UEFA expert group statement on nutrition in elite football. Current evidence to inform practical recommendations and guide future research

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ABSTRACT

Football is a global game which is constantly evolving, showing substantial increases in physical and technical demands. Nutrition plays a valuable integrated role in optimising performance of elite players during training and match-play, and maintaining their overall health throughout the season. An evidence-based approach to nutrition emphasising, a 'food first' philosophy (ie, food over supplements), is fundamental to ensure effective player support. This requires relevant scientific evidence to be applied according to the constraints of what is practical and feasible in the football setting. The science underpinning sports nutrition is evolving fast, and practitioners must be alert to new developments. In response to these developments, the Union of European Football Associations (UEFA) has gathered experts in applied sports nutrition research as well as practitioners working with elite football clubs and national associations/federations to issue an expert statement on a range of topics relevant to elite football nutrition: (1) match day nutrition, (2) training day nutrition, (3) body composition, (4) stressful environments and travel, (5) cultural diversity and dietary considerations, (6) dietary supplements, (7) rehabilitation, (8) referees and (9) junior high-level players. The expert group provide a narrative synthesis of the scientific background relating to these topics based on their knowledge and experience of the scientific research literature, as well as practical experience of applying knowledge within an elite sports setting. Our intention is to provide readers with content to help drive their own practical recommendations. In addition, to provide guidance to applied researchers where to focus future efforts.

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UEFA EXPERT GROUP STATEMENT ON NUTRITION IN ELITE FOOTBALL: EXECUTIVE SUMMARY

Football (soccer) is a global game which is constantly evolving with substantially increasing physical and technical demands of match play. Training regimens have become more demanding physically, in an attempt to prepare players to cope with these evolutions and to address individual player needs. Nutrition can play a valuable role in optimising the physical and mental performance of elite players during training and match-play, and in maintaining their overall health throughout a long season.

Good nutrition choices can support the health and performance of footballers: the type, quantity and timing of food, fluids and supplements consumed can influence players' performance and recovery during and between matches.[1 2] However, the rapid evolution of the game itself, in addition to changes in our understanding of sports nutrition, has created uncertainty as to the appropriate nutritional decisions to make at specific moments in time and in specific contexts. In 2017, the steering committee of the current UEFA nutrition expert statement (JC, RM, JB, AMcC) committed[3] to undertake an expert-led statement to update the knowledge and research about nutrition in elite football. We highlighted that the last expert-led statement on elite football nutrition had been written 11 years earlier.

While sports nutrition research since the last expert statement[1] has in some instances helped to advance our knowledge and shape our practical strategies with elite footballers, the influx of new research brings with it confusion as to the relevance and veracity of current advice. It is often difficult for practitioners to interpret the available evidence and make sense of the controversies that may exist, in particular with the influx of different and opposing messages, especially from social media channels.[4] In these instances, expert-led statements can be a powerful tool to aid practitioners with clarity on current research evidence.

This executive summary of the full scientific article—the 'UEFA expert group statement'—provides a series of infographics illustrating important practical applications and insights that are intended to help practitioners take away some key points from the full article. We strongly advise practitioners to read and digest the full article and not only the practical infographic summary. This will ensure a more in-depth appreciation of the scientific evidence and the critical appraisals from the many experts involved which accompany the recommendations, in addition to understanding the fuller context and how to apply in their own practice.

In this expert group statement, nine specific topics have been identified: (1) match day (MD) nutrition, (2) training day nutrition, (3) body composition, (4) stressful environments and travel, (5) cultural diversity and dietary considerations, (6) dietary supplements, (7) rehabilitation, (8) referees and (9) junior high-level players. Our narrative synthesis and critical appraisal takes into account the diversity of the footballing community, including both male and female players, outfield players and goalkeepers and match officials.

As part of this process, UEFA has consulted with many specialists from the game to provide insights on the current role and future direction of nutrition in football. We often hear from the scientific community of the importance of sports science within football, but too often the voices of coaches are not heard in best practice guidelines, when they could offer valuable insight. Part of this executive summary includes an editorial by one of the world's most iconic coaches, Arsène Wenger, who discusses the coach's perspective on nutrition within the current footballing landscape and looks to the future of nutrition for players and teams around the world. We also have a brief 'warm up' to this UEFA expert statement from Marc Vouillamoz, UEFA Head of Medical and Antidoping and an editorial from Dr Tim Meyer, Chairman of the UEFA Medical Committee: these provide important antidoping and medical perspectives on the importance of nutrition in football.

As you will read in the full article and is evident throughout the series of infographics, the UEFA expert statement advocates an evidence-based approach to nutrition, and emphasises a 'food first' philosophy (ie, prioritising food over supplements to meet nutrient requirements) as being fundamental to ensure effective player support. It is crucial that clubs and national associations, where possible, use the services of qualified professionals with nutrition-related undergraduate degrees, postgraduate qualifications in sport and exercise nutrition and professional registration (depending on the country).

The expert statement process was created by a steering committee (JC, RJM, JB, AMcC) who identified the topics to be included and compiled a list of research and field-based experts. Expert group members (n=31 in total) included basic and applied researchers (n=6) and field-based practitioners (n=5); the majority (n=14) had a background of both research and field-based practice and six were UEFA Medical Committee members. It is intended that this narrative synthesis will provide readers with the scientific underpinning to inform their practical recommendations and strategies. In addition, we aim to guide applied researchers to focus their future efforts in regards to elite football nutrition research.

INTRODUCTION

Good nutrition choices can support the health and performance of footballers: the type, quantity and timing of food, fluids and supplements consumed can influence players' performance and recovery during and between matches.[1 2] However, the rapid evolution of the game itself, in addition to changes in our understanding of sports nutrition, creates uncertainty as to the appropriate nutritional decisions to make at specific moments in time and in specific contexts.

The physical and technical demands of elite football have increased in recent years,[5 6] as have the financial implications of winning or losing. Training regimens have been adapted accordingly; they are more demanding and more sophisticated as they prepare players to cope with the evolution in match demands. Congested match schedules have been suggested to increase the risk of injury to players.[7 8] Kick-off times have become more variable, with teams required to play early or late to accommodate television schedules. The travel required to compete in multiple domestic and international tournaments adds to the demands on players, with different logistical challenges depending on the geographical location. The reality being that the best players play the most often. Moreover, football truly is a global game[9]: frequent intracontinental and intercontinental matches and the migration of foreign players both result in greater cultural diversity and associated nutritional considerations.

The exponential rise in sports nutrition research in recent years has advanced our knowledge and expertise, but brings with it confusion as to what is actually sound advice. Those providing sports science support at elite level should follow an evidence-based approach,[10] but it is often difficult for practitioners to interpret the available evidence and make sense of the controversies that may exist in particular with the influx of noise (ie, flawed messages) from social media channels.[4] This, in part, reflects the limitations of our current knowledge: we know, for example, that the recommended dietary allowance (RDA) is the average daily dietary intake that suffices to meet the nutrient requirements of nearly all (98%) healthy people, but it is unclear how these values should be applied in the assessment of dietary intakes of footballers and other athletic populations. We should also recognise that much of the available data on dietary intakes is flawed, and probably does not reflect the true nutrient and energy intake of the populations that have been studied.[11] Expert-led statements can be a powerful tool to aid practitioners in these instances, but although there are recent examples in different sporting situations,[2 12] the most recent example of this in football-specific nutrition was a consensus published over a decade ago.[1]

The aim of this paper is to provide a narrative synthesis of the current evidence relating to various topics in elite football nutrition and in doing so, this manuscript is targeted at researchers, scientists and practitioners with scientific knowledge and understanding.

This UEFA expert group statement endorses and supports a 'food first' philosophy. This aims to establish best practice recommendations and represents an important next step in supporting the growth of nutrition within football. It is crucial that clubs and national associations, where possible, use the services of qualified professionals with nutrition-related undergraduate degrees, postgraduate qualifications in sport and exercise nutrition and professional registration (depending on the country); for simplicity, we use the term 'sports nutritionist' throughout.

We note several limitations to the evidence base from which recommendations of best practice can be reached:

1. There is little research specific to football, and the laboratory models that have been developed to simulate the game generally fail to replicate the demands of match play. As such, results need to be extrapolated from different sports and simpler exercise protocols.
2. Those studies that have used football as a model have been done with players engaged at recreational level. There is very little information derived from studies of elite players.

3. Many of the methods that have been used to assess the dietary habits of players and their nutritional status are fundamentally flawed and do not provide reliable information.
4. As with all studies, publication bias can increase the risk of a skewed picture of the efficacy of nutrition interventions, especially those involving the use of supplements. Studies that do not produce a positive outcome are less likely to be published than those that produce positive results.

We also recognise that, despite the great popularity of women's football, there are few relevant studies. Nutritional needs and practices likely vary more within one sex than between sexes: the sex of the player is therefore another factor to be taken into account when considering the needs of an individual player.

EXPERT GROUP STATEMENT PROCESS

A steering committee (JC, RJM, JB, AMcC) identified the topics to be included and compiled a list of research and field-based experts. Expert group members (n=31 in total) including basic and applied researchers (n=6) and field-based practitioners (n=5); the majority (n=14) had a background of both research and field-based practice and six were UEFA Medical Committee members. An outline of the expert group statement was agreed by all members: the authors were asked to focus on what is currently known from scientific research combined with their practical knowledge and expertise. First drafts of each section were collated by the steering committee to form the basis of the first full draft. This was circulated to all expert group members: the applied researchers focused on the narrative synthesis of the scientific research literature and the practitioners on the ecological validity in the football setting. Comments were collated and changes made before further review by the expert group. This process continued until agreement was reached on the specific sections and recommendations included (the whole process lasted from December 2017 to December 2019). A meeting between the steering committee and UEFA Medical Committee members (June 2019) was held to discuss and agree on any final amendments or additions that needed to be made and these were then circulated to the expert group for their review. This resulted in one further draft version before finalisation (December 2019).

The key recommendations are aimed at both male and female professional players, the majority of whom will be training and playing full time. Distinctions between male and female players are clearly made where appropriate; unless otherwise stated, the key recommendations apply to both sexes. Additional sections focus on elite referees and elite junior players (ie, players aged under 18 years and belonging to a professional football academy and training full-time).

EXPERT GROUP TOPIC 1: MATCH DAY NUTRITION

Match play demands

During a football match, players engage in a variety of activities from walking to sprinting, changing direction, jumping and striking the ball, in addition to contact with opposition players. In outfield players, heart rate is maintained at an average of 85% of maximum and the average relative exercise intensity at 70% of maximal oxygen uptake (VO_2max) over the duration of the match,[13] equating to an energy expenditure of ~1300–1600 kcal,[14 15] whereby carbohydrates (CHO) contribute about 60%–70% of the total energy supply.[15] The total MD energy expenditure has been estimated at ~3500 kcal.[16] To date, no studies have been performed to assess the physiological demands or fatigue responses of goalkeepers specifically.[17] Limited research suggests that goalkeepers perform extended (~45–60 min) pre-match warm-ups and, while they cover less total distance and perform fewer high-intensity activities, they are rarely substituted and need to be prepared for a full 90–120 min match.[17] The physical and technical demands of match play for elite outfield male footballers have increased substantially in recent years,[5 6] likely as a result of tactical modifications.[6] While the total distance covered decreased by a trivial magnitude of 2% (10679±956 vs 10881±885 m) between 2006 and 2013, high-intensity and sprint running have increased substantially, with high-intensity running distance and high-intensity actions up by ~30% (890±299 vs 1151±337 m) and ~50% (118±36 vs 176±46), respectively.[5] Over that same period of time, sprint distance and number of sprints rose by ~35% (232±114 vs 350±139 m) and ~85% (31±14 vs 57±20), respectively. This trend is seen in all outfield positions (central defenders, full-backs, central midfielders, wide midfielders and attackers).[5] Evolutions in technology have revealed that players make more passes (35±17 vs 25±13), and that these are more successful (83%±10% vs 76±13%).[5] These increased physical and potentially technically demanding (eg, cognitive) tasks make effective nutritional strategies even more important.

Research on elite female players is sparse. The available evidence highlights that elite female players (international level) cover approximately the same average total distance as their male counterparts, but they run less at high speeds.[18] An important point to note is that no study has compared the high-speed or sprinting demands of male and female players relative to individual maximum speed. The use of absolute speed thresholds does not reflect differences in the maximum speed of individual players[19] or gender differences.

Preparation for match play (carbohydrates and fluids)

CHO is the primary fuel for muscle during high-intensity activities; it is therefore a key macronutrient when preparing players for match play. On the day prior to a match (MD-1), training is usually light and CHO intake should be at least 6–8 g/kg body mass (BM) to elevate muscle and liver glycogen stores.[20] While the glycogen cost of elite match play in either male or female players is not yet known,[21] data from a friendly match involving lower division Danish male players demonstrate that approximately 50% of muscle fibres are classified as empty or partially empty after match play.[22] Players who begin a game with low muscle glycogen stores will cover less distance and much less at high speed, particularly in the second half, than those who have ensured adequate glycogen stores.[23] Where the match schedule consists of congested fixtures (eg, domestic fixtures, European competition, international games), CHO intake should be maintained within this range (6–8 g/kg BM/day) for the 48–72 hours between games to promote adequate glycogen storage. The reality is that players often consume less than this and daily intake may be closer to about 4 g/kg BM.[16] A conscious focus on the intake of CHO-rich foods is needed, with increased CHO intake at the cost of fat intake (and possibly protein intake) to ensure adequate glycogen restoration.

Maintaining an appropriate hydration status will support players' health and performance.[24] Sweating is the primary mechanism to dissipate the metabolic heat generated during football training and match play in both cool and hot environments.[25 26] Players should aim to start the match fully hydrated: daily BM measurements,[27] degree of thirst,[28] urine colour,[29] osmolality and urine-specific gravity can be useful indicators of hydration status.[30] A urine osmolality of <700 mOsmol/kg or a specific gravity of <1.020 suggests euhydration and >900 mOsmol/

kg, hypohydration, although individual variability is present.[31] For games with an early kick-off, the day prior to the match represents a key opportunity to optimise the players' hydration status for the match the following day.

It has become popular in recent years to suggest that the only advice relating to hydration that is either necessary or appropriate for those involved in sport is to drink according to the dictates of thirst.[32] This may not be appropriate in many team sport contexts, including football training and match play.[33] The availability of fluids and the sensation of thirst may not coincide, and some forward planning (eg, understanding individual sweat losses, developing individualised hydration plans, alongside player education) can ensure that each player's hydration needs are met.

Pre-match (CHO and fluids)

On MD itself, CHO intake is again one of the most important considerations. Within an overall guideline of 6–8 g/kg BM CHO per day, it is recommended that players consume a CHO-rich meal (1–3 g/kg BM) 3–4 hours before kick-off to ensure that they begin the match with adequate glycogen stores. The pre-match meal is of particular importance for the promotion of liver glycogen stores, given that such stores can be reduced by about 50% after an overnight fast.[34] This may be particularly important for matches with a lunchtime kick-off, and it highlights the importance of optimising nutritional preparation during the day prior to the match. The pre-match meal should be easily digestible to reduce the risk of gastrointestinal problems (eg, reflux, discomfort). The pre-match meal should also make players 'feel better'[35] so comfort should be considered, rather than rigid strategies focused solely on meeting CHO intake guidelines. Player 'rituals' can be strongly held and education combined with practising pre-match fuelling in training or lower priority matches, can be an important tool to optimise glycogen stores and player readiness for match play.

Data from many studies suggest that high CHO intakes before and during a match can delay fatigue[36] and enhance the capacity for intermittent high-intensity exercise.[37,38] Benefits of pre-match meals may extend to players' technical performance. For example, increased dribbling speed was observed when professional youth footballers consumed a larger breakfast (500 vs 250 kcal, with 60% CHO) 135 min before a match.[39]

Finally, players should aim to start the match euhydrated by ingesting 5–7 mL/kg BM of fluid in the 2–4 hours prior to kick-off.[40] This allows time for excess fluid to be voided prior to exercise, targeting a urine that is pale yellow in colour.[29]

During match play (CHO and fluids)

Sufficient CHO and fluid intake are the two main nutritional considerations during match play. Research evidence typically shows performance benefits in protocols simulating football matches when CHO is consumed during exercise at rates of ~30–60 g/hour,[41–44] or when 60 g is consumed before each half.[45] It is therefore recommended that ~30–60 g CHO is consumed after warm-up and again at half-time to meet these guidelines. CHO ingestion during intermittent exercise also seems to improve shooting performance,[38,46] dribbling speed,[47] and passing,[46,48] although the effects on sprinting, jumping, change of direction speed and cognition are less consistent.[37,41] The current practices of elite players appear to be at the lower end of the ~30–60 g/hour scale; players in the English Premier League reported mean CHO intakes of 32 g/hour just before and during a match.[16] This may be attributed to the match rules, which limit intake to warm-up and half-time (see below) and to the fear or actual experience of gastrointestinal problems during matches. This is a situation where sports foods (eg, CHO drinks, gels) can provide a preferred delivery option, to minimise these gastrointestinal issues. Stoppages during the match may also provide a valuable opportunity for players with increased CHO and/or fluid needs or for the whole team in hot conditions (see the section 'Expert group topic 4' on stressful environments).

Receptors in the oral cavity detect CHO consumed during exercise and exert central effects that may reduce the perception of effort.[49] CHO mouth rinsing has been shown to increase self-selected jogging speed with likely benefits in sprint performance during intermittent exercise.[50] The implications for football are still unclear,[51] but the use of CHO mouth rinsing during breaks in match play (eg, half-time, extra-time, injury stoppages, medical breaks) could potentially enhance performance in situations where CHO consumption is limited by gastrointestinal concerns. On the other hand, it has been noted in recent tournaments that some players appear to misunderstand the mouth rinsing strategy and spit out the CHO-containing fluid even when there are no gastrointestinal problems. This may be partly due to the design of a scientific investigation in which there is an interest in distinguishing between the central nervous system and muscle fuel effects of CHO intake during exercise. Indeed, swallowing the drink following a ~5 s exposure in the mouth allows both effects to occur simultaneously; this will be important in scenarios in which a player's workload is high and CHO supplies may become limiting. It should be remembered that matches can extend to extra time and penalty shoot-outs where both the brain and muscle may benefit from additional fuel support and activation.

Sweat rates vary greatly between players and are primarily influenced by the intensity of exercise, environmental conditions and acclimation status.[52] During training and matches sweat rates in male players have been reported to range from 0.5 to 2.5 L/hour[26,53,54]: lower values are generally reported in female players because of lower BM and lower absolute work rates.[55–57]

Sweat also contains electrolytes, primarily sodium, concentrations of which vary substantially between players.[54] Mechanisms by which sweating-induced hypohydration might impair football performance are not completely elucidated, but may include increased cardiovascular strain,[58] impaired cognitive function,[59] increased perception of effort,[60] reduced physical function[60] and reduced technical skills.[61] It is likely that individual players may be more or less sensitive to hypohydration during exercise. Therefore as a guide, players should aim to drink sufficient fluids to prevent a deficit of >2%–3% of pre-exercise BM during exercise,[39,62] while avoiding gains in BM (hyperhydration) and also ensuring their fuel needs are met.[38]

Both hydration and CHO intake may require special attention in matches where extra time (2×15 min) is played. All match nutrition strategies, including the use of supplements (eg, sports foods), should be practised in training and minor matches to allow individualised protocols to be developed and to identify adverse effects in players, as well as allowing them the opportunity to become accustomed to any potential adverse effects, with minimal impact on important match performance.

Recovery from match play (CHO, fluids, protein)

A primary objective following a competitive match is to reduce the time needed to fully recover.[63] One essential goal is to rapidly replenish CHO stores. Postmatch meals and snacks should target a CHO intake of ~1 g/kg BM/hour for 4 hours.[64] This is usually facilitated by the consumption of drinks and snacks in the changing rooms followed by post-match meals at the stadium, during travel and at home. Sports foods may provide a preferred option to supply macronutrients, especially to achieve CHO guidelines when appetite may be reduced or when sourcing food away from the home environment. Players should also aim to reduce any fluid and electrolyte deficit soon after the match[65]; however, in most situations there is sufficient opportunity and time to restore euhydration and electrolyte balance with normal eating/drinking practices, while also meeting other recovery objectives.[63 65]

Elite football players may not achieve CHO targets in recovery from evening games,[66] suggesting suboptimal glycogen resynthesis patterns, the result of which is likely problematic for recovery and preparation during congested fixture schedules. As discussed above, daily CHO intake in the range of 6–8 g/kg BM in the 24 hours following a game (MD +1) will continue to replenish glycogen stores and this intake should be maintained for up to 48–72 hours after the match during congested fixture schedules. Higher intakes and additional nutritional strategies may be required when players report symptoms of muscle soreness and damage, as glycogen synthesis is impaired in the presence of muscle damage.[67–69] To optimise protein synthesis for repair and adaptation, meals and snacks should be scheduled to achieve intakes of 20–25 g of (high-quality) protein at 3–4 hour intervals.[70–72] Furthermore, there is emerging evidence that consuming 30–60 g of casein protein prior to sleep can enhance overnight protein synthesis.[73]

Although postexercise protein intake undoubtedly increases protein synthetic rates and net protein accretion, this is a slow process and there is little evidence of acute improvements in muscle function.[74] Some studies have reported reductions in muscle soreness with postexercise intake of protein or branched chain amino acids,[75] but the overall effects are small. Consuming polyphenol-rich tart cherry juice has become a popular intervention to accelerate muscle recovery in different sports,[76 77] but recent investigation in football did not show improved recovery markers of function or subjective soreness.[78] Therefore, the available evidence does not support its specific use in football. Reducing exercise-induced muscle inflammation and free radical production, particularly with large doses of individual antioxidant vitamins C and E, may interfere with adaptive processes in muscle and is therefore discouraged.[79]

Alcohol

Some players may drink alcohol in social settings with teammates, friends and family, or as a means to relieve stress, anxiety or depression; this is particularly likely to occur after a match.[63] Occasional intake of small amounts (no more than 2 units/day) of alcohol is not harmful, but alcohol use can interfere with recovery by impairing liver and glycogen resynthesis,[80] muscle myofibrillar protein synthesis[81] and rehydration.[82] Drinking large doses of alcohol can also impair next-day countermovement jump performance[83] and also directly suppress a wide range of immune responses[84] and players should therefore minimise or avoid intake during key periods of training and match play when recovery is a priority.

EXPERT GROUP TOPIC 2: TRAINING DAY NUTRITION

Overview of training calendar, objectives and training load

The football season is typically categorised into three distinct phases: preseason, in-season and off-season (see table 1). Despite more than four decades of research examining the physical demands of match play,[6 85 86] detailed analysis of the customary training loads of elite footballers is comparatively recent and remains limited.[20 87–89] These data demonstrate that training loads are lower than those experienced in match play, including total distance (<7 vs ~10–13 km),[20] high-speed running distance (<300 vs >900 m),[90] sprint distance (<150 vs >200 m)[91] and average speed (<80 vs ~100–120 m/min).[20] Absolute daily training loads depend on many factors including phase of the season,[89] player position,[89] coaching philosophy,[88 89] frequency of games,[92] player starting status[88] and player-specific training goals such as manipulation of body composition[93] or rehabilitation from injury.[94]

In the traditional in-season scenario of one match per week, players may complete four to five 'on-field' training sessions where the absolute training load is likely to be periodised across the weekly microcycle according to the proximity and importance of the game itself.[20] Players may also undertake additional 'off-field' sessions, such as strength training. The aim is to stimulate both aerobic and strength adaptations while simultaneously rehearsing technical skills and tactics. It is noteworthy, however, that gym and field-based training sessions may not always be delivered in a systematic and structured sequence.[95] The order of these can influence players' habitual macronutrient intake and the magnitude of the strength adaptations induced.[96] Both absolute daily intake and distribution of macronutrient intake have the capacity to affect training performance and recovery and to modulate training adaptations.

Carbohydrate requirements for training

Given the role of muscle and liver glycogen in supporting energy production during match play,[22] it is important to consider their contribution to training goals. Unfortunately, the lack of specific data on muscle glycogen utilisation during typical field-based football training sessions makes it difficult to develop clear guidelines on the CHO requirements for training[97] other than to suggest that they differ from the requirements for match play. Some information can be gleaned from the investigation of energy expenditure in English Premier League players during a 7-day in-season microcycle consisting of two games and five training days.[16] The mean daily expenditure of outfield players was assessed at ~3500 kcal/day,[16] with goalkeepers' energy expenditure being ~600 kcal/day less.[98] In these studies, the mean daily energy intake reported by players was comparable to energy expenditure, and BM did not change during the assessment period. Players reported an adjustment of daily CHO intake according to the perceived load, whereby ~4 and 6 g/kg BM were consumed on training and MDs, respectively. Nonetheless, given the importance of muscle glycogen for preparation and recovery from match play, it is suggested that players should increase CHO intake on MD-1, MD and MD +1 to between 6 and 8 g/kg BM. However, even at ~8 g/kg BM, muscle glycogen content in type II fibres may not be completely restored 48 hours after a match.[99]

Alternatively, given the lower absolute daily loads on typical training days (ie, one session per day in a one game per week microcycle) coupled with the fact that players typically do not perform any additional structured training outside of the club, daily intakes ranging from 3 to 6 g/kg BM may be sufficient to promote fuelling and recovery. In accordance with these lower absolute loads, it is unlikely that most players require CHO intake during training.[16] However, this may depend on the duration and intensity of the training session, the timing of training in relation to the last meal and the potential benefits of practising

Table 1 The training carbohydrate intake continuum

Training scenario	Training objectives	Desired training adaptations	Typical daily external training load parameters **(as quantified during pitch-based training according to GPS; HSR ≥19.8 km/hour)**	Suggested daily CHO range	Comments
Preseason training	▶ To improve players' physical/ mental/tactical qualities ▶ To prepare players for a full playing season ▶ To avoid injury and illness	▶ Increase aerobic and anaerobic fitnessIncrease lean mass/reduce fat mass ▶ Increase/maximise strength, speed, power for performance and injury prevention	Duration: 60–180 min Total distance: 3–12 km HSR: >400 m	4–8 g/kg BM	Suggested range accommodates likely variations in loads (eg, potential twice per day sessions, recovery days) as well as individual training goals (eg, manipulation of body composition to accommodate weight loss and fat loss or weight gain and lean mass gain). For example, twice per day training structures would likely require higher CHO intakes (eg, 6–8 g/kg BM/day), whereas lower absolute intakes may be required where players are aiming for body fat loss or training intensity and duration is reduced (eg, 4–6 g/kg BM/ day).
In-season training (one game per week)	▶ To maintain physical qualities (and improve where possible/appropriate) ▶ To keep players injury and illness free ▶ To practise MD nutrition strategies	▶ Maintain aerobic and anaerobic fitness ▶ At least maintain strength, power, speed ▶ Maintain lean BM ▶ Train the gut to tolerate CHO during football-specific training (occasional use)	Duration: 45–90 min Total distance: 2–7 km HSR: 0–400 m	3–8 g/kg BM	Suggested range accommodates likely variations in loads across the microcycle (eg, low load days and MD-1 CHO loading protocols) as well as individual training goals (eg, manipulation of body composition). For example, MD-1 and MD +1 would require higher CHO intakes (eg, 6–8 g/kg BM/day), whereas lower absolute intakes may be required on other days of the week (eg, 3–6 g/kg BM/day) depending on training intensity, duration and player-specific goals.
In-season training (congested fixture periods)	▶ To avoid injury and illness ▶ To accelerate recovery	▶ Restore muscle function as quickly as possible ▶ Promote glycogen resynthesis ▶ Fluid replacement: rehydration ▶ Alleviate mental fatigue	Duration: <60 min Total distance: <3 km HSR: <50 m	6–8 g/kg BM	Suggested range accommodates the requirement to replenish muscle glycogen stores in the 48–72 hours period between games. During this time, it is suggested that players consistently consume CHO within this range so as to promote glycogen availability.
Off-season training	▶ To avoid detraining ▶ To ensure players come back ready for the demands of the preseason	▶ Minimise the loss of aerobic and anaerobic capacity ▶ Minimise decrements in strength, power, speed ▶ Minimise decreases in lean mass and increases in fat mass	N/A	<4 g/kg BM	Suggested intake accommodates the cessation of normal training loads, to avoid gains in fat mass. Note, for players who may be undergoing higher training loads (eg, off-season training programmes) CHO intake should be increased accordingly.

BM, body mass; CHO, carbohydrate; HSR, high speed running; MD, match day; N/A, not available.

CHO consumption during exercise to 'train the gut' to better absorb and tolerate intake during matches. Daily CHO requirements for training should operate on a sliding scale of 3–8 g/kg BM/day depending on the specific training scenario, fixture schedule and player-specific training goals (further context is provided in table 1).

Protein recommendations for training

Daily football training places stress on the musculoskeletal and tendinous tissues, and there is a need to remodel and repair these protein-containing structures to maintain and improve their integrity and function. Players may benefit from the provision of higher quantities of protein than are needed by the general population. The RDA for protein is 0.8 g/kg BM/day in Europe,[100] but higher intakes up to 1.6–2.2 g/kg BM/day appear to enhance training adaptation.[101] Such levels of protein intake can easily be achieved from a mixed diet provided the energy intake is sufficient to meet the demands of training.[102] Recent dietary surveys suggest that most professional players report meeting or exceeding the 1.6–2.2 g/kg BM/day protein intake recommended for football. In professional players from the English Premier League, reported daily intakes of protein averaged 2–2.5 g/kg BM/day and were consistent across a 7-day in-season training period.[16] This intake (approximately 200 g/day) was greater than that previously reported (<150 g/day) by adult players from the Scottish[103] and Dutch[104] leagues and is around twice the RDA in Europe, as previously highlighted. With judicious dietary planning, protein supplements are probably not needed for most players, although they provide a convenient and easily digestible alternative to foods, especially in the post-training period.

Where protein supplements are consumed at a dose of 0.3–0.4 g/kg BM/meal, whey protein is considered a prudent choice owing to its higher leucine content and digestibility.[105]

Ideally, three to four discrete protein-containing meals should be consumed each day, with at least ~0.4 g/kg BM/meal, which at four meals would provide ~1.6 g protein/kg BM/day.[101] This strategy requires a plan to include protein-rich foods at each eating occasion to provide a sufficient dose to stimulate protein remodelling. Protein quality may be important for players as the amino acid leucine, is an important trigger for muscle protein remodelling and ~2.5 g of leucine per meal would be optimal.[105] Leucine content is highest in dairy-based proteins (2.5 g leucine/25 g serve of whey protein), high in meat (2.5 g leucine/140 g of lean beef or boneless chicken breast), eggs (2.5 g leucine/5 standard eggs) and plant-protein isolates like soya (2.5 g leucine/30 g serve of isolated soya protein).[105] Plant-based proteins can also be used, but a higher protein intake is required for the same effect on muscle protein synthesis.[105] As in the general population, football players often exhibit a skewed pattern of daily protein intake (the hierarchical order in which protein is consumed being dinner>lunch>breakfast>snacks), which while potentially meeting their daily protein intake (~1.6 g protein/kg BM/day) does not optimally stimulate protein synthesis on each meal occasion, although footballers are reported to consume ~0.3–0.4 g/kg BM at main meals,[66] in line with current recommendations.

Emerging research on presleep protein consumption suggests that this is an important consideration for football players. Overnight is a natural regenerative phase and yet is also a time when nutrient intake is usually low or absent. Preliminary evidence supports presleep protein ingestion[106 107] at a dose of ~0.4 g/kg BM within 3 hours of bed in a full meal or perhaps 0.5 g/kg BM if consumed as supplemental protein 1–2 hours before bed to improve training adaptation during periods of high training volume.[66] Professional players have typically reported an intake of only 0.1 g/kg BM at this time-point, highlighting an opportunity for improved nutritional choices that would potentially improve training adaptation.[66]

During energy restriction, protein requirements are likely increased due to the catabolic milieu created by an energy deficit.[108 109] Nonetheless, it is possible, even during a severe energy deficit, at least for athletes with high body fat, to lose fat and gain muscle simultaneously.[108] For this reason, it is prudent to recommend a higher protein intake (perhaps 2.0–2.4 g/kg BM/day) that is dependent on training load and other metabolic stresses, such as weight loss or rehabilitation from injury (see the section 'Expert group statement topic 7' on nutrition for injury rehabilitation).[94 110]

Fat requirements for training

Dietary fat is an important part of a player's training nutrition as an energy source, a vehicle for the intake and absorption of fat-soluble vitamins and a source of essential fatty acids. Adequate intakes of linoleic acid (an omega-6 fatty acid) and α-linolenic acid (an omega-3 fatty acid) typically provide ~10% of the overall dietary energy intake of sedentary people.[111] Athletes are often advised to adjust fat intake to allow protein and CHO requirements to be met within total energy targets and to follow community guidelines regarding the minimal intake of trans fatty acids and caution with the intake of saturated fats. This typically leads to a fat intake of 20%–35% of total dietary energy. While some players may restrict fat intake to reduce total energy intake or because they think it is 'healthy', overrestricting fat intake to <15%–20% of energy often requires an unnecessary avoidance of a range of foods with valuable nutrient profiles. At the other end of the spectrum, there is renewed interest in chronic adaptation to a ketogenic low-CHO, high-fat (LCHF) diet to enhance the capacity for fat utilisation during exercise.[112] Although there are anecdotal reports that some professional football players or teams follow such a diet (or a low-CHO (LC) diet), no observational or intervention studies involving team sports and LCHF diets are available. Furthermore, it has been shown that although trained muscle can use large amounts of fat at relatively high exercise intensities (eg, up to 75% VO_2max) when CHO availability is limited, this is associated with an increased oxygen cost/reduced exercise economy which may at least partially explain the impairment of performance at higher exercise intensities.[113] Due to the lack of evidence, an LCHF diet is not recommended for footballers.

Essential micronutrients for training

For elite footballers, the demands of both training and match play may also increase the requirements for some micronutrients to support metabolic processes within the body. There are many different classifications of micronutrients, including vitamins, minerals and trace elements essential for growth and development of the body. The most frequent cases of suboptimal status and key recommendations are outlined below.

Vitamin D

Vitamin D is a controversial topic in sports nutrition. Inadequate serum vitamin D concentrations have been reported to impair muscle function and recovery[114] and to compromise immune health,[115] so it is essential that football players who are deficient are identified and treated accordingly. It is a unique vitamin in that it can be synthesised in the skin via sunlight exposure, with <20% of daily needs typically coming from the diet.[116] The average daily intake across the world is approximately 100–250 IU (1 ug = 40 IU), which is less than the current RDA of 400 IU (UK) and 600 IU (North America). The ability to synthesise vitamin D from sunlight is dependent on geography and meteorology, with UVB radiation being insufficient to convert 7-dehydrocholesterol in the skin to vitamin D at high latitudes, especially in the winter months. Paradoxically, studies demonstrate that, compared with Caucasians, black and Hispanic people are at elevated risk of vitamin D deficiency (with darker skin colour reducing synthesis) but at lower risk of osteoporosis, rapid bone loss and associated fractures.[116] Given that many footballers reside in countries far from the equator, and that many of them use sunscreen during the summer months, it is not surprising that footballers[117] occasionally present with vitamin D deficiencies. English Premier League football players showed a seasonal pattern in vitamin D status, with 65% of players presenting with inadequate serum concentrations of 25(OH)D (25-hydroxy vitamin D, the best marker of vitamin D status) in the winter months.[118] Low intakes have also been recorded in female players.[119 120] The current target serum 25(OH)D concentration defined by the US Institute of Medicine and European Food Standards Agency is 50 nmol/L, although this may be conservative[121] and it would be reasonable for athletes to aim for serum 25(OH)D concentrations of at least 75 nmol/L. There is emerging evidence that athletes can have too much supplemental vitamin D[122]; therefore, if a deficiency is observed, 2000 IU/day of vitamin D_3 is suggested with retesting to confirm postsupplementation levels.

Iron

Iron is the functional component of haemoglobin and myoglobin as well as being an essential constituent of non-haem sulphur enzymes and haem-containing cytochromes involved in oxidative ATP production. Therefore, iron deficiency, even without anaemia, can have negative implications for aerobic performance.[123–125] Due to regular blood loss during menstrual bleeding (and possibly due to a diet less rich in meat), postpubertal female players are at the highest risk of iron deficiency.[126 127] While iron deficiency in athletes is common, with a prevalence of about 15%–35% in female athletes and 5%–11% in male athletes,[128] data on professional football players at various stages of the season are limited. Iron deficiencies may present as lethargy and reduced performance and can be identified through blood screening. A reasonable time frame for assessment of iron status is once per year in male players and twice per year in female players (more frequently when iron deficiency has been detected in recent monitoring).

Anaemia is considered present when blood haemoglobin levels are <115 g/L (females) or <125 g/L (males), although some laboratories may use slightly different cut-off values. Iron deficiency is defined as low serum ferritin (<35 µg/L) and normal (ie, not yet affected) blood haemoglobin values. In young athletes, iron deficiency represents the most frequent cause for anaemia; it is typically tested for by determining serum ferritin, the most established marker for the amount of stored iron.[129 130] Anaemia in the presence of low serum ferritin indicates that the anaemia is due to iron deficiency. For anaemia with regular ferritin values, it is necessary to consider other possible causes. In the cases of iron deficiency anaemia, there is a need for iron substitution. When only ferritin is lower than normal, a diet rich in iron, particularly red meat, is recommended to avoid the development of overt anaemia and make sure that other haem-containing proteins/enzymes can be maintained at a sufficient level. Additionally, a period of iron supplementation may be considered at levels above the RDA after consultation with qualified medical and dietetic practitioners. Parenteral (ie, intravenous) supplementation is usually not indicated. Only in cases of pathologically impaired iron digestion from the gut (such as in coeliac disease) is an intravenous administration justified, also with further consideration of maximum infusion volumes outlined by the most recent antidoping regulations. Determination of transferrin saturation can be an alternative means of assessing iron status when ferritin is not available.[130] This sometimes occurs when an infection or inflammation is present at the same time because ferritin is an acute-phase protein and typically increases slightly during such episodes.

Low iron status may result from red cell haemolysis, gastrointestinal bleeding, sweating, inflammation, menstruation in female players and inadequate dietary intake.[131 132] The bioavailability of dietary iron is substantially lower in vegetarian diets than meat-based diets, so the growing interest in veganism is a concern with regard to dietary iron content. The current RDA for iron is 18 mg (in North America) or 14.8 mg (in the UK) for females, and 8 mg (North America) or 8.7 mg (UK) for males. Where possible, iron should be consumed from highly bioavailable sources (haem iron), including meat and seafood. Vitamin C should be co-ingested with non-haem iron sources to enhance absorption, and foods or fluids that impair iron absorption, such as tea and coffee, should be avoided around meal times. Numerous oral iron preparations are available, and most are equally effective if appropriately taken. Gastrointestinal side effects of supplementation can include constipation, nausea and black stools. The tolerable upper intake level (UL) is 45 mg/day; high-dose iron supplements of >45 mg/day elemental iron should not be taken unless iron deficiency is present, as there is a real danger of harmful iron toxicity. For further information on iron considerations, readers are directed to a review by Sim *et al*.[128]

Table 2 .Food sources of calcium

Food and serving size	Calcium content (mg)*
Whole or skimmed cows' milk (200 mL)	240
Calcium-enriched soy milk (200 mL)	240
Hard cheese, for example, cheddar (30 g)	220
Yoghurt (120 g)	200
Sardines, with bones (½ tin)	258
Broccoli (2 spears)	34
Kale (67 g)	100
Orange (1 medium size)	75
Typical multivitamin/mineral supplement	200

*Note that the RDA is 700–1000 mg/day.
RDA, recommended dietary allowance.

Calcium

Calcium is important for the maintenance of bone tissues, skeletal muscle and cardiac contraction and nerve conduction. Serum calcium concentration is tightly regulated by calcitonin and parathyroid hormone regardless of acute calcium intake. The largest store of calcium in the body is in the skeleton and this store is mobilised when dietary intake is inadequate, leading to demineralisation of bone tissue through the action of parathyroid hormone. Dairy products are the main dietary sources of calcium, but it is also found in green leafy vegetables, nuts and soya beans (table 2) The RDA for calcium is 1000 mg/day (North America) or 700 mg/day (UK) for adults and 1300 mg/day (North America) or 1000 mg/day (UK) for adolescents. An athlete's diet should include a higher intake of 1500 mg/day through dietary sources or supplementation if required to optimise bone health in cases of relative energy deficiency in sport (RED-S).[133] Calcium may be lost through sweat, although modestly; this can hypothetically reduce serum ionised calcium concentration, resulting in an increase in parathyroid hormone production, thus stimulating bone resorption.[134] Significant dermal calcium losses have been reported following prolonged exercise alongside an increase in parathyroid hormone.[135] In support of this hypothesis, ingestion of 1350 mg of calcium 90 min prior to exercise has been shown to attenuate deleterious changes in biomarkers of bone resorption.[136] This suggests that dermal sweat losses, as well as urinary losses,[137] although small, may be an important consideration. Particular attention should therefore be given to football players training or competing in hot environments, especially if they have low dietary calcium intakes. If supplements are to be used, calcium carbonate and calcium citrate are well absorbed. Finally, recent research has highlighted that magnesium is an emerging consideration with its role in energy production, muscle function, bone heath, immune function and pain modulation. A recent 8-year study in Olympic athletes highlighted 22% of athletes were deficient (estimated from erythrocyte magnesium concentration) at one time-point. Furthermore, athletes with a history of Achilles or patella tendon pain had significantly lower magnesium levels than average.[138]

Staying healthy throughout the season

The high physical and psychological demands of participation in elite football may weaken immunity and increase the risk of illness.[139 140] The most common illnesses in elite footballers are those affecting the respiratory tract (58%) and gastrointestinal tract (38%), with an incidence of 1.5 illness episodes per 1000 player-days.[141] Several factors are associated with increased risk of illness, including preseason training (higher training load and low energy intake to implement weight loss strategies for some players), winter months, fixture congestion,[92] psychological stress and depression.[139 142 143] Poor oral health has also been reported in elite players,[144] with pain, psychosocial impacts and effects on eating and sleeping affecting their ability to train, their MD performance and their recovery. Players should take responsibility for their oral health aided by their existing medical team and a dentist.

Preventing illness in players

Preventing or at least minimising the risk of illness is a key component in player health management. Illness prevention strategies are important to achieve uninterrupted training and to reduce the risk of illness that can prevent participation or contribute to underperformance in both training and matches. Several nutritional strategies may be effective in helping immunity,[145 146] although other considerations are just as important in reducing infection risk, including good personal, home and training venue hygiene, managing the training and competition load, ensuring adequate recovery and sleep, psychological stress management and monitoring players to detect early signs and symptoms of illness, overreaching and overtraining.[139]

Nutritional strategies to limit illness risk

Performance teams can consider adopting nutritional measures to maintain robust immunity in players.[145 146] For most players, and particularly for those who are illness-prone, these should be implemented throughout the season or at least during the autumn and winter months and during periods of fixture congestion, when infection risk is highest. Adequate levels of essential nutrients are important to support immune health. Inadequate protein-energy intake or deficiencies in certain micronutrients (eg, iron, zinc, magnesium, manganese, selenium, copper, vitamins A, C, D, E, B_6, B_{12} and folic acid) decrease immune defences against invading pathogens and make the individual more susceptible to infection.[145 146] Low energy availability (EA) is associated with increased risk of illness, and restricting CHO (eg, 'training low') may increase immunosuppressive stress hormone responses.[140] Protein intakes of at least 1.2 g/kg BM/day are required for optimal immune function[147] and there is some evidence, in cases of overreaching, that even higher intakes (up to 3 g/kg BM/day) can reduce the incidence of respiratory infection.[148] In general, a broad-range multivitamin/mineral supplement is the best choice to support food intake in situations where food choices and quality may be limited. Several studies in athletes and the general population have provided evidence of the importance of vitamin D status in optimising immune defence against the common cold.[115 116] Hence, players who are deficient or insufficient in vitamin D are likely to benefit from vitamin D_3 supplementation (2000 IU/day to correct a deficiency or to avoid the possibility of a deficiency during the winter months). Taking 75 mg/day of zinc supplements (lozenges) when symptoms of a cold begin is reported to reduce the duration of symptoms.[140 149]

High intakes of fresh fruit and vegetables are associated with reduced infection risk in highly physically active people,[145 150] therefore footballers should follow the standard recommendation of at least five portions of fruit and vegetables per day on at least 5 days per week. Several studies in athletes indicate that daily consumption of polyphenol supplements[151 152] or beverages (eg, non-alcoholic beer, green tea)[152 153] is also associated with reduced respiratory infection risk in athletes. Footballers should limit alcohol intake to no more than 2 units per day and avoid binge drinking, which is known to negatively impact the functioning of immune cells.[84]

Some well-controlled studies in athletes have indicated that daily probiotic ingestion results in fewer days of respiratory illness and lower severity of illness symptoms,[145 154] with general support for a reduced incidence of respiratory illness being provided by a recent meta-analysis of data from 12 studies involving both athletic and non-athletic populations.[155] These benefits have been limited to protocols involving *Lactobacillus* and *Bifidobacterium* species, with daily doses of $\sim 10^{10}$ live bacteria. A smaller number of studies indicate that probiotics may also reduce the severity and/or duration of gastrointestinal illness in athletes.[154] Currently, there is insufficient evidence to justify the use of any other supplements to boost immunity and/or reduce infection incidence.

Finally, serious gastrointestinal illness caused by bacterial contamination may occur in relation to the storage and preparation of food consumed in training ground restaurants or venues used for postmatch buffets (eg, the changing room or team bus). Minimising the risk of such problems requires attention to food hygiene, with a focus on cross-contamination, cleaning, chilling and cooking. Resources that address these '4 Cs', including hygiene training documents and videos, can be found on the UK Food Standards Agency website (www.food.gov.uk/business-industry/food-hygiene).

EXPERT GROUP TOPIC 3: BODY COMPOSITION

Nutrient intakes can have a profound impact of a player's body composition which in turn may impact their performance. There are different time points throughout the season where players may need to manipulate their intake to elicit changes in fat mass (FM) or skeletal muscle mass (fat free soft tissue mass (FFSTM)).[156] This may occur during preseason or during injury where nutrient intake may need to be altered to the needs of physical output.[157] This relationship is very important to the athlete's health and performance as it is often not reflected in BM measurement alone.

The sports nutritionist and performance team are required to work closely to plan out how the interaction between diet and training will change body composition. These interventions should be justified, well planned out and executed.[158] Increased FFSTM may be a desired training adaptation with benefits of enhanced strength and power. Moreover, the preservation of FFSTM during injury and immobilisation is crucial.[93 159] In contrast, excess body fat will negatively affect a player's power-to-weight ratio, acceleration capacity and overall energy expenditure.[160] However, players may also choose to manipulate body composition (FFSTM or FM levels) to achieve a desired appearance, and the desire for a lean or muscular physique may conflict with the player's performance goals. Each player's body composition goals should be agreed between the player and the performance team.

Assessing body composition

Methods of assessing body composition in football must be valid, reliable and practically feasible to monitor meaningful change, with four or five compartment (4C or 5C) methods remaining the criterion method of assessment, known as gold standard. Adherence to standardisation in any assessment protocol will assist minimising technical and biological error and allow recognition of the smallest meaningful changes and therefore improve longitudinal tracking of body composition.[161 162] Field methods such as anthropometry (skinfolds), bioelectrical impedance analysis and ultrasound are all commonly used with degrees of accuracy and precision in athletic populations.[163–167] Many of the current laboratory methods including underwater weighing, air displacement plethysmography, isotope dilution methods, MRI, three-dimensional photonic scanning and dual X-ray absorptiometry (DXA) have precision errors between 1% and 4.5%,[164] but are not often easily accessible, expensive and may require high levels of expertise to process and interpret results.

With advancements in technology and reductions in costs, there is a recent shift toward the use of DXA scanning to assess body composition including bone mineral density in elite athletes. Indeed, there have been many studies that have described the body composition of a wide array of different athletes in numerous sports that have used the field method of DXA. There have now been several validation studies, mostly in healthy humans, showing that DXA has greater levels of accuracy than alternate methods such as skinfold-derived body fat or bioelectrical impedance analysis measures.[168 169] In fact, several validation studies with various manufacturers of DXA have shown a similar level of accuracy as the 4C model.[170 171] Indeed, recent research has demonstrated that the DXA-derived FM percentage was strongly associated with a gold standard 5C model (24.4%±12.0% vs 24.9%±11.1%, $r=0.983$, $p<0.001$).[172] Due to several manufacturers and software, many different DXA units, while not interchangeable, showed exceptionally good precision and accuracy for FFSTM, bone mineral content and FM and may be more appropriate when assessing change in leaner athletic populations in comparison to other practical methods, namely anthropometry and bioelectrical impedance analysis.[173]

Ensuring standardisation in positioning, food and hydration status will reduce errors associated with the use of DXA.[161 162 174] Practitioners must recognise that radiation exposure, although generally small, will limit the frequency of measurements, so the timing of assessments should be carefully planned. Anthropometry provides an acceptable, cost-effective, practical, assessment of body composition, when conducted by someone with appropriate kinathropometric training (eg, International Society for the Advancement of Kinanthropometry). The use of absolute skinfold measurements is recommended to assess changes in body composition rather than calculating percentage body fat using equations.[175]

What is the optimum body composition for an elite football player?

The optimum physique, in terms of FFSTM and FM levels, varies according to an individual player's physiology, and their field position and playing style. Indeed, there is no single value for either BM or FM content against which targets or judgements should be made. Mean FM levels in elite male players measured by DXA typically range from ~8% to 13%,[93 176] although lower[158] and higher[177] values have also been recorded. Goalkeepers are typically taller and heavier with greater FM than outfield players.[158] Elite senior male players have, on average, higher FFSTM than players in under (U)21 and U18 teams, although differences in FM may not be significant.[93] Data on elite female players are scarce, but mean FM levels of approximately 16% have been observed in US collegiate division 1 players. Most elite clubs regularly monitor players, and this area of research will continue to evolve in terms of position-specific and seasonal trends. To date, it appears that seasonal changes typically include lower FM and greater FFSTM mid-season and at the end of the season.[176]

Notwithstanding these observations, both male and female players may perform well with FM levels outside the normally accepted range: it is not known if a change in physique would result in better performance. Performance metrics, such as training or match data (eg, GPS) or functional tests (eg, countermovement jumps), alongside body composition may help to provide objective feedback as to what is appropriate for each player.

Relative energy deficiency in sport

In an attempt to conform to various self-imposed expectations or demands from others, many female athletes restrict energy intake and develop the clinical syndrome originally known as the female athlete triad[178] and later introduced as RED-S[179] applicable in both male and female athletes with or without disordered eating (DE) or eating disorders (ED). Although football is not considered one of the high-risk sports for RED-S[179] or DE,[180] it should be noted that only a few studies have evaluated markers of low EA[181] and conditions associated with RED-S and/or DE in football players.[132]

Reed *et al*[181] assessed EA based on the match between reported energy intakes and training expenditure in the NCAA women's division I; they found that 26%, 33% and 12% of players met the criteria for low EA preseason, mid-season and postseason, respectively. It is known, however, that such assessments are fraught with errors of reliability and validity.[182] Meanwhile, Prather *et al*[183] investigated 220 female football players representing a youth club, an NCAA division I university team, and a women's professional team to identify components and outputs of low EA; they found that 8% were at risk for ED, while 19% had menstrual dysfunction and 9% reported stress fractures. In a study of 17 female Norwegian junior and senior national team football players, 24% had DE, 9% had menstrual dysfunction and 13% reported a history of stress fractures.[132] The contribution of low EA to bone health and injury rates is one of the key reasons for concern about energy mismatches, and it has been identified as a problem in males as well as females.[181] Indeed, a recent study of male and female endurance runners by Heikura *et al*[184] found a 4.5-fold increase in bone injury rates with low EA in 37% of females (with amenorrhoea) and 40% of males (with low serum testosterone). Factors which may contribute to low EA include changes in BM and composition, and changes to training volume/intensity without associated changes to fuelling.[179]

The management of body composition in football requires knowledge and skills in how to approach an athlete with unrealistic expectations, methods or goals regarding lower FM, how to present/discuss the results of body composition assessments and when to raise the alarm and engage other support staff, to prevent severe energy restriction or EDs.[175 180] It is also recommended that team protocols are standardised to ensure that monitoring is undertaken precisely, accurately and longitudinally, that body composition data are integrated with other test parameters, and that team support staff are aware of the health risks associated with RED-S and DE.

EXPERT GROUP TOPIC 4: STRESSFUL ENVIRONMENTS AND TRAVEL

When matches are played in stressful environments, the cardiovascular, thermoregulatory, metabolic and perceptual strain is exacerbated.[185 186] Heat exposure is a widely recognised risk, with increased sweat loss and dehydration presenting a threat to performance and health.[187] Conversely, exposure to cold and high-altitude environments stimulates diuresis, increases respiratory water loss and reduces thirst, again predisposing athletes to dehydration.[185] Furthermore, international fixtures, major tournaments and preseason training camps can require extensive long-distance air travel, with exposure to dry cabin air and altered access to fluid and nutritional intakes potentially resulting in mild-to-moderate dehydration.[188] Congested competitive schedules seldom permit prior exposure to these environments, and although exposure to heat, altitude or travel may be brief, rarely is physiological or perceptual acclimatisation available to attenuate the strain. A range of thermoregulatory, sleep and travel interventions exist to assist in these environments; however, with the exception of heat, there is limited evidence for recommended nutritional strategies to further support players exposed to match demands in stressful environments. In this section, we focus on playing in hot environments and make some reference to the limited information pertaining to nutritional interventions in other stressful environments, in the hope of stimulating future research in these areas.

Hot environments

Important matches are often played in hot conditions, such as the UEFA Champions League final (played in May each year) and the UEFA European Football Championship or FIFA World Cup finals (played in June and July every 4 years). Football matches in the heat result in decreased total and high-intensity distance covered, partly compensated for by altered technical engagement, for example, increased successful passes and crosses.[186] Furthermore, increased deep organ and muscle temperatures, alongside similar cardiovascular responses for reduced match work rates, highlight the increased thermal strain of playing in the heat.[186]

In hot environments, dehydration potentiates hyperthermia, increases cardiovascular strain and elevates perceived exertion. Specifically, a body weight loss of 3%–4% induced by dehydration may decrease muscular strength by 2%, power by 3% and high-intensity exercise endurance by 10%.[189] Field measurements of sweat losses during football training show increasing sweat rates as ambient temperature increases.[54] Laboratory studies indicate that ambient temperature,[190] humidity[191] wind speed[192] and solar load[192 193] all influence endurance performance. While UEFA competitions implement designated 3 min cooling breaks during each half when temperatures are >32°C dry bulb and >27°C wet bulb globe temperature, further interventions such as precooling may assist player performance and health. The risk of players experiencing significant hypohydration is exacerbated when training or playing matches in the heat. Accordingly, the primary nutritional needs of players in a hot environment are to replace fluid and sodium losses. It is not necessary to drink to fully compensate sweat losses but, as a guide, BM loss should be restricted to less than about 2%–3% of the starting mass.[194] Important additions to rehydration beverages therefore include CHO and electrolytes (particularly sodium) to optimise football performance.[45 46 178]

When rehydration is the priority, ingesting a 2%–6% CHO beverage may be of greater benefit to the player than more concentrated solutions, which can slow the delivery of fluid to the body.[195] It is also recommended that CHO intake after the warm-up and at half-time is reduced to ~20–50 g, when fluid intake is prioritised over substrate delivery. Furthermore, providing chilled beverages will promote voluntary fluid intake[196] and can limit the rise in core temperature that would otherwise occur.[197] In particular, CHO-infused ice-slushies offer an appealing strategy for cooling, rehydrating and nutritional replenishment.

The few players who have both a high sweat rate and a high sweat sodium concentration (which can be determined using validated sweat composition testing) should receive individualised guidance and monitoring of salt and fluid intake. However, the whole-body balances of water, sodium and potassium are complex and determining the dietary intake required to replace sweat and urine losses requires considerable technical expertise and laboratory instruments.[198] The ideal solution involves accurate diet records, urinalysis and whole-body sweat analyses.[182] Other methods (eg, estimation, normal clinical values, extrapolation of local sweat collections) fail to characterise an athlete's fluid-electrolyte turnover accurately. When the support of a sports nutritionist, exercise physiologist or sports medicine physician is not possible, we recommend two actions: first, consume ample fluids and foods with high sodium, potassium and water contents.[199] Second, self-assess hydration status each morning by recording body weight, assessing thirst and observing urine colour.[200]

High altitudes and cold environments

Matches played at altitude are the least common of the stressful environments for practitioners to plan for. The most notable include matches in La Paz, Bolivia (~3600 m). Altitude (>1500 m) results in decreased running performance for unacclimatised players.[185 201] At elevations >1500 m, appetite decreases and food preferences change,[202] so that both the absolute and voluntary consumption of CHO increases at the expense of fat and protein. Also, endurance exercise performance is adversely affected if diet is manipulated to decrease CHO intake. Easily consumed liquid or solid CHO foods can help to maintain performance and macronutrient balance. When residing at altitude for more than a few days, for example, during altitude training camps, maintenance of body weight (ie, ensuring adequate daily energy and water intake) is a priority.[203] Above an altitude of 3000 m, the increased production of red blood cells may require an adequate dietary iron intake (100–300 mg of elemental iron per day),[204] but this should be guided by the team doctor based on an individual player's iron status; particularly for extended camps if predeparture iron is low.[205] Given the lack of evidence on nutrition-based interventions for competition at altitude, further research is required.

While some matches may be played in extreme heat, others may be played in cold conditions, including some UEFA Champions League matches or other leagues around the world. Players can cope with cold environments by wearing appropriate clothing. Provided the weather is not extreme and the work rate is maintained at a high level, cold should not be a problem if appropriate clothing is worn. UEFA regulations on playing in the cold specify that when the temperature is −15°C or colder, the match is postponed unless both teams agree to play. CHO requirements are increased in cold environments, while the effects of dehydration may be less detrimental to performance.[2] However, further research is needed to determine the effects of playing in the cold and how nutritional strategies might be able to help.

Flying across time zones

The speed and power of professional footballers are reduced in the aftermath of long-haul travel (>15 hours) across multiple time zones (>4–5), although it is reportedly possible to maintain prolonged intermittent-sprint performance.[206] It is likely that reduced performance exists with travel distances of >10 hours and 2–3 time zones. The disrupted sleep patterns resulting from desynchronisation of endogenous circadian rhythms and external day-night cues (ie, jet lag), concurrent with reduced mood and motivation (ie, travel fatigue), are the likely causes of reduced player performance for up to 72 hours following travel. The severity of this disorder is proportional to the number of time zones crossed and the cumulative sleep loss, thus primary interventions that target improved sleeping behaviour, limit perceived fatigue and improve motivation are important.[207]

Light is the most powerful external regulator of circadian rhythms. Dietary manipulations such as moderating food amount, type and intake patterns have been proposed,[188] but the evidence does not support any method unequivocally.[208] Oral melatonin,[209] slow-release caffeine[210] or a combination of the two may reduce the negative consequences of jet lag.[210] There are important considerations around the sourcing and side effects of melatonin and readers are directed to a recent review[211] for further considerations for travel. All pharmacological sleep interventions should be overseen by a medical doctor, although sleep hygiene (as part of wider travel hygiene) should always be considered first.

EXPERT GROUP TOPIC 5: GLOBALISATION—CULTURAL DIVERSITY AND DIETARY CONSIDERATIONS

The elite football community has become much more mobile in recent years. This progression has been particularly evident in Europe since the 1995 Bosman ruling, with player migration within the five major European leagues (England, France, Germany, Italy and Spain) increasing from 19% in 1995/96 to 47% in 2015/16. Differences in migration are seen across continents: North American Major League Soccer (49%) and Europe (48%) have the highest proportion of foreign players (the English Premier League having the highest at 66%), with lower proportions in Asia (18%) and Latin America (14%).[212] In addition to the evolving diversity of elite teams, there are multiple international club and national team competitions, preseason camps, friendly games and commercial obligations that mean travel to foreign countries is now a common occurrence for elite teams and their players. As a consequence of this increasing globalisation, various related challenges are more apparent for performance and nutritional team staff.

Religious beliefs and implications for dietary practices

Practitioners should be aware of the cultural considerations for all players. Collaboration with the club chefs is important to ensure all foods provided on training and MDs are culturally acceptable. With approximately 23% of the world's population being Muslim and >50 countries considered Muslim majority nations,[213] Ramadan is an important consideration for players and a particular challenge for many elite football teams. During the holy month of Ramadan, Muslims fast from sunrise until sunset. Many Muslim players will continue to train and compete during Ramadan, although each must decide how they approach the situation. The available evidence indicates that elite players can maintain most parameters of physical performance over Ramadan, although sleep and nutrition should be optimised to reduce the likelihood of any cumulative fatigue.[214] For a comprehensive overview on Ramadan in football, readers are directed to Maughan *et al*[215] for further information.

Where possible, training should be scheduled to allow for the most appropriate nutrition support: when training is scheduled after sunset, players can benefit from food and fluid consumption before, during and after training.[216] Players should make the most of the important meals: *Suhour* (the predawn meal) should be eaten as close as possible to sunrise and should be high in CHO, as well being used to contribute to daily protein and fluid targets; *Iftar* (the first meal after sunset) is important to support recovery and may be adapted to meet the overall nutritional needs for the day.[216] Players should still fuel according to the demands of the training or MD (maintaining the overall intakes outlined in the sections 'Expert group topics 1 and 2' on match and training day nutrition, respectively). Making use of fluids and sports foods may reduce gastrointestinal discomfort. Sufficient fluid and electrolyte intake should be achieved in small amounts spread over the waking hours after sunset, to fully replace sweat losses.[216]

Players should be individually monitored with training loads prescribed accordingly, to reduce the risk of illness and injury, and limit unnecessary dehydration.[216] Adherents to other faiths and their practices should also be considered, for example, Tisha B'Av, the annual Jewish day of fasting, which coincided with the London 2012 Olympic Games.[216]

Food allergies and intolerances

A food allergy is defined as an adverse immune-mediated response, which occurs reproducibly on exposure to a given food and is absent when the food is avoided.[217] Reactions can range in severity from minor abdominal discomfort through to anaphylaxis, with reactions generally developing within minutes of exposure. The most common food allergies include fish, shellfish, peanuts and tree nuts, with some geographical variance.[218] Food allergy is determined by means of a thorough medical and nutrition history to guide validated diagnostic methods, such as a skin prick measurement of food-specific IgE levels or double-blind, placebo-controlled food challenges.[218 219]

Food intolerances are reactions which are not immune-mediated (eg, lactose or gluten intolerance). The symptoms are less clear, with frequently unspecific symptoms occurring hours to days after exposure, possibly including abdominal bloating or pain, loose stools, fatigue or headache.[219] At this time, aside from lactose intolerance, there are no validated diagnostic methods for establishing food intolerance.[218] Coeliac disease is another common condition (autoimmune disease) for which validated medical testing exists. It is important that validated diagnostic testing is conducted, under the guidance of a medical doctor, before undertaking an exclusion diet in response to allergy or intolerance-related symptoms.

Special diets

There is increasing interest in a more diverse range of diets for football players (and athletes in general) with some consuming and even advocating specific diets such as gluten-free, vegetarian and vegan for performance reasons. The reality is that, despite an increase in the number of players adopting these emerging diets, there has been no scientific research into their effect on football performance. However, it is important to discuss the issue and provide our expert opinion at this time.

Gluten-free diets (GFDs) have gained popularity among athletes, with 41% of athletes without coeliac disease reported to consume a GFD at least half of the time.[220] Following a GFD is essential when managing clinical conditions such as coeliac disease (a serious autoimmune disease of the small intestine triggered by gluten that affects about 1% of adults) or wheat allergy; many others may follow GFDs due to perceived health or performance benefits, although no differences in gastrointestinal symptoms, systemic inflammation or exercise performance in athletes without coeliac disease have been shown when following a GFD.[221] Rather than avoiding gluten itself, a low fermentable oligosaccharides, disaccharides, monosaccharides and polyols (short-chain CHOs) diet has been associated with improvements in gastrointestinal symptoms for individuals with non-coeliac gluten sensitivity.[218 222]

There are many different types of vegetarian diet. Vegetarian diets exclude meat, fish and poultry, whereas stricter vegan diets exclude all animal products including dairy, eggs and honey. Other varieties include lacto-vegetarian (permits dairy but not eggs), ovo-vegetarian (permits eggs but not dairy) and flexitarian (includes meat, poultry, fish, eggs or dairy but only occasionally or in small quantities). The recent popularity of vegetarian diets appears to reflect current public trends, although considerable variability exists in different countries.[223] Approximately 22% of the world's population is thought to be vegetarian,[224] although the only study in elite athletes found the prevalence to be 8%.[225] Although a vegetarian diet has been associated with a reduced risk of chronic diseases in non-athletic populations,[226] its effect on athletic performance has not been established.[218 227] A well-balanced vegetarian diet can provide a full range of macronutrients and micronutrients but, depending on the type of vegetarian diet, may result in lower calcium, iodine, iron, zinc, vitamin B_{12}, omega-3 fatty acid and creatine intakes, although protein needs are commonly met in athletes meeting overall energy requirements and eating a variety of protein-rich foods.[226]

Evidence suggests there are health benefits associated with vegetarian diets, but at present there is little evidence that vegetarian diets are superior to omnivorous diets for improving athletic performance. Finally, and as previously detailed in the section 'Expert group topic 2' on training day nutrition, there is little evidence to support a ketogenic, LCHF diet for player performance.

Further work is required to understand the interplay between sports nutrition and sustainability and how principles can be incorporated within best practice nutrition recommendations. Now more than ever, players may also modify dietary habits for their own perceived health, performance or ethical reasons. The literature about this is scarce within athletic populations; readers are directed to a review by Lis *et al*[218] for further information.

Personalised nutrition

A player's nutrition should be periodised and personalised to meet their training and match demands and individual objectives (eg, reduced body fat or increased muscle mass) but, as highlighted in this section, cultural, religious, ethical, medical and even just individual food preferences will affect a player's food choices.

Due to the risks to health and/or performance associated with many forms of dietary restriction, any major dietary change should be evaluated and monitored under the guidance of the team's sports nutritionist and medical doctor.

Where biomarker testing (ie, blood, urine, saliva) is required to inform any intervention (eg, a blood test for iron or vitamin D status), it is crucial that this is overseen by the medical and performance support team with input from the sports nutritionist where appropriate. In the face of increasing unvalidated technology available to players and staff, any testing must be both valid and reliable, and used to answer a specific question about an individual player. There is currently a lack of evidence for genetic testing and nutrition prescription.

Food contamination

The findings of food contamination with the prohibited anabolic agent clenbuterol both in China[228] and in Mexico, where at the FIFA U-17 World Cup in 2011, a total of 109 out of 208 urine samples yielded clenbuterol findings, although at very low levels,[229] are a cause for concern. Player vacations and travel for competitions may lead to exposure. Teams should consult their national association or WADA for the latest advice. Player education is crucial, and sports nutritionists may devise meat-free menus or advise eating at recommended outlets to minimise risk. Such precautionary measures can reduce, but not eliminate, the risk of inadvertent exposure to clenbuterol in at-risk countries, for example, Mexico, China and Guatemala,[230] so it is important to inform the relevant antidoping organisations (WADA, National Anti-Doping Organizations, antidoping commissions of national associations) about the whereabouts of individuals and teams.

EXPERT GROUP TOPIC 6: DIETARY SUPPLEMENTS

Definition and categorisation of supplements

Dietary supplements come in many shapes and forms, and any definition or classification system must recognise this diversity.[231] There is no single definition of a 'supplement' that is completely satisfactory and independent of context. In a recent IOC consensus statement,[232] the following definition of 'dietary supplement' was proposed:

> A food, food component, nutrient, or non-food compound that is purposefully ingested in addition to the habitually-consumed diet with the aim of achieving a specific health and/or performance benefit.

Athletes/players give many reasons for using supplements, and these are often shaped by the promotional materials targeted at them by manufacturers. Claims such as 'build muscle', 'burn fat', 'increase energy' and 'stay healthy' are emotive and highly valued by athletes. It is important to remember, however, that the supplements industry is driven by financial motives and responds to consumer demand and acceptance. The evidence to support these claims is often lacking and may also be at risk of both natural and industry-driven publication bias. In general, the scientific literature favours studies reporting positive findings as they are considered more 'newsworthy', but some of the authors of this statement have also found that studies showing 'positive' effects are promoted while those finding no (or negative) effects may be blocked by sponsors of the research.

Prevalence of supplement use within elite football

Supplement use is widespread in sport and there is some evidence that its prevalence varies according to the sport, as well as the training and performance level, age, sex and culture of the individuals concerned.[231] In elite football, only two studies have provided data on the prevalence of supplement use.[233 234] Aljaloud and Ibrahim[233] reported that 93% of 108 players from three different Saudi professional teams regularly used supplements. The most-used supplements were sports foods (87% of players consumed sports drinks) and vitamins (81% consumed vitamin C). Studies conducted on national team players during the 2002 and 2006 FIFA World Cups also indicated widespread use of supplements.[234] Each team physician was asked to document nutritional supplements taken in the 72 hours prior to each match during both tournaments, making the objective validity of these data questionable. Approximately 43% of players in the 2002 and 2006 tournaments were reported to have used supplements. Sports foods and drinks were not considered supplements in this study, resulting in a lower prevalence than in other studies.

Supplements that may be useful

The football player's nutritional programme should be centred around a 'food first' approach, with supplements used only to meet specific health and/or performance objectives. The dose and duration of supplementation should be recorded, and responses, including both positive and adverse effects, should be monitored by the team's sports nutritionist in collaboration with other key stakeholders, including the team's medical doctor. Regular review is essential.

Recognising that any system of supplement classification must take into account the needs of many diverse groups, including consumers, manufacturers and legislators, categorisation by target function or action is recommended. While accepting that there is no sound evidence of efficacy in many cases, the classes of supplements listed in table 3 might nevertheless be recognised. Products with very different characteristics might be found within the same category, and some supplements might be found in more than one category. The recommendations here are closely aligned with those of the IOC consensus.[232]

Micronutrients

Where a player is identified as suffering from a specific micronutrient deficiency, a dietary solution should be sought, although a prompt and effective solution may not always be possible. Micronutrients often requiring supplementation in athletes include vitamin D, iron and calcium.[232] Supplements used for this purpose should be sourced from a reputable supplier and used only at the therapeutic dose and for the shortest possible time required to restore adequate nutrient status. Players with restricted eating patterns, whether for religious, cultural or ethical reasons, or due to restricted energy intake during periods of weight reduction, may benefit from the use of a broad spectrum, low-dose multivitamin and mineral preparation, but again this should be assessed on an individual basis. These supplements present no major risk for health, except with chronic supplementation and/or high doses. Routine iron supplementation can do more harm than good, and the risk of iron toxicity is very real.[235] It should also be recognised that athletes who self-prescribe supplements to provide essential nutrients are often those least likely to require them.[236] Players are therefore advised not to purchase their own supplements but to use only those provided/recommended by the sports nutritionist, or at least agreed on by the team doctor.

Sports foods

Footballers should have clear nutritional guidelines to follow on training and MDs. Due to the usual organisation of training sessions in a day (concurrent 'on pitch' sessions followed by resistance work) with limited breaks in training and match play, it is not always possible for players to consume foods in the form of meals. In this situation, sports foods (eg, CHO-electrolyte drinks, gels and recovery shakes) can provide a convenient alternative to meet nutrient targets. Table 3 lists sports foods with supporting scientific evidence that may be considered in the circumstances where 'food-first' is not feasible.

Performance

Although some dietary supplements may be effective in improving performance in some specific exercise models or sports, very few have undergone football-specific tests and some studies of match play simulations have involved participants with only recreational level experience or an absence of any football experience. The evidence that professional footballers would benefit from these supplements is very limited. Furthermore, based on general methodological considerations it is likely that there are fewer benefits than in other sporting contexts. Since many commonly used supplements will display a large interindividual variability in terms of response, they should be trialled and monitored in training before being used in competition. The evidence for some performance supplements (eg, caffeine, creatine) is stronger than for others (β-alanine, nitrate). Sodium bicarbonate was removed from this category by the expert group due to its lack of use within elite football. Negative effects must also be considered, as highlighted in the 'concerns and use' column in table 3. Performance supplements not listed here can be considered to have insufficient evidence to support use.

Supplements and adverse analytical findings

The risk of a positive doping test resulting from the use of dietary supplements has been recognised for two decades. Both independent analyses carried out by various laboratories and analytical checks carried out by the US Food and Drug Administration have identified contamination of supplements with pharmaceutical agents that are not listed on the label. Geyer *et al*[237] analysed 634 nutritional supplements from 215 different suppliers in 13 countries with ~15% containing prohormones not declared on the label. In 2007, it was reported that ~25% of 58 supplements purchased through US-based outlets were contaminated with steroids.[238] In a more recent survey, Matthews[239] concluded that 'poor manufacturing processes and intentional contamination with many banned substances continue to occur in dietary supplements'. Historically, anabolic steroids have been the pharmaceuticals most commonly found in muscle building supplements, while stimulants and anorectic agents are more commonly found in tonics and weight loss supplements, respectively. However, new supplements have appeared on the sport supplements market in recent years, containing a larger variety of different prohibited doping substances.[240–243] Banned stimulants have been found in so-called training or pre-workout boosters, while muscle building products have been shown to contain prohibited selective androgen receptor modulators, aromatase inhibitors, β_2-agonists, new anabolic steroids and growth hormone releasing peptides. Products containing prohibited diuretics, stimulants and β_2-agonists are frequently advertised as weight loss or fat burner supplements. Also, erythropoiesis-stimulating agents, that is, endurance performance enhancers, were found to contain prohibited inorganic cobalt and nickel.[240–243] This may be interpreted as supporting the idea that contamination is not accidental, but rather the result of deliberate adulteration of otherwise ineffective products. Inadvertent doping with stimulants and anabolic steroids may also result from the consumption of traditional Asian medicines.[241 244] The principle of strict liability means that ignorance of the presence of a prohibited substance in a product is not an acceptable excuse and sanctions will still be applied.[230]

Table 3 Dietary supplements, sports foods and beverages that are potentially useful for footballers (adapted from Maughan *et al*[232])

Type of supplement and examples	Use	Concerns	Main mechanisms	Protocol
Micronutrients				
Vitamin D Iron Calcium	Prevent or treat deficiency to help maintain health and performance.	Inappropriate use or when taken with lack of monitoring or supervision can lead to health problems.	See section on micronutrients.	According to Doctor's prescription.
Sports foods				
Carbohydrate (CHO)-electrolyte drinks CHO gels Sports bars and confectionery Recovery shakes Protein drinks Protein-enhanced food Liquid meal supplements	Supply convenient macronutrients to support energy or recovery needs for training and match play.	Greater cost than whole foods. Inappropriate use or amounts when taken with lack of monitoring or supervision.	Macronutrient and/or fluid supply.	See sections on match day (topic 1) and training (topic 2).
Performance				
Caffeine	Reduces perception of fatigue, enhances endurance, repeated sprint performance,[301 302] skill and fine motor control[303 304] and improves cognitive function.[304]	Highly individual response (both positive and negative). Side effects with high doses include anxiety, nausea, insomnia, tremors and reduced sleep quality. More serious side effects include tachycardia and arrhythmias.	Central nervous stimulant. Adenosine receptor antagonist.	3–6 mg/kg BM, in the form of anhydrous caffeine (ie, pill or powder form), consumed ~60 min prior to exercise or lower caffeine doses (<3 mg/kg BM, ~200 mg), provided both before and at half-time consumed with a CHO source. Sports foods (or coffee) provide multiple options for delivery. Dose of caffeine should first be evaluated using lower caffeine doses to assess response, especially if used regularly in training and match play. *Note: caffeine is currently on WADA's monitoring programme, so the WADA list should be checked prior to use in case of a change in status*.
Creatine	Improves high-intensity repeated sprint performance.[305] Enhances training capacity and chronic training adaptations (muscle strength and power[306] and lean BM).[307 308] May also support brain function.[309]	Potential for 1–2 kg BM increase after creatine loading. No negative health effects following appropriate protocols.[310] Falsely increased creatinine levels.	Increases muscle creatine stores, increasing the resynthesis of phosphocreatine.[311]	Loading phase: ~20 g/day (divided into four equal daily doses), for 5–7 days. Maintenance phase: 3–5 g/day (single dose) for the duration of the supplementation period. Lower dose approaches (2–5 g/day) for 28 days may avoid the associated increase in BM[307]; ~4–6 weeks are required following chronic creatine supplementation for levels to return to baseline. 20 g of creatine (5 g dose on four occasions beginning on the same day of fatiguing exercise) may promote muscle glycogen resynthesis in the first 24 hours postexercise.[312] *Note: concurrent consumption with a mixed protein/CHO source (~50 g of protein and CHO) may enhance muscle creatine uptake via insulin stimulation*.

Continued

Table 3 Continued

Type of supplement and examples	Use	Concerns	Main mechanisms	Protocol
β-alanine	Evidence is contradictory: may improve high-intensity exercise and repeated sprint performance.[259] May enhance training capacity.[305]	Possible skin rashes and/or transient paraesthesia (skin tingling). A positive correlation between the magnitude of muscle carnosine change and performance benefit remains to be established. Sprint training may be more effective to increase the buffering capacity of the muscle.[313]	Increases muscle carnosine, an important intracellular buffer.[314]	Daily consumption of ~65 mg/kg BM, ingested via a split-dose regimen (ie, 0.8–1.6 g every 3–4 hours) to give up to 6.4 g/day over an extended supplement time frame of 4–12 weeks. Protocol requires planning alongside training and match loads. Further investigation required into long-term supplementation (ie, >12 weeks).
Nitrate	Limited football-specific evidence. Improves economy and endurance exercise performance,[305] and football-specific intermittent exercise performance in amateur players.[315]	Individual response to supplementation. Possibility of minor gastrointestinal upset. Beetroot juice may discolour urine. Performance gains harder to obtain in highly trained athletes with well-developed aerobic capacity.[316]	Increases tissue nitrite and nitric oxide, which reduces the oxygen cost of exercise via enhanced function of type II muscle fibres and reduces the ATP cost of force production.	Protocol: acute performance benefits are most likely seen within 2–3 hours following a nitrate bolus of 5–9 mmol (310–560 mg). Prolonged periods of nitrate intake (>3 days) may also be beneficial to performance. High nitrate-containing foods include leafy green and root vegetables, including spinach, rocket salad, celery and beetroot, which may provide a food first solution for chronic use.

In a team sport such as football, where it may be decided by the sports nutritionist or doctor that supplements should be given to a whole team (either the same mix or a different combination per player), extreme caution must be taken by everyone involved. WADA rules state that if three or more players from the same team commit an anti-doping rule violation in the same competition period, the entire team may be disqualified from competition.[230]

How to minimise risk

The difficulty in quality assurance for dietary supplements is not so much a question of regulation but rather one of enforcing the regulations that are already in place. In almost every country, consumer protection legislation exists to ensure that products on sale are fit for purpose. In the case of supplements, these regulations relate primarily to safety rather than to efficacy. Third-party testing programmes are now in place that allow athletes who use supplements to make choices that will reduce the risk of a positive doping outcome as a result of using contaminated supplements. Examples include: 'Kölner Liste' for Germany, 'Informed Sport' for the UK, 'AFNOR NF V 94–001' for France and 'HASTA' for Australia. These programmes cannot eliminate the risk entirely, but the sensible player will limit the use of supplements and will choose supplements that have been screened for the presence of doping agents by a reputable and independent company. None of the current athlete-centred quality assurance programmes for dietary supplements tests for the presence of the active ingredients. They are focused entirely on the presence of WADA-prohibited substances. Athletes should be aware of this and should not see these schemes as a guarantee that a product is safe and effective to use. Rather, they should be part of a risk reduction strategy.[245]

Where so much is at stake, often for little tangible return, the risks associated with supplements should be considered carefully before use. An expert panel assembled by the Medical and Scientific Commission of the IOC has recently published a decision tree to guide athletes, and those who advise them, through decisions on supplement use.[245]

EXPERT GROUP TOPIC 7: NUTRITION FOR INJURY REHABILITATION

Nutritional considerations of the injured (elite) athlete have historically been neglected within research related to sports nutrition, which has primarily focused on performance and recovery/adaptation. Nevertheless, while there is much to learn in this space, a collection of laboratory-based studies and elite athlete case studies can be drawn on to devise some nutritional strategies that may be appropriate for the injured footballer.

The high physical demands of the elite game combined with increasingly dynamic movements mean that the risk of injury is also high. When an injury occurs, teams are faced with a unique challenge: to bring a player back as quickly but also as safely as possible. Nutrition may aid in optimising the rehabilitation process and facilitating the desired return.

Injury healing process

Most injuries rapidly trigger inflammatory processes that initiate wound healing and soft tissue and/or bone repair. Care should be taken to ensure sufficient energy and protein intake and avoid deficiencies in calcium, vitamins D and C, zinc, copper and manganese, all of which may impair the initial healing process.[246 247] Injuries sustained in football typically occur when performing intense muscular contractions; this is likely to exacerbate the level of systemic and local inflammation after injury (a physiological response assumed to contribute to the subsequent deconditioning of the muscle and/or tendon).[248] Although a range of 'nutraceuticals' (including phenolic compounds, curcuminoids and n-3 polyunsaturated fatty acids) have been proposed as potential strategies to combat the acute inflammatory process,[249] direct evidence of their anti-inflammatory effects in humans is lacking. Furthermore, inhibition of postinjury inflammation has not been shown to attenuate tissue deconditioning, and could be counterproductive to the healing process.[250 251] Thus, while several important questions remain, the available evidence does not support any nutritional strategies that might limit injury-induced inflammation.

Minimising effects of deconditioning

After the initial wound healing response comes rehabilitation, which is possibly of most nutritional relevance to the injured footballer by virtue of the time spent in this phase. Rehabilitation requires a period (anywhere from days to months) of whole body (eg, hospitalisation/bed-rest) or local (eg, limb immobilisation) disuse and/or reduced activity (eg, reduced/absent training load). During this time, rapid soft tissue and bone deconditioning can be expected as a result of mechanical unloading. Skeletal muscle appears to be the tissue most susceptible to disuse, with atrophy and deconditioning (eg, reduced force-generating and oxidative capacities) evident after only a few days.[252] Bone demineralisation has been reported as early as 1 week into disuse,[253] and although tendon tissue seems more resistant to disuse atrophy, by ~2 weeks tendon metabolic and functional properties begin to decline.[254 255]

Alterations in energy requirements during rehabilitation should be monitored, since shifting to a positive or negative energy balance will modulate aspects of deconditioning.[256 257] Moreover, a decline in dietary protein intake will accelerate muscle loss irrespective of energy balance.[258] The rapid development of muscle 'anabolic resistance' to protein intake[239 259] requires defined dietary protein recommendations during disuse. Current recommendations for attenuating muscle loss (and regaining muscle) during rehabilitation include: distributing[240 241] adequate amounts (20–30 g)[242 243] of leucine-rich (≥2.5 g per meal)[259] protein throughout the day, including pre-sleep.[239] The efficacy of such an approach is supported by (limited) laboratory data[245] and applied case studies,[90] with the resultant recommended daily protein intake being ≥1.6 g/kg BM.[106] Emerging data indicate potential roles for specific nutritional compounds in retaining/restoring muscle tissue during rehabilitation (eg, omega-3 fatty acids,[260] β-hydroxy-β-methylbutyrate,[261] ursolic acid[262]), although these require corroboration in relevant human studies[110] and therefore cannot be recommended at this time.

The bone collagen protein synthesis rate also increases in response to protein provision,[263] with an overall positive effect on bone turnover.[264] Although collagen present in tendon and muscle appears resistant to the anabolic effects of protein,[263] data indicate that protein supplementation augments tendon hypertrophy during training.[265] Furthermore, recent work has identified vitamin C enriched dietary gelatin (which can be included as part of daily protein provision) as a novel strategy to support tendon repair.[266] Collectively, therefore, available data suggest that nutritional considerations for the rehabilitation of bone and tendon are similar to those for muscle after injury (with respect to energy balance and macronutrient intake).

It must also be recognised that the different phases of injury provide a continuum of altered nutritional needs depending on stage and duration of injury. To date, establishing nutritional guidelines along this continuum, especially with such diverse injuries (in terms of duration, severity and type), are not available. A recent case study measured energy expenditure of ~3100 kcal/day during the first 6 weeks of ACL rehabilitation in an elite Premier League player,[159] close to that of outfield players in full training. Given the metabolic demand of tissue/wound recovery processes, staying as close to energy balance as possible and thus avoiding drastic reductions in energy intake, is perhaps the most crucial nutritional aspect during rehabilitation. Bearing in mind that the majority of absences from training or competition due to injuries will be ≤4 weeks,[267] it is prudent to follow the above guidelines while the player is away from normal training, and move back towards nutritional recommendations to support optimal training performance and adaptations (detailed in the section 'Expert group topic 2') as the player moves along the spectrum of return to play.

EXPERT GROUP TOPIC 8: REFEREES

Refereeing is an intermittent high-intensity activity, and elite football referees are reported to maintain about 80%–90% of their maximum heart rate and 70%–80% of their maximum oxygen uptake during competitive matches,[268] while expending up to 1200 kcal.[269 270] Blood lactate concentration may be elevated at crucial moments of the game when repeated sprinting with incomplete recovery occurs.[268 271] Unlike players, referees are not involved in body contact, but they must keep up with the game whatever the imposed tempo, limiting their possibility to compensate for demanding phases of the match.[271] The amount of high-intensity activity is similar to that reported in midfielders, but referees accumulate a lower overall sprint distance, although with longer bouts during the match.[268 271 272] The physical and physiological demands can impact cognitive performance in decision making.[271]

There is limited literature on the nutritional considerations of match officials. Historically, nutritional recommendations for elite referees were mainly adapted from those of professional football players, without considering the different characteristics (ie, age and body composition) or the particular match/training demands of the two populations.[273] A new publication on the most recent male and female FIFA referee selections (for both the 2014 FIFA men's and 2015 women's World Cups) offers more specific knowledge in this area.[274] Elite football referees have lower energy needs relative to top-class footballers on MD. During training, total energy and CHO intakes should be adapted according to the individual training load and increased only around MDs and during periods of intense training or when engaged in occupations with a high-energy demand. Specific nutrient recommendations are generally similar to those for players.

EXPERT GROUP TOPIC 9: JUNIOR PLAYERS

It is important to highlight some specific considerations and key recommendations for junior elite football players (ie, professional, under 18 years). Nutritional support is key to ensuring that junior players can cope with the demands of training and match play. An additional goal is to ensure life-long buy-in to good nutritional choices as this will help to optimise growth, health, performance, recovery, training adaptations and body composition. The nutritional approach to junior players has the particular challenge of dealing with young people whose bodies are changing as they mature biologically, a process which does not necessarily correlate with chronological age. Young players may have different nutritional needs from those of adults because they are in a phase of growth, and they are more reliant on fat oxidation during exercise.[275] The RDAs of some essential micronutrients (eg, calcium and phosphorus for both males and females, and iron for males) are higher for junior players than adults, although it should be recognised that good young players are often physically, if not always emotionally, mature. As with adult players, emphasising a 'food first' philosophy is essential when educating junior players.

Energy demands

Football does not overemphasise leanness, but some studies using self-reporting techniques have reported that male[276–279] and female[120 181 280 281] junior football players may not meet their extra dietary energy needs. A severe chronic energy deficit will impair growth and general health, as well as being detrimental to participation in football training. Conversely, participation in youth sports seems to promote the optimum physical activity level to stimulate growth and bone health when nutritional needs are achieved.[282] The magnitude energy availability of elite adolescent football players varies and energy deficit appears to be greater on MDs and heavy training days,[276] which may affect their performance.

Recent research has quantified changes in body composition and resting metabolic rate (RMR) in a cohort of male English Premier League academy soccer players from U12 to U23 age groups. An increase in both fat free mass (FFM) and RMR of ~400 kcal/day was recorded between ages 12 and 16, thus highlighting the requirement to adjust daily energy intake to support growth and maturation.[283] In addition, a subsequent study demonstrated that daily total energy expenditure (TEE) progressively increases as players transition through the academy pathway, likely a reflection of growth and maturation of key physical parameters as well as increased physical loading: U18 players presented with a TEE (3586±487 kcal/day) that was approximately 600 and 700 kcal/day higher than both the U15 (3029±262 kcal/day) and U12/13 players (2859±265 kcal/day), respectively.[284] Such differences in TEE is likely due to a combination of differences in anthropometric profile, RMR and physical loading between squads. An important finding is that TEE is comparable to or exceeds that previously reported in adult Premier League soccer players.

As already mentioned (in the section 'Expert group topic 3'), energy deficiency in sport (RED-S)[179] may affect female junior athletes, and the junior males, with deleterious effects on various nutrition-related functions, such as gastrointestinal, immunological and hormonal functions, as well as on bone development and the risk of developing eating disorders. Players should be evaluated on joining a football academy and monitored periodically thereafter using appropriate charts to examine changes in height-for-weight, weight-for-age, BMI-for-age and body composition.

Macronutrients, micronutrients and supplements

For specific information on different macronutrients and micronutrients, readers are directed to expert group topic 2 on training day nutrition for all ages.

Daily CHO recommendations by body weight for junior footballers are similar to those of senior players,[285] with CHO ingestion spread strategically over the day and in amounts relative to the intensity of training loads,[286] varying from very low to moderate (~3–6 g/kg BM), and high to upper level (~6–8 g/kg BM).[2] Elite junior football players have been reported to have lower CHO intakes than currently recommended.[287 288]

Studies on CHO loading in young players are lacking, but intake should be sufficient to optimise glycogen stores and deliver glucose as energy for repeated high-intensity sprints and performance. During long training sessions and matches, some CHO intake may be favourable. Active boys consuming CHO (60 g/L) beverages shifted their relative energy reliance to the exogenous intake in both temperate[289] and hot (38°C)[290] conditions. Sparing endogenous CHO reserves could help delay fatigue and improve performance.

Protein needs increase during adolescence and with intensive football training, so a daily intake of up to 1.6 g/kg BM for junior players would be appropriate.[285] Such extra protein intake is easily achievable from dietary sources, without the need for supplements. One study has recently shown that junior male footballers met or exceeded the dietary protein recommendations, although their distribution of protein intake over the day was not optimal.[288] The relative distribution of protein ingestion was, as in adults, skewed from dinner (highest) to lunch to breakfast (lowest). Recommendations should emphasise balanced distribution of protein in meals to optimise muscle development. Players, especially those undertaking restrictive or vegetarian diets,[285] should be individually evaluated to verify that they are achieving a sufficient protein intake.

Daily energy intake from fat should be 25%–35% of total energy intake and cholesterol intake should not exceed 300 mg.[291] A higher absolute intake for junior players should only be as a result of increased energy demands, and there is no evidence for a greater dietary need compared with their non-athletic peers. Due to concerns about becoming overweight, some junior players restrict dietary fats, which may cause micronutrient deficiencies including iron, calcium and vitamins A, D, E and K.[111] Milk provides a good amount of calcium (~300 mg/250 mL serving), which is critical for bone mineral growth and health. Adolescent athletes' daily calcium intake should be 1200–1500 mg (compared with 700 mg RDA for adults).[285] A 7-year prospective study[292] showed that inadequate vitamin D intake increased the risk of stress fractures among adolescent girls, especially those involved in daily high-impact activities. Overall, recommendations for adolescents vary from 400 to 600 IU/day. Assessment of bone health (densitometry) and vitamin D status may be useful, particularly in those with previous injuries or a slighter build, since collisions and intense efforts are frequent in football.

Iron requirements are also high during growth, especially in girls following menarche, and iron deficiency may impair high-intensity and endurance performance. To achieve the daily recommendations according to age (8 mg from 9 to 13 years and 11–15 mg from 14 to 18 years, for boys and girls), players should ingest iron-containing foods with vitamin C and limit their intake of absorption inhibitors (eg, tea and coffee). It is important to examine the iron status of junior football players regularly by measuring their serum ferritin and blood haemoglobin concentrations. Unless iron deficiency is confirmed, iron supplementation is not beneficial.

Mild (1%–2% BM loss) hypohydration has been shown to impair high-intensity cycling[293] and basketball[294] performance in active and athletic boys. A concern when playing in the heat is further hypohydration, which exacerbates hyperthermia and the risk of exertional heat illness.[295] Challenges to hydration status include tournament play-offs involving successive games, with insufficient time for recovery. Junior players have been reported to arrive for training sessions and competitions already hypohydrated, as indicated by urinary markers.[296–298]

Dietary supplements

Due to a lack of benefit/safety evidence, general use of dietary supplements should be restricted, and a sports nutritionist or team doctor should evaluate the specific needs[299] of the individual players, the team and local policies. Many adolescents consume supplements, often as a result of mass media and misinformation provided by suppliers.[299] Parents and coaches may also have erroneous beliefs and wrongly supply their children and/or athletes with supplements.[300]

In summary, well-planned nutritional strategies may help junior football players to achieve a successful athletic performance and to optimise their recovery, growth, maturation and body composition, avoid injuries and achieve a long athletic and healthy lifestyle.

CONCLUSION

Over the past decade, the game of football has changed, both physically and technically. At the same time, football-specific research in sports nutrition has expanded greatly. To reflect these changes, UEFA commissioned an expert group, including applied researchers and field-based practitioners, to provide an overview and narrative synthesis of the current evidence on a range of topics related to the optimisation of the health and performance of elite players and officials in order to guide practical recommendations and guide future research. We share a series of updates on scientific knowledge and where possible and appropriate provided a critical narrative synthesis.

Specifically we have covered (1) MD nutrition, (2) training day nutrition, (3) body composition, (4) stressful environments and travel, (5) cultural diversity and dietary considerations, (6) dietary supplements, (7) rehabilitation, (8) referees and (9) junior high-level players.

Our narrative synthesis and critical appraisal takes into account the diversity of the footballing community, including both male and female players, outfield players and goalkeepers and match officials. We have outlined how the type, quantity and timing of foods, fluids and supplements can influence the performance and recovery of players during and between matches, while also recognising the cultural significance of food and nutrition as part of this truly global sport.

With this expert statement, we hope that these scientific underpinnings can inform practitioners to drive a set of clear practical recommendations in their own setting. In addition, we will highlight the key areas for future research to be targeted in order to improve confidence in recommendations and shed light on emerging areas within football nutrition. The reader should note that this expert group statement represents level 5 (expert opinion) evidence.

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Contributors The main steering committee consisted of JC, RJM, MG, JB and AMcC. All authors contributed to the full manuscript. The authors were assigned a specific topic to write fully and then all authors reviewed and provided input for final version. Specifically AJ—match-day nutrition, JPM and LB—training day nutrition, MG—staying healthy, GLC—micronutrients, JB—body composition, LA, RD—stressful environments, JC and TM—cultural and dietary differences, RJM and JL—supplements, BW—rehabilitation nutrition, CC and MB—referees, FM—junior players, JS-B and EL-M—key differences between male and female players. Football nutrition practitioners/heads of performance GD, DM, BB, PR and AL reviewed all stages of the planning and written manuscript to ensure ecological validity to the practical setting. The UEFA Medical Committee members TM, MV, MD'H, HG, CC and NP were involved in planning stages as the governing body commissioning the experts. They were additionally involved in all stages of the manuscript to review and provide editing suggestions and comments. AMcC and JC were the main coordinators during the process.

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Competing interests JC has received payment for sports nutrition consultancy work with Arsenal Football Club, England Football Association and France Football Federation. Through his consultancy he also receives payment for nutrition services with individuals and corporate organisations. He is author of a book (The Energy Plan) for which he receives payment from Penguin Random House. He has written articles for BBC Good Food for which he has received payment. He co-authored an article in 2014 and presented at European College of Sports Sciences in 2019 for The Gatorade Sports Science Institute, for which he received honoraria. He has received travel and accommodation expenses to speak at conferences over the past 5 years including; UEFA Medical Symposium, Isokinetic Football Medicine Strategies, Swedish Sports Medicine Congress and International Sport & Exercise Nutrition Conference. He is a council member and past president of The Royal Society of Medicine's Food & Health Forum. He received from UEFA the cost of flight and accommodation to attend an Expert Group Meeting with the UEFA Medical Committee in Brussels, Belgium, to discuss preparation of this manuscript." He did not receive any other form of financial support directly related to this manuscript. RM holds an honorary (unpaid) professorship at the School of Medicine, St Andrews University, Scotland. He holds visiting (unpaid) professorships at Stirling University and at the Chinese University of Hong Kong. He is co-author of two books published by Oxford University Press (Biochemistry of Exercise and Training; The Biochemical Basis of Sports Performance) for which he receives royalties. He is Program Director on the IOC Diploma programs in Sports Medicine, Sports Nutrition and Sports Physical Therapies, for which he receives honoraria and additionally contributes lectures to those programs, for which he has received honoraria. He was a member of the Expert Scientific Committee of the IOC Medical and Scientific Commission. This position was unpaid, but travel to meetings and accommodation were provided. He contributed a scientific review to a meeting of the Gatorade Sports Science Institute

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