**After 1 week:** Reported better energy in practice. She has added afternoon snack every day. **After 1 month:** Reported feeling good and increased hunger.	Reported an increase to 4-5 meal-like eating opportunities per day in addition to during and post-training energy intake focused on carbohydrates. Playing and feeling the best she has ever felt. Coaches giving very positive feedback on play and fitness.
DIETITIAN	Considering worries of weight gain, initial goals included increasing carbohydrate intake during practice, starting with 1 cup of sports drink and to consider adding an afternoon eating opportunity. Framing goals of increased calories as 'adding something' can help shift athletes focus away from calories.	**After 1 week:** Positive experience with carbohydrate intake during practice allowed for suggestion of halftime carbohydrate supplement. **After 1 month:** Gave reassurance that increased hunger is a positive sign and provided support for athlete's suggestion of making afternoon snack a meal.	Encouraged continued intake through the summer to maintain and continue to build positive outcomes (increased lean mass, improved fitness and play) through summer in preparation for fall season.
GOALS	Focus on 'adding something' like a mid-practice snack, rather than focusing on increasing overall caloric intake. Add a carbohydrate snack into activity and one afternoon eating opportunity.	Add carbohydrate supplement at halftime of games. Increase afternoon eating opportunity into more meal-like portion.	Maintain intake and performance, as well as positive feelings towards body composition.

TIPS FOR CONVERSATIONS AROUND INCREASING ENERGY INTAKE

Paint the big picture including effects of LEA and REDs from a system standpoint (i.e., disrupted sleep, trouble concentrating, GI distress, increased injury/illness, longer recovery, decreased strength/power/endurance performance).	Avoid recommendations of immediate large increases of energy or macronutrient intake. This increases likelihood athlete will experience bloating, 'feeling heavy', or like they have gained weight.	Instead, suggesting small increases of carbohydrate sources and protein strategically around training can help avoid negative feelings and emotions while improving energy and performance during training.	Communicating intake in terms of type or kinds of food can be received better than caloric focus, alongside providing education about why nutrient intake is essential for health and performance. This approach helps foster a positive relationship with food and nutrients which underlies the necessary paradigm shift for establishing global sustainable behavior changes for the athlete.

Fig. 4 Case study: A 22-year-old center back experiencing symptoms of fatigue, under-recovery, regular and cyclical menstrual cycle–related cramping, and body dissatisfaction. Working with the sports dietitian, the player increased energy intake in a stepwise manner. This example assumes 250 kcal were expended from exercise. Substantial improvements were made in body composition, characterized by increased lean mass and reduced fat mass. Further, the player and staff reported noteworthy improvements in physical and tactical performance. *GI* gastrointestinal, *LEA* low energy availability, *REDs* Relative Energy Deficiency in Sport, *RMR* resting metabolic rate. *Note this is based on data from a few real-world athlete examples, with manipulations made for an illustrative case

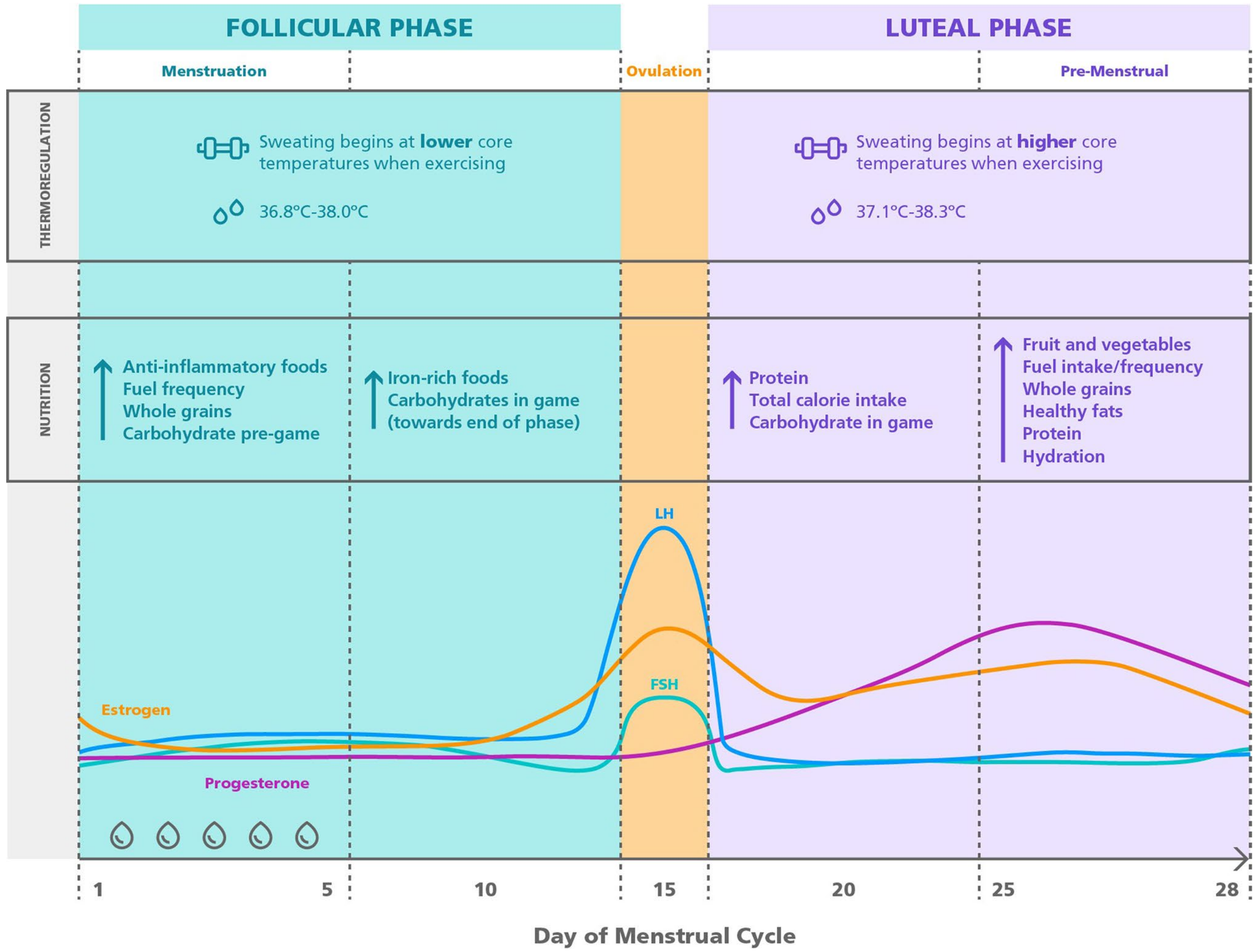

Fig. 5 Nutritional and thermoregulation considerations across the menstrual cycle. Nutritional alterations across the cycle may help support menstrual cycle–related symptoms and inflammation. If a player experiences menstrual cycle symptoms, some nutrition alterations may be effective. Sweat rates and core temperature may be altered across the cycle and with some forms of hormonal contraceptives [67]. *FSH* follicle stimulating hormone, *LH* luteinizing hormone

breakdown [74]. This increased carbohydrate breakdown decreases carbohydrate stores and may result in an increase in muscle damage and inflammatory markers in women if not addressed by a deliberate increase in carbohydrate intake [75]. The reduced capacity for glycogen storage in the early FP has been found to be negated with a carbohydrate loading protocol of greater than 8 g/kg per day in moderately trained endurance athletes [76]. Increasing carbohydrate consumption in the early FP may reduce muscle glycogen utilization, offsetting some menstrual cycle–related symptoms. Nonetheless, additional research is needed to provide more precision to these recommendations in elite women athletes.

During the late FP, rising estrogen concentrations promote a shift toward increased reliance on free fatty acids as a substrate at lower exercise intensities, thereby conserving carbohydrate stores [64]. In the LP, characterized by elevated estrogen and progesterone, the capacity for muscle glycogen resynthesis may be impaired when carbohydrate intake is insufficient. Increasing carbohydrate intake during the LP is an effective nutritional strategy to mitigate these limitations and support glycogen restoration [77]. Estrogen tends to spare glycogen by reducing carbohydrate oxidation, while progesterone opposes this effect by increasing glycogen use and impairing insulin-mediated glucose uptake, creating a combined hormonal environment that can slow glycogen restoration. Carbohydrate requirements should be determined according to training load, with consideration of exercise intensity and duration. Subsequent emphasis should be placed on the timing of carbohydrate ingestion around training sessions to optimize glucose availability and recovery. The proliferative activity of the endometrial lining during the LP increases total energy expenditure and may necessitate an additional 200–300 kcal/day to maintain energy balance. Concurrently, elevated amino acid utilization associated with endometrial growth may increase protein requirements. Evidence suggests that protein intakes exceeding 1.6 $g \cdot kg^{-1} \cdot day^{-1}$, or approximately 0.3–0.5 $g \cdot kg^{-1}$ per meal, enhance amino acid availability under conditions of high estrogen and progesterone [78], thereby supporting recovery and tissue repair.

5.3 Hormonal Contraceptive Use

The prevalence of HC use among elite women athletes (28–50%) is lower than that reported in physically active women (60–65%) [79–81]. Despite the substantial proportion of athletes using HCs, few studies have characterized their effects on performance and metabolism. Variation in endocrine profiles across HC types likely contributes to this research gap, as metabolic responses can differ according to hormone dosage, progestin type, and generation [82]. No current evidence exists that supports distinct nutritional recommendations for HC users. However, combined HCs, which supply exogenous estrogens and progestins throughout most of the cycle, may induce a hormonal milieu resembling that of the LP, with potentially similar metabolic and nutritional implications. These effects are influenced by both the formulation and dosage of the HC. Further research is warranted given that many women athletes use HCs not only for contraception but also for health- and lifestyle-related reasons.

5.4 Nutrition for the Management of Menstrual Cycle Symptoms

Symptoms around and during menstruation are widely reported by athletes, with more than 70% of athletes reporting dysmenorrhea and premenstrual symptoms [83]. These can have debilitating effects on both quality of life and perceived exercise performance [84]. While the role of nutrition in the etiology of symptoms is not fully elucidated, limiting highly processed foods, alcohol, and caffeine is evidenced to reduce likelihood of symptoms [85, 86]. Emerging research has demonstrated that insufficiencies in several micronutrients including calcium, magnesium, vitamin D, and zinc may also be associated with worsened symptoms [87, 88]. Adequate intake of these micronutrients may reduce the presence and/or severity of symptoms; supplementation should not exceed daily recommended values. A food first approach is advisable. Inflammation has also been reported to be highest during the late LP and early FP, often accompanied by an increase in menstrual cycle symptoms and menstrual cramping [89]. Dietary strategies that may help reduce inflammation, menstrual cycle symptoms, and cramping include increasing essential fatty acids and antioxidant consumption in the pre-menstrual and menstrual windows (Fig. 3). Adequate hydration during menses has been associated with a reduction in bleeding duration and symptoms of pain [90]. Tailoring nutrient intake to these hormonal fluctuations can help women athletes maintain energy levels, reduce fatigue, and enhance overall performance [7, 91, 92].

6 Conclusion

Adequate energy and nutrient intake play a key role in optimizing the health and performance of women footballers. Due to the high physiological demands of football, awareness of athlete nutrient needs and barriers for optimal consumption are essential. To maintain or improve performance and health, women footballers should prioritize adequate energy intake, with careful attention to the timing of intake around training and matches. Further, individual adjustments can be made in response to hormonal fluctuations, potential changes in fuel utilization, inflammation, thermoregulation, and symptom management. The theme and case study approach provided in the present paper allows for translation of scientific evidence into real-world nutritional solutions, which may be subtle and can be modified according to level of play, athlete demographics, goals, and resources.

Funding This article is published as part of a supplement issue that was supported by Fédération Internationale de Football Association (FIFA). Authors received financial support from FIFA for the writing of this paper.

Declarations

Author Contributions AESR conceptualized the manuscript, led the writing and revision process, and coordinated contributions from all authors. SRM contributed to manuscript development, figure creation, and writing. MA provided real-world case studies, contributed to writing, and assisted with revisions. EC supported manuscript writing, designed all figures, and participated in revisions. LC contributed practical insights for the dietary components and assisted with figure development, writing, and revisions. ACH, JKI, RSM, and GB contributed to writing and manuscript revisions. GB also provided expertise in practical translation and editing. All authors reviewed and approved the final manuscript.

Conflict of interest/competing interests ASR receives research funding through the university to complete research studies on dietary supplements and serves as a scientific advisor for Alzchem and Create Wellness. GB is a consultant with Orreco, who provide consultancy to women athletes and the free FitrWoman app. All other authors (SRM, MA, EC, LC, ACH, JKI, RSM) have no conflicts to declare

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