

Module 3. Energy balance and physique management in football

Unit 1: Energy balance in football

Introduction

In football, league competition does not require players to “peak” for an individual match. Instead, players are required to sustain a high level of performance over periods of weeks and months. Thus, an objective of the professional football player is to maintain a body mass throughout the competitive season that is “realistic” from both a health and performance perspective. The energy intake and macronutrient content of the diet should be adjusted depending on the demands of training or match day performance as well as the specific goals of the player. Therefore, there is no “one size fits all” approach; rather the dietary requirements are specific to the individual player and should be modified depending on the training and competitive schedule (Jeukendrup, 2014; Impey et al., 2016).

To achieve dietary adjustments, the sports nutritionist may modify the training and match environment to impact the behaviour of the player (Module 4) (Betts and Gonzalez, 2016). Nevertheless, educating the player on how to modify energy intake appropriately is the overall objective to achieve long-term success. That is, players taking ownership for their own nutrition choices. In this unit, we will cover how to apply the basic concepts of energy balance in football. The aim of Unit 2 is to understand best practice with regard to body composition assessment, as well as the benefits and limitations of common assessment techniques.

Energy for football

Energy can be defined as the ability to do work. It is common to use the term “calories” to express the energy content of food. More accurately, energy is measured in kilocalories (kcal) which are units of heat or kilojoules (KJ) which are units of work. The energy content of the main macronutrients recommended in a player’s diet are listed in table 1. Different



foods will contain more or less energy (kcal). Rarely are the foods or meals a player eats made up of a single macronutrient. To this end, it is important for nutritionists and players to understand the energy available from different dietary sources.

Table 1. Energy content of the main dietary macronutrients

| Macronutrient | Energy (Kcal) | Energy (KJ) |
|------------------|---------------|-------------|
| 1 g carbohydrate | 4 | 16 |
| 1 g fat | 9 | 37 |
| 1 g protein | 4 | 17 |

Source: own elaboration.

Packaged foods available from shops should display nutritional value information. The nutrition information will be listed on the food label and should contain the weight of the food, all ingredients (listed in quantity order), the breakdown of macronutrients, storage conditions and, finally, if the food contains any ingredient which may cause allergic reactions. The energy content of the food should be displayed and the quantity of macronutrients (carbohydrate, proteins and fat) listed on the label. Different countries will have varying legislation with regard to the information required on food packaging. Therefore, it is encouraged for those completing this course to become familiar and understand the food labels of their own country or the country they are working in.

Did you know?

A calorie is a unit of energy. A calorie is the amount of heat required to raise the temperature of 1 gram of water by 1 degree Celsius.

1 calorie = 4.2 Joules
1000 calories = 1 kcal = 4.2 KJ



The thermic effect of food is the increase in the player's metabolic rate that is caused by the ingestion, digestion, metabolism and storage of the food. It is also known as diet induced thermogenesis.

Principles of energy balance

Energy balance in football is a dynamic process

(Galgani and Ravussin, 2008). Energy is provided to the player via all foods and beverages (non-water) in their diet. This energy is used by the player in several fundamental processes including cellular maintenance, thermoregulation, growth, reproduction, immunity and locomotion (Loucks et al., 2011). When players train or compete, energy expenditure is increased significantly, which increases the need for additional energy to be ingested through the diet. Numerous factors operate in concert on each side of the energy balance equation, which will ultimately determine the body mass and composition (physique) of the player (Manore, 2015).

Basal metabolic rate (BMR), the thermic effect of food (TEF) and the thermic effect of activity (TEA), all contribute to the total energy expenditure (TEE) equation. Thus, total energy expenditure is not easy to accurately calculate.

$$\text{TEE} = \text{BMR} + \text{TEF} + \text{TEA}.$$

The terms basal metabolic rate (BMR) and resting metabolic rate (RMR) are often used interchangeably. For the purpose of this course, both may be defined as the amount of energy required by the players' body at rest to maintain basic life functions such as respiration, circulation, thermoregulation and brain activity.

Did you know?

The RMR of a player can be measured using indirect calorimetry (Fogelholm et al., 1995) or prediction equations. Common prediction equations to determine RMR include the Cunningham or Harris-Benedict equations (Cunningham, 1980; Harris and Benedict, 1918). Despite having been developed a century ago, the Harris and Benedict (1918) equation remains a common method to estimate RMR in clinical practices. This equation typically overestimates BMR by approximately ~5 %, and some studies report a variance of error between 10 % and 15 % (Frankenfield et al., 2003). Lean body mass (muscle) remains metabolically active when at rest. Thus, lean body mass (LBM), is a good predictor of RMR. Based on this observation a simplified equation to estimate RMR was proposed by Cunningham in 1980. Gender-specific equations will not be required when using this equation as, in general, women players will have lower lean body mass and a greater fat mass in comparison to their male counterparts.



Harris and Benedict BMR equation:

Men: $66.5 + (13.75 \times W) + (5 \times H) - (6.76 \times A)$

Women: $655.1 + (9.56 \times W) + (1.85 \times H) - (4.68 \times A)$

Where

W: weight, in kg.

H: height, in cm.

A: age, in years.

Cunningham (1980):

$BMR = 500 + 22 \times LBM$

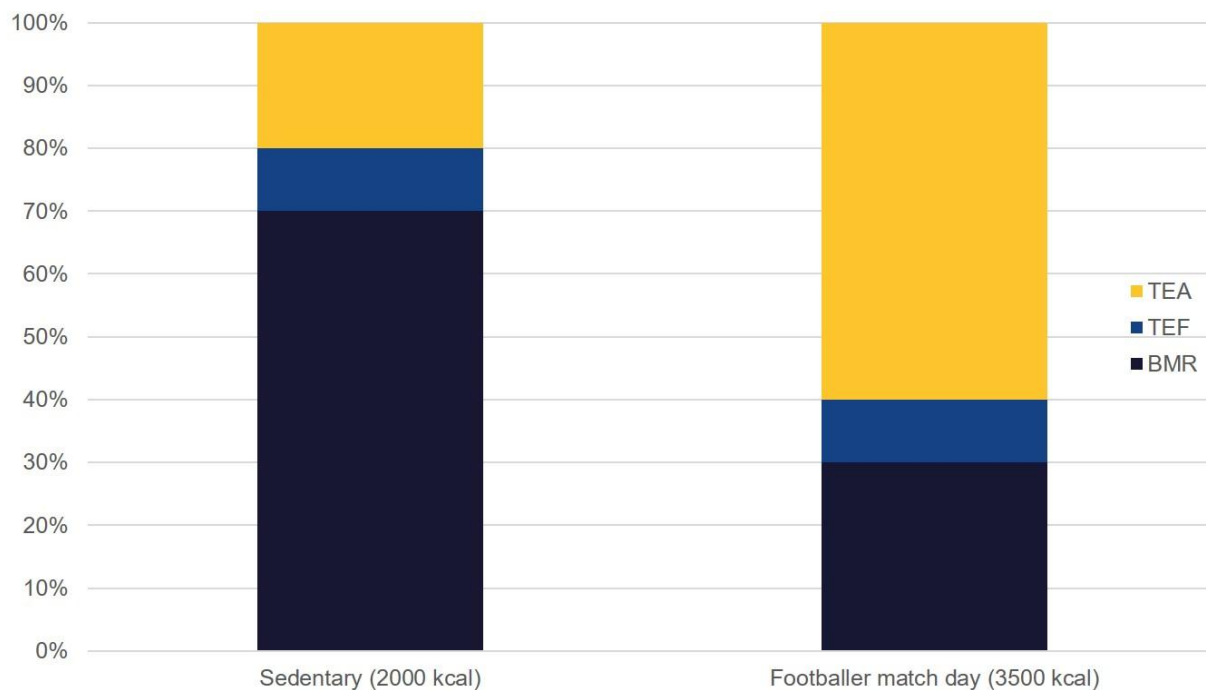
Where

LBM: lean body mass, in kg.

The resting energy expenditure of a sedentary adult represents between 60 % and 75 % of daily energy expenditure, but might be as low as 38-47 % of total energy expenditure for football players engaged in intense training or on match day, who normally have a thermic effect of activity of approximately 50 % of total energy expenditure (Manore and Thompson, 2006).

Figure 1. Total energy expenditure (TEE) in a sedentary person in comparison to a football player on match day





BMR: Basal metabolic rate.
 TEF: Thermic effect of food.
 TEA: Thermic effect of activity.

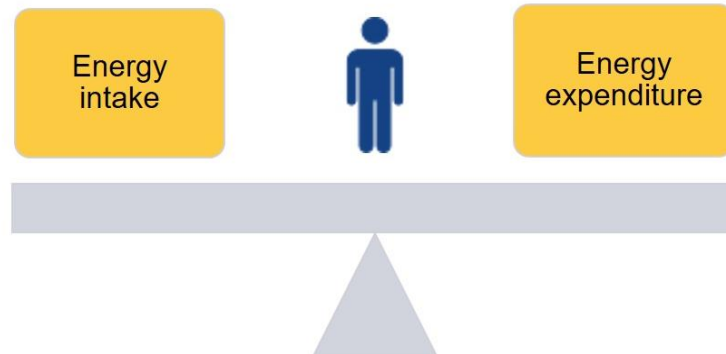
Source: own elaboration.

If the total energy expenditure of the player, including exercise-related expenditure and the energy required to support daily physiological function, exceeds that of energy intake, the player is said to be in negative energy balance. Alternatively, if energy intake exceeds total energy expenditure, the player will be in positive energy balance. The maintenance of body mass over time is an indication that the player is in a state of energy balance, where energy intake (total calories consumed) equals energy expenditure (total calories expended).

Figure 2. Energy balance



Energy balance



Source: own elaboration.

It is important to recognise that when training is modified to expend more or less energy, players should also modify their diet to increase or reduce energy availability in the management of body composition (Loucks et al., 2011). The main factors governing the energy expended during exercise are the intensity and duration of training/matches as well as the amount of muscle the player has. Other factors which also contribute to energy expenditure include exposure to cold or heat, stress, high altitude exposure, specific drugs or medications (e.g. caffeine), increases in lean mass or the luteal phase of menstrual cycle may increase energy expenditure (Manore and Thompson, 2000). Conversely, in the event of immobilisation, such as if a player is injured, energy expenditure can be substantially reduced, and therefore energy intake should also be adjusted accordingly (Football Nutrition Skills Course). To this end, the energy requirements will vary depending on the individual player and the phase of competition/training/recovery/rehabilitation in which they are involved. The diet (energy intake) and match/training programs (energy expenditure) need to be carefully managed to modify body composition, achieve performance goals, optimise recovery and avoid ill health.

For example, a chronically low energy intake has been considered one of the potential factors contributing to functional overreaching (Leutholtz and Kreider, 2001). Thus, daily or weekly monitoring of player body mass can provide a gross assessment of a player's energy balance over the season. So that meaningful differences in body mass can be assessed, the players' weight should be recorded at the same time of day and when players are euhydrated. Nonetheless, it is important to consider the full discussion and guidance on recording of body mass of players in Unit 2.

Did you know?

Euhydrated means a “normal” state of body water content.

Energy expenditure in football

The composition of the players' body and their metabolism will influence energy expenditure. For example, players with more muscle expend more energy, even when at rest. It is important to note that away from football, most professional players generally lead a sedentary lifestyle. For example, a study of Premier League football players reported that 79 % of post-training time is spent engaged in sedentary behaviour (Weiler et al., 2015). Thus, the major occasions of energy expenditure are training and matches.

There are various methods that can be used to assess energy expenditure in football. From a clinical research perspective, studies have used measurements of body temperature (Saltin and Hermansen 1966; Edwards and Clark 2006), continuous heart rate monitoring (Esposito et al., 2004; Eniseler, 2005) and lightweight portable oxygen analysers (Kawakami et al., 1992). These methods consistently report the mean metabolic load of a football match to be approximately 70 % of a player's maximal oxygen uptake. The practicality of using these systems routinely during matches or day-to-day training sessions is not realistic. Furthermore, many of these methods do not provide information on the high intensity exercise component of football, which significantly increases the energy expenditure (Bangsbo, 1994; Bangsbo, 2014).

To estimate the energy cost of high intensity exercise (sprinting) during football, studies have investigated the correlations between the energy cost of running on flat terrain versus uphill running at constant speed (di Prampero et al., 2005; di Prampero et al., 2015). The estimation of the energetic cost of accelerations and decelerations has shown the high intensity efforts account for approximately 42 % of the total energy expenditure during a game (Osgnach et al., 2010).

In order to adequately balance the players' energy intake with their energy expenditure, valid measurements that allow for the quantification of physical activity and energy expenditure are needed. The importance of adequately meeting the players' energy requirements is based on the fact that adequate energy intake is essential for maintaining lean body mass, as well as immune, skeletal health and reproductive functions, i.e. the overall health of the player. Secondary to health, energy intake can be adjusted to optimise the body composition of the player for the ultimate purpose of improving footballing performance (Thomas et al., 2016).

Matches



Methods of match analysis are covered in detail in Module 1. Detailed analysis of matches has led to the accurate assessment of individual physical performance (Reilly, 1983; Carling et al., 2008; Carling, 2010; Castellano et al., 2014; Carling et al., 2016). To recap, the data allows an estimation of energy expenditure of players using distances covered, relative speeds and technical performance. Video analysis also provides valuable insight into the number of ball interactions, passing (number, precision, distance and pitch location), the percentage possession of the ball and areas of the pitch where the greatest activity has occurred (Carling et al., 2012; Schuth et al., 2016) (Module 1).

Data provided by global positioning satellite (GPS) gives a valuable resource for clubs to monitor match and training activities. This approach allows the nutritionist to identify the how energy requirements differ for an individual player on different days and well as between players. The GPS units are light-weight, safe, easily worn and are unobstructive to the player's natural movements. Data gathered from GPS systems can be processed "live" or downloaded rapidly following exercise. At present, the current GPS systems and video analysis are unable to account for the energy expenditure associated with activities such as tackling, heading, kicking, dribbling or backwards running (Bangsbo, 1994; Bangsbo, 2014). As such, it is likely that GPS methods significantly underestimate total energy expenditure during football specific play (Murakami et al., 2016).

On the appropriate occasions, a player will control and dribble the ball (typically for no more than 4 seconds). Dribbling a ball has been reported to increase the energy cost (+5.2 kJ /min) of exercise (Reilly, 1997). The increased energy cost is likely to be a consequence of the player breaking from their optimal stride pattern and the additional muscle recruited to control the ball and move it forward.

The average energy expenditure during matches has been estimated to range between 1000-1500 Kilocalories (Kcal) (Ekblom, 1986; Bangsbo, 1994; Stolen et al., 2005; Bangsbo et al., 2006). It is important to note that greater energy expenditures (i.e. distance covered and high intensity running) do not necessarily translate to superior "performance" (Bradley et al., 2013; Di Mascio and Bradley, 2013, Fernandez-Navarro et al., 2016). For example, analysis of La Liga professional teams revealed that the top-class players performed less high-intensity activity (>19.1 km/h) during a game which they were winning in comparison to when they were losing (Lago et al., 2010). Therefore, it is important to appreciate that the factors which influence the energy expended during matches are highly complex and are affected by, amongst many others, physical and mental fatigue, the phase of play and team tactics (Paul et al., 2015) (Module 1).

To date, few studies have reported the daily energy expenditure of professional players using the gold standard of doubly labelled water which would capture energy expenditure non-invasively under "free living" conditions (Westerterp et al., 1986). Those



studies, which have used doubly labelled water, have measured both energy expenditure and energy intake during a two-game week playing schedule where consecutive games were separated by two days. Interestingly, the mean values of daily energy expenditure (3566 ± 585 kcal) and energy intake (3186 ± 367 kcal) of six premier league footballers are remarkably similar to those reported previously in seven professional Japanese players (3532 ± 432 and 3113 ± 581 kcal, respectively) (Ebine et al., 2002, Anderson et al., 2017).

The energy expenditure of goalkeepers has been reported to be approximately 600 kcal/day less than outfield players (Anderson et al., 2024). This is interesting, as buffet food options in football are typically designed to cater for outfield players. Therefore, specific nutrition guidance is required for goalkeepers and modified depending on the required daily and weekly loading patterns. Furthermore, additional attention should be given to the non-starting goalkeeper on match day.

Table 2. Individual differences, average daily energy intake and average daily energy expenditure of professional football players during a 7-day period of the competitive season

| Player | Energy intake (kcal) | Energy expenditure (kcal) | Body Mass Day 0 (kg) | Body Mass Day 8 (kg) |
|---------------|----------------------|---------------------------|----------------------|----------------------|
| 1 (CF) | 2817 | 3047 | 90.1 | 89.2 |
| 2 (WD) | 2905 | 3050 | 73.2 | 73.7 |
| 3(WM) | 3563 | 4140 | 71.0 | 71.1 |
| 4(CDM) | 3166 | 3179 | 80.1 | 79.1 |
| 5(CAM) | 3701 | 3580 | 78.9 | 78.1 |
| 6(CB) | 2961 | 4400 | 89.0 | 88.9 |
| Mean \pm SD | 3186 ± 367 | 3566 ± 585 | 80.4 ± 7.9 | 80.0 ± 7.6 |

Note. Each player's position is shown in brackets. CF = center forward, WD=wide defender, WM= wide midfielder, CDM=central defending midfielder, CAM= central attacking midfielder and CD= central defender

Source: Anderson et al., 2017, <https://lc.cx/LpsQZT>

Players at all levels of the game can experience fatigue as the duration of the match nears 90 minutes (Module 2). To remind you, fatigue can often be seen through a decrease in maximal sprint speed or a reduction in distance covered (5 %–10 %) in the second half



(Bangsbo et al., 2006; Krstrup et al., 2006, Osgnach et al., 2010; Bendiksen et al., 2012). This observation highlights the importance of modifying energy intake, specifically with regard to carbohydrate ingestion on match day, to sustain performance for the duration of the match, as well as promoting glycogen resynthesis post exercise (Module 4).

Training

During a competitive season, professional players may complete up to 120 team training sessions (Gaudino et al., 2015). This equates to approximately 3 training sessions a week during a 38-week season. Therefore, the time spent engaged in training exceeds that of competition. The energy expended during training will vary depending on the intensity and duration of exercise as well as the body composition of the player. Training will also vary depending on the phase of the season and managerial regime.

It is common practice for professional clubs to monitor the external training load by GPS systems as well as heart rate and other measures such as player rating of perceived exertion (RPE) scores (Scott, Lockie et al., 2013, Rampinini et al., 2015). Total distances covered at high speed running (>14.4 km/h), number of impacts and accelerations (>3 m/s²) are representative of higher training loads which can be reflected in the players subjective response to training i.e. via the 1-10 point RPE scale (Gaudino et al., 2015).

The training intensity and duration are likely to fluctuate in relation to the proximity to match day. Therefore, it is important for the player to recognise the increase or decrease in energy requirements (Impey et al., 2016). Paradoxically, football specific activity, i.e. high intensity exercise, may blunt appetite-regulating hormones, which may consequently result in reduced energy intake and disrupt recovery strategies (Stensel, 2010; Bailey et al., 2015; Briggs et al., 2015). In these circumstances, practical approaches include:

delaying the intake of food post exercise to allow time for blood to redistribute to the gut from the exercising muscle; add calories via beverages in the players diet i.e. provide fruit juice or sports beverage rather than water; provide “smaller” meals routinely, rather than a few “big” meals.

Energy intake

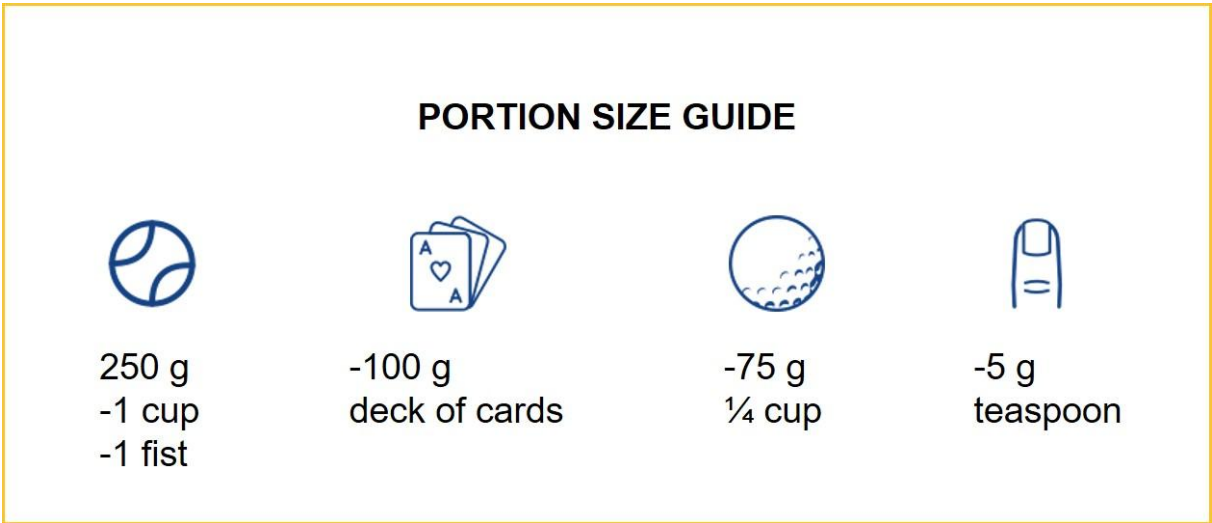
All foods and several beverages in a player’s diet are characterised by their composition of macro and micronutrients. Macronutrients are carbohydrates, proteins and fats, whilst micronutrients include vitamins and minerals. The energy content of carbohydrate and



protein is approximately 4 kcal/g, whereas the energy value of fat is 9 kcal/g (table 1). The role and appropriate intake of carbohydrate, protein and fat in the players diet are discussed in Macronutrients and Fluid for Football Course. Diets abundant in high fat foods are discouraged as they can replace those foods which contain the other macronutrients essential for football performance, recovery and adaptation. It is important to note that although not classified as a nutrient, water is the other essential component to a player’s dietary intake. Accordingly, fluid deficits >2 % body weight can produce deleterious effects on sports performance, especially in hot weather (Shirreffs and Sawka, 2011) (Module 4).

The energy intake will be a function of the portion size, energy density and the frequency which foods and beverages are ingested. Players and staff at a club will most likely have unrealistic perceptions of what recommended “portions” of food look like. Figure 3 below provides a suggested guide as to how to translate portion sizes to players, staff or club chefs. Following review of the players diet (Unit 2), one strategy is to demonstrate how the suggested on-packet portion size differs from the players actual intake.

Figure 3. Portion size



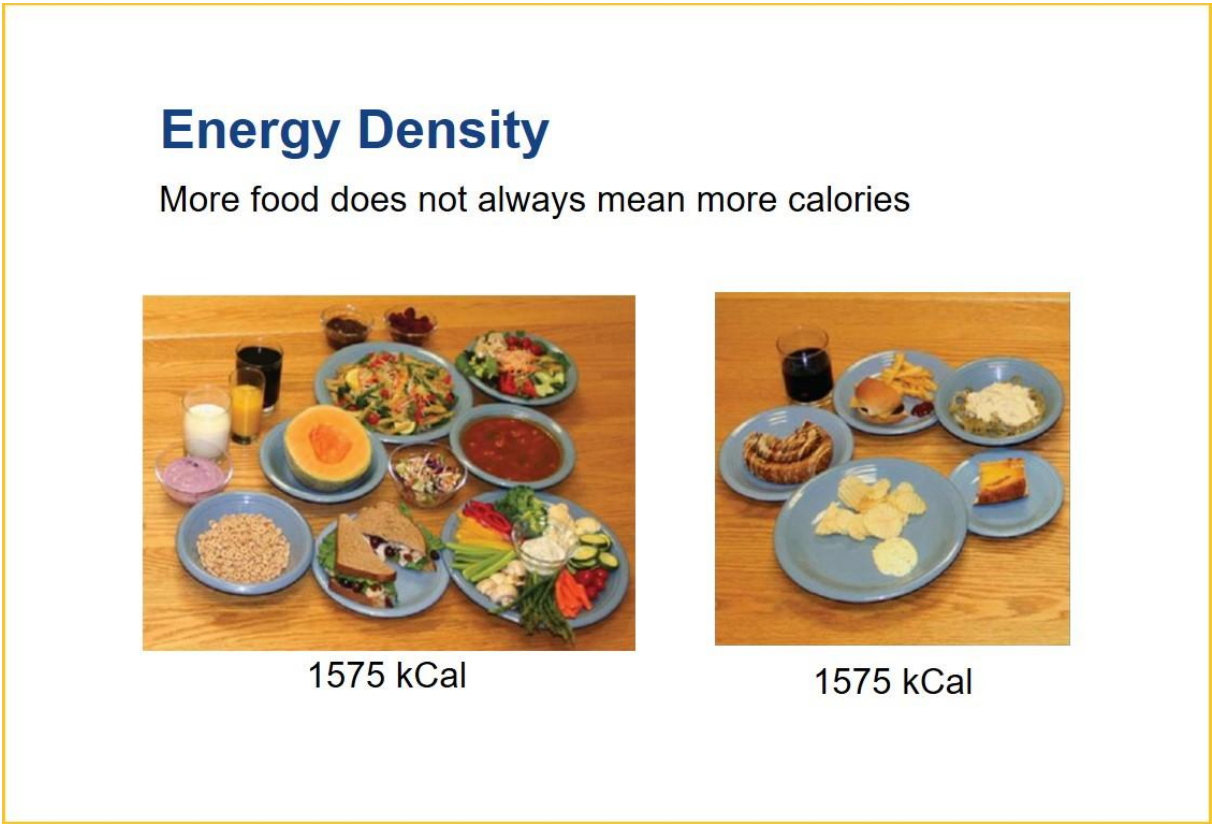
Source: own elaboration.

The energy density of food will depend on its composition of carbohydrate, protein and fat (table 1). Specifically, the amount of energy (kcal) for a given quantity (g) of food. Thus, the key concept here is that more food does not necessarily mean more calories ingested. As an example, a low-energy dense diet for a player would be high in fruits and vegetables, whole grains, and incorporates low-fat dairy, legumes/beans, and lean meats and fish. Therefore, just because a player's plate is full, does not mean they are consuming more



calories. Please also note the quantity/volume of foods for the equivalent calories (figure 3). Including more low energy dense foods can be a good strategy to help physique management (Unit 2). Low energy dense foods also tend to be higher in micronutrients, serving to enrich the players diet (Nutrition Considerations in Football Course). Finally, the frequency of food intake is also important. The importance of timing of food ingestion will be covered in future modules. Nonetheless, from an energy perspective, high fibre and protein based foods typically improve feelings of “fullness” after ingestion. Players are therefore less likely to ingest “energy dense snacks” between meals.

Figure 4: Quantity vs. calories



Source: own elaboration.



Table 3. Energy density of different foods

| Very Low (<0.6 kcal/g) | Low (0.6-1.5kcal /g) | Medium (1.6-3.9 kcal/g) | High (>4.0 kcal/g) |
|---|--|---|---|
| Consume these foods frequently (E.g free foods) | Select often, but eat reasonable portion sizes | Monitor frequency and portion size; energy content per g of food is higher | Use infrequently or small portions energy content is high per g of food |
| Most whole fruits: apples, berries, citrus fruit, melons, peaches, pears, nectarines | Others fruits: Bananas, grapes | Fruits: Avocado Dried fruits: aA pricots, raisins, apples, figs | Nuts: All nuts an nut butters |
| Most whole fruits: Broccoli, celery, carrots, cauliflower, greens, spinach, tomatoes, zucchini | Starchy vegetables: Corn, peas, winter squash, baked potato w/ skin, tofu | Vegetables/ added fat: French fries, hummus | |
| Non-fat dairy | Low fat dairy foods | Reduced fat feta, mozzarella, swiss cheese | Full-fat cheeses, mayonnaise, sour cream, dressings butter and oils |
| Broth based dairy foods | Cereals: Cooked wet grains (e.g., oatmeal, Brown rice, bran flakes, shredded wheat) Soups: Chowders prepared with milk, Split pea | Cereals: Whole wheat (WW)/ White breads, com tortillas Baked or low-fat snack foods: pretzels, tortilla, chips Desserts: Ice cream, frozen yogourt | Snack foods: Regular potato/tortilla chips wheat or graham crackers, Candy, chocolate, most sport and granola bars Desserts: Brownies, cakes, cookies, muffins, pastries, other foods with added sugar and/ or fat |
| | Shrimp (steamed), tuna, tilapia, lean ham and turkey | Eggs, red meat, salmon, chicken breast, no skin | Bacon pork spareribs |

Source: Manore, 2018. p.12.

Did you know?

Concurrent exercise is a combination of resistance and endurance training.

It is important to note that the misuse of alcohol can be detrimental for achieving nutritional goals because of its potential impact on the player's dietary choices leading to excesses of energy intake. This is particularly relevant in the post exercise occasion when muscle recovery and glycogen resynthesis should be prioritised (Maughan, 2006). Alcohol-containing beverages have a high energy content (7 kcal/g). However, the actions of alcohol on the central nervous system are likely to result in impaired skill and poor decision making that may negatively influence performance. The ingestion of excess alcohol is also likely to affect the player hours after ingestion (hangover). Importantly, studies have reported that alcohol consumption reduces rates of muscle protein synthesis following a bout of concurrent exercise, even when co-ingested with protein. Thus, alcohol ingestion will suppress the anabolic response in skeletal muscle. The blunted adaptive response may impair recovery from football training and subsequent match performance (Parr et al., 2014). Players are ultimately responsible for all the foods and drinks they ingest in their diet. Given the historical association between alcohol and



football (socialising post match), nutritionists should encourage players to drink alcohol responsibly and avoid excess consumption during the competitive season.

Players are encouraged to work together with the club's professional sports nutritionist or dietician for meal planning based on energy requirements and individual goals, translating nutrient guidelines into food equivalents. Part of the players' nutritional education is to understand those foods that contain more or less of the macronutrients, as well as those foods, which are rich in vitamins and minerals. Thus, the player should understand how to piece together meals on a daily basis that provide the appropriate quantity of macro and micronutrients for health, body composition and performance. The challenge for the nutritionist will be to understand the food preferences of the player, so that nutritional recommendations are realistic. Information of players' "routine" foods can be obtained via interview, questionnaires or food diaries.

Did you know?

A food preference is a greater liking for one food over an alternative. Quite simply, players will not eat or drink something if they do not like it.

Dietary analysis

Energy intake remains one of the most difficult measures to record accurately in sports nutrition (and in public health). This is because the measures of energy intake are usually reliant on self-reporting or recall of those players completing them. This process frequently results in an under-reporting of dietary energy intake (Poslusna et al., 2009). Developing expertise in the assessment of energy intake requires an appreciation that there are different reasons for undertaking an assessment, different approaches to completing it and different tools that can be used (Burke, 2015). A player's energy intake from food, fluids and even supplements can be recorded by food weighing methods (taken every 3-7 days), multi-pass 24-h recalls, although such methods have intrinsic limitations, bias being the most prominent one (Thomas, 2016). In order to avoid bias, extensive education regarding the purpose and protocols of recording methods is recommended. The gold standard of energy intake assessment would require the players to weigh and record all the food and beverages in their diet. This information is then entered into dietary assessment computer programmes for energy intake and breakdown of macro/micronutrient content. Nevertheless, even accurate assessments only provide brief insights into the players' energy intake over the duration of the assessment. Food frequency questionnaires are used to assess the frequency, i.e. how often certain types of foods are ingested. This method does not provide information on total energy intake *per*



se but can help identify common foods in a player's diet and those foods making the greatest contribution to total energy intake.

Table 4. Traditionally used methods for collecting dietary intake information

| | Overview of methods | Period of interest | Pros | Cons |
|------------------------------------|--|--|---|--|
| Retrospective | | | | |
| 24 h recall | Subject describes foods consumed over the last 24 h or a "typical day". | 24 h | <ul style="list-style-type: none"> - Speedy to implement - Low burden for the subject - Interview can be structured around daily activities - Does not alter intake - Suited to epidemiological research | <ul style="list-style-type: none"> - Relies on subject's honesty, memory and food knowledge - Requires trained interviewer - Day for recall may be "atypical" - Suitable for group surveys, but not representative of individual's normal intake |
| Food frequency Questionnaire (FFQ) | Subjects asked how often they eat foods from a standardized list and to estimate portion sizes often using photos or food models as a prompt | From 24 h period to open-ended | <ul style="list-style-type: none"> - Can be self-administered to lower burden on the investigator - Can be used to cross-check data obtained from other methods - Validated for ranking individuals - Can be modified to target certain nutrients - Can be automated to allow quick processing by investigator | <ul style="list-style-type: none"> - Relies on responder's honesty, memory, literacy and food knowledge - Validity dependent on the food list and the quantification method |
| Diet history | Open-ended interview concerning food use, food preparation, portion sizes, food like/dislikes and a food checklist | Open-ended or over a specified period | <ul style="list-style-type: none"> - Accounts for daily variation in food intake by investigating a "typical" day - Can target contrasts between periods of interest as a sub-theme - Collects information on timing on timing of intake and factors that influence food patterns | <ul style="list-style-type: none"> - Relies on responder's honesty, memory, food knowledge - Labour intensive & time consuming - Requires trained interviewer - Mostly appropriate for qualitative assessment rather than quantitative |
| Prospective | | | | |
| Written food diary (diet record) | Weighed | May be undertaken for 1-7 d, with increasing ability to track usual intake as duration increases, but reduced compliance | <ul style="list-style-type: none"> - Provides a more accurate quantification of foods than household measures - Considered the "gold standard for dietary assessment". | <ul style="list-style-type: none"> - Relies on participant's honesty and food knowledge - Time consuming for subjects to keep and investigator to process - Distorts food choice and quantity: subject alters their diet to improve their intake or to reduce the workload of recording |
| | Household measures (descriptions of cups, teaspoons, dimensions of food portions, etc) | | <ul style="list-style-type: none"> - Improved compliance with subjects compared with weighed record - Less alteration of normal eating pattern compared to weighed or semi-weighed records | <ul style="list-style-type: none"> - See comments for weighed record - Requires checking by trained person - Needs standardized set of household measures - Subjective/inaccurate assessment of portion sizes |

Source: Burke, 2015, <https://lc.cx/fBFyuV>

Technological advances, through web based or mobile tablet applications, have provided novel ways to collect and process energy intake information. Many of these systems provide electronic versions of paper and pen questionnaires, such as 24 h recall (Rangan et al., 2016). Key advantages of the technology are that applications can provide a huge database of food pictures, be updated in real time and provide rapid feedback. The nutritionist should be encouraged to embrace new methods of dietary analysis, but critically evaluate their application to football (table 2, 3) (Stumbo, 2013, Burke, 2015).



Table 5. New technologies and techniques for dietary assessments

| Examples of new protocols | Potential benefits associated with new tools and techniques |
|---|---|
| <ul style="list-style-type: none"> • Web-based food frequency questionnaires and 24 h recall systems using images to guide food portion selections PDA (Personal Digital Assistant) platforms for recording food diaries electronically from food database • Smart card technology to record meals chosen by inmates of a closed environment (e.g. hospital, school, prison) • Smartphone and Tablet apps for directly recording intake of foods from personalised food database, processing nutrient composition and transmitting data to sports nutrition professionals • Digital photography on mobile smartphones that time stamps and confirms food intake • Includes technology that can identify and quantify food intake from these images | <ul style="list-style-type: none"> • Enhancement of compliance with recording food intake in real time since the electronic device (e.g. mobile phone) may already be an habitual accessory in the athlete's lifestyle • Alternative techniques to gain information on food/fluid descriptions (e.g., automated calculations from digital photos) or food that may be less reliant on the subject's motivation or food literacy. • Less bias in altering typical food patterns since the act of the recording (e.g. scanning, photographing) may be less intrusive, thus reducing the self-reporting • In the case of digital-savvy populations, which includes most athletes, familiarity and ease of use. • Ability to automatically interface information on food and fluid intake into databases for food composition analyses, assessment and feedback: minimises handling errors and time burden on the researcher/sport dietitian • Ability to transfer information electronically and in realtime, enabling rapid and remote interaction with the sports nutrition professional or other feedback sources • Electronic integration with other data such as training log, energy expenditure calculations, health and physique parameters |

Source: Burke, 2015, <https://lc.cx/fBFyuV>

Did you know?

Food monotony is common in football players. i.e. players ingest the same types of food all year. The completion of food diaries can identify food monotony. Encourage players to eat sufficient quantities of different types foods to support intake of the various macro and micronutrients.

Energy availability

The ingestion of an appropriate amount of energy (energy intake) is the most basic and essential nutritional requirement for all football players. The energy used for vital physiological functions (e.g. maintaining cellular function, thermoregulation, growth, reproduction, immunity, movement, etc.) is not available for other functions, such as energy expended when exercising. Thus, energy availability (EA) is the amount of residual



energy available for the rest of the biological processes after deducting training energy expenditure.

Determining energy availability offers some advantages over the concept of energy balance when it comes to managing training and for nutritional programs attempting to optimise the players' health and performance. One of these advantages is that calculating energy availability involves estimating training energy expenditure instead of a total energy expenditure, which has a larger degree of uncertainty and error. Energy availability thresholds have been established (table 6). As a general rule, for healthy adolescents and adult players, diets should provide approximately 45 kcal/kg of fat free mass (FFM) per day. Diets providing ≤ 30 kcal/kg of FFM have been proposed as a threshold after which reproductive and bone growth formation would be altered (since this value corresponds very closely with resting metabolic rate) (Loucks et al., 2011). Insufficient energy availability may also have a negative effect on the immune and reproductive function, especially in female players (Loucks et al., 2001).

Steps to determine the energy availability in football players:

- 1- Determine the players fat free mass (FFM, Unit 2).
- 2- Determine exercise energy expenditure (EEE).
- 3- Choose an energy availability value appropriate for the player, aligned to the player's current training objectives (table 6).
- 4- Calculate the required daily energy intake
 $EI \text{ kcal/day} = EA + EEE.$
- 5- Build a diet plan that meets that EI, around player's preferences.
- 6- Support the player in completing the diet plan, independent of the player's hunger/appetite.

Table 6. A guide to determine the appropriate energy availability according to the players desired objective



| Energy availability | Player objective |
|----------------------|---|
| >45 kcal/kg FFM/day | Gaining body mass, muscle hypertrophy, glycogen overload. |
| ~45 kcal/kg FFM/day | Maintaining body mass, emphasis on motor ability development. |
| < 45 kcal/kg FFM/day | Losing mass or body fat |

Source: own elaboration based on Loucks, 2013.

Summary

- Energy is measured in kilocalories (kcal) which are units of heat or kilojoules (KJ), which are units of work.
- Energy balance of a player is a product of their energy expenditure and energy intake.
- Energy is provided to the player via all foods and beverages in their diet (energy intake). The portion size, frequency and energy density of foods in a player's diet can be modified depending on the daily demands of training or matches (energy expenditure).
- Energy intake is difficult to measure, but can be estimated via various dietary analysis methods.
- An objective of the sports nutritionist is to modify the energy of the player's diet to meet the demands of exercise and individual goals.

3.2 Physique management in football

Introduction

To achieve sustained performance in football, there is a requirement for ongoing player development. Developing fast, technically proficient, strong and resilient professional players requires appropriate nutrition behaviours to be practised frequently. When striving to support players, the sports nutritionist must acknowledge that discussions



about performance, physique, nutrition and lifestyle are necessary. The sports nutritionist should interact with the sports medical department to optimise the environment to enable player physique management that supports a resilient body image, through non-judgemental communication that is health and performance oriented.

The physique of a player refers to its structure. In the simplest terms, the player's body can be divided into fat free mass and fat mass. Fat free mass includes all those tissues that are not attributed to fat, including muscle, bone, internal organs and water. Fat mass is everything that remains. The assessment of body composition using fat and fat free mass is referred to as a 2 compartmental model. A more detailed assessment of body composition uses a 4 compartmental model. In this model, the player's body is divided into body water (intracellular and extracellular), proteins (muscle), minerals (bone and blood) and fat. The details of common methods to assess body composition will be discussed later in this unit.

It is important to note that body fat is required for the healthy functioning of the player's body. Body fat has several vital roles such as storage and source of energy, structural material of cells (such as the cell membranes), and the transport of fat soluble vitamins A, D, E, and K into the body. No player will have a body which has 0 % body fat. Reports of body fat percentages of ≤ 5 % have either been assessed incorrectly or are discouraged, with respect to the long-term health of the player.

Did you know?

The water in a player's body is divided into two components, intracellular and extracellular fluid. The intracellular fluid (fluid in the body cells) makes up approximately two-thirds of total body water.

Considerations before measuring player body composition

A players' training environment and the language used by the sports medicine team and staff to discuss physique can overtly and inadvertently influence players' behaviours. Without a thoughtful, purposeful approach to developing a physique optimised for health and performance, unhelpful behaviours may manifest. These include, but not limited to, excessive training, restricting food intake and body dysmorphia, which can ultimately compromise health.

The assessment and monitoring of a player's fat and muscle are common practice in



football environments, and is often the responsibility of the sports nutritionist. Consistent messaging throughout the academy, development and professional squads is an important process to educate players how to eat for health, performance and body composition management.

Before embarking on a body composition assessment, the question should be “is it justified”. For example, specific physique measures may be appropriate for assessing maturation status in academy, but should not be used in isolation for talent identification. Importantly, any physique measurements should be planned and undertaken with the consent of the player. Players should be able to opt-in without the risk of consequences. The main consideration is to ensure physique assessments are aligned with key performance indicators, such as strength and power assessments or incidence of illness/injury, in partnership with the sports medical team at the club.

Physique: player’s body composition

The association between body composition and health is well established. At the extremes, and for those that are sedentary, excess body fat (obesity) is a significant risk factor for both metabolic (Way et al., 2016) and cardiac disease (Koene et al., 2016). Conversely, individuals with an intense fear of gaining weight and distorted cognitions regarding weight, shape, and drive for thinness may suffer from eating disorders and extremely low body fat (Gorwood et al., 2016). In football, “optimal” values of body fat and muscle tissue required for health and football specific performance are less clear. This is because of the difficulty in measuring performance per se and the variability in player somatotype, which, depending on the tactics of the team, may differ by playing position. Thus, there is no one “optimal” body composition for a football player.

Elite male professional players have been reported to be characterised by a lower body fat percentage, in comparison to junior counterparts. Interestingly, this difference was not a result of lower absolute body fat, but higher values in muscle mass (Milsom et al., 2015). Indeed, compared to body composition, lean mass and leg strength have been reported to have greater associations with sprint and jump performance in sub-elite male footballers (Nikolaidis et al., 2016). Having too low or too high body fat is an important consideration in football as both have been reported to increase the risk of injury (Richmond et al., 2013; Kemper et al., 2015). It is intuitive that a player’s physical performance would be hindered by an excess of body fat. Equally, sustaining very low values of body fat during periods of intensified training or competition may compromise player “robustness” and ultimately performance (Nieman, 2000; Moreira et al., 2014).

On the other hand, optimal values of muscle mass are also important for football players; for instance, excessive body weight gain as a result of muscle hypertrophy is not desirable



since the player will have to transport a higher body mass. Moreover, higher levels of muscle hypertrophy does not always lead to a better strength and velocity profile, but often promotes a physique which may not be optimal for football performance (Tesch and Larsson, 1982).

Did you know?

Hypertrophy is the enlargement of part of the body due to the increased size of the constituent cells. Skeletal muscle is responsive to training stimulus, which results in its growth.

Body composition in footballers

The body composition of the footballer will affect their physical performance. There is not a single 'optimal' body composition for a group of players. Research studies have reported that the typical body fat percentage of elite male football players **ranges** between 7 and 19 % (Wittich et al., 2001; Reilly et al., 2009) (table 6). Less data is available on elite female football players (Mala et al., 2015). Based on available research and our own data (FCB, unpublished observations), female body fat percentage ranges from 16-24 % (Sedano et al., 2009). It is discouraged to establish rigid prescriptions for individual players. Instead, it is advised to propose a range of acceptable values for body fat and body mass for players within a team.

Historically, it is typical for football players to accumulate body fat in the off-season. Indeed, seasonal trends reflect an increase in body fat levels during the off-season, which are then reduced during the preseason, where training volume is highest (Carling and Orhant, 2010). It can also be common for lean muscle mass to be reduced during heavy training volumes in some players if adequate energy is not ingested. Simple routine (daily, weekly or monthly) monitoring of body mass provides a quick and non-invasive method to monitor the player's energy balance. Beyond physical appearance, significant deviation from normal body mass provides the first indication of changes in fat or lean tissue composition. This early indicator may then provide stimulus for further body composition analysis and consultation if required. It is also important to note that although body mass index (BMI) has been used as an indicator of body composition in the general population, this method is not recommended for an elite football population. This is because higher levels of muscle mass normally achieved by players as a part of physical training would overestimate levels of fat mass predicted by this index.



Table 7. Reported values for percent body fat for elite soccer players estimated by means of generalised skinfold equations. Means \pm SD are cited

| Source | N | Age (years) | Competitive level | Occasion | %BF |
|-------------------------|----|-----------------|-------------------------------|------------------------|----------------|
| Al Hazza et al. (2001) | 23 | 25.5 \pm 2.3 | Saudi professionals | Mid- season | 12.3 \pm 2.7 |
| Bury et al. (1998) | 15 | 24.2 \pm 2.6 | Belgian professionals | Mid- season | 7.9 \pm 1.6 |
| Casajus (2001) | 15 | 26.3 \pm 3.1 | Spanish professionals | Mid- season | 8.2 \pm 0.9 |
| Dunbar and power (1995) | 18 | 22.5 \pm 3.6 | English professionals | Mid- season | 12.6 \pm 2.9 |
| Mujika et al. (2000) | 17 | 20.3 \pm 1.4 | Spanish professionals | Mid- season | 7.9 \pm 1.6 |
| Rienzi et al. (2000) | 11 | 26.2 \pm 4.0 | South american internationals | End of season | 11.6 \pm 3.3 |
| Strudwick et al. (2002) | 19 | 22.0 \pm 2.0 | English premier league | Copa de América finals | 11.2 \pm 1.8 |
| Tiryaki et al. (1995) | 16 | 18.0 \pm 30.0 | Turkish Div. 1 | Mid- season | 7.6 \pm 0.7 |
| | 16 | 18.0 \pm 30.0 | Turkish Div. 2 | | 7.1 \pm 0.4 |
| | 16 | 18.0 \pm 30.0 | Turkish Div. 3 | | 7.2 \pm 0.5 |
| White et al. (1998) | 27 | 26.0 \pm 4.8 | Top English league | Pre- season | 19.3 \pm 0.6 |

Source: Reilly et al., 2009, p. 611.

Body mass management

A common objective for many players is to lose body fat while gaining or maintaining muscle mass, although the periods for such gains and losses are infrequent and often short. There are several options available to lose body fat and the general recommendation is for weight loss not to exceed 1 kg per week (Burke and Deakin, 2015). Given the previously discussed principle of energy balance (Unit 1), one option is to reduce energy intake by up to 1000 kcal/day/week, the other to increase energy expenditure by up to 1000 kcal/day/week (whilst keeping energy intake constant) or finally a combination of the two.

For players already engaged in football training or in-season competition, a moderate approach to energy intake reduction, i.e. 500–700 kcal/day is a more appropriate approach (Garthe et al., 2011). Although this method may take longer to achieve weight loss goals (Donnelly 2009; Garthe et al., 2011), it may reduce the risk of the diet negatively impacting daily performance and feelings of mood/motivation of the player (Achten et al., 2004).

One strategy which is effective in decreasing energy intake, without affecting hunger or the enjoyment of food, is to reduce the volume of high energy dense foods in the diet (foods that have higher amount of energy per gram) and substitute them with lower energy dense foods (Unit 1). This method is considered more effective than reducing the portion size of meal servings because players are able to eat similar quantities of food. Increasing the intake of foods with a high water and fibre content promotes satiation and may increase the adherence to the dietary modification (Manore, 2015).



When energy intake is restricted, it is important to acknowledge the corresponding decrease in protein ingestion. Therefore, particular attention should be placed on increasing or maintaining protein ingestion during periods of energy restriction to help preserve skeletal muscle integrity, in both physically active or inactive (injured) players (Carbone et al., 2012; Phillips, 2014). In general, the protein needs of football players may be higher (1.4–1.7 g/protein/kg BM/day) than that recommended (0.8 g/protein/kg BM/day) for non-active individuals. In addition, during periods of energy restriction, increasing dietary protein to 2-3 g/kg BM/day can help maintain muscle mass, when combined with strength training (Mettler et al., 2010; Thomas et al., 2016). The quantity and type of protein required may depend on volume and type of exercise and the level of energy restriction (Phillips et al., 2007; Carbone et al., 2012; Philips 2013). It is recommended that the appropriate quantity of protein is ingested at routine meals spaced throughout the day (Moore et al., 2009). Timing of protein ingestion is as important as quantity because daily fluctuations in muscle protein synthesis and muscle protein breakdown will determine the net gain, loss or no change of skeletal muscle proteins. In this sense, it is recommended to ingest doses of 20-25 g protein/meal or 0.25-0.30 g protein/kg body mass/meal at regularly-spaced intervals throughout the day to maximize the anabolic response (Phillips, 2013). As well as providing precursors for muscle growth and repair, diets rich in protein may also increase ratings of satiety, and therefore, can be effective in managing *ad libitum* energy intake (Weigle et al., 2005). Conversely, this may hinder those players attempting to gain lean body mass. In this circumstance, similar quantities and timing of protein intake is advised whilst increasing energy intake to promote a positive energy balance.

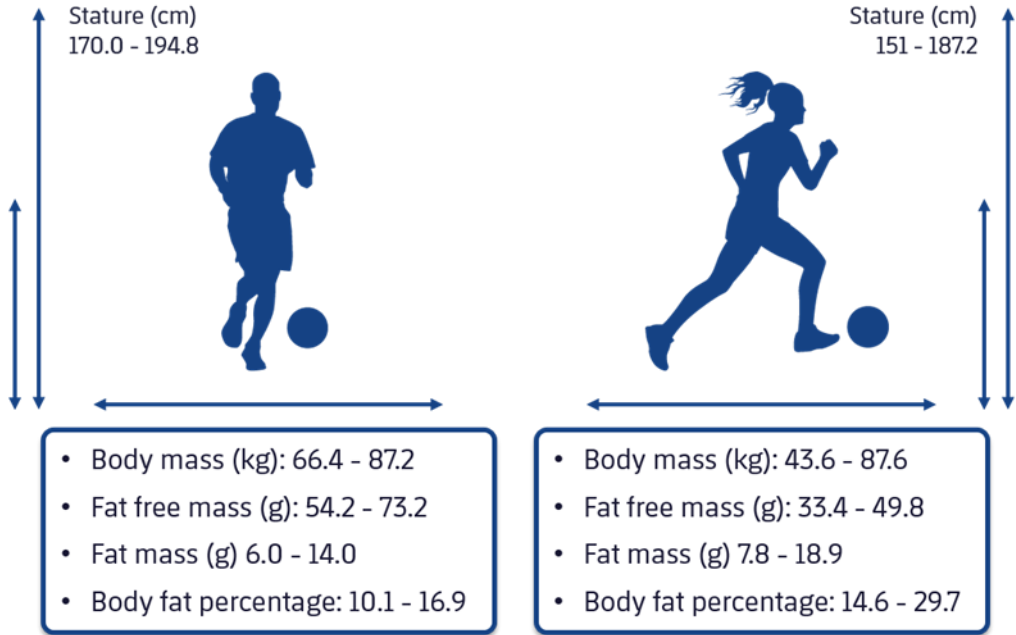
High risk groups

Research suggests that when energy availability is less than 30 kcal / kg of lean muscle mass per day, problems such as tiredness, fatigue, reduced performance, and compromised immune function may follow (Burke, 2003; Loucks, 2004). It is important to recognise populations known to be at greater “risk” of experiencing detrimental effects of a negative energy balance. To this end, female football players are identified as being at greater risk of not ingesting enough energy to cover the demands of both exercise and reproductive function (Kyriazis et al., 2012; Reed, De Souza et al. 2014). In addition, the satiating effect of high-protein, high-fibre, low-energy diets combined with the hunger-blunting effects of intense exercise should be a particular “watch out” for females engaging in daily football training (Manore, 2012; Manore, 2015). The “female athlete triad” is the co-existence of disordered eating, disturbed menstrual function and suboptimal bone density and has received considerable research attention (Loucks, 2003; Birch, 2005; Beals and Meyer, 2007). Expert advice from sports medicine professionals, including dietitians, psychologists and physicians, emphasises the importance of the early



detection and management of problems related to body composition and nutrition in female players (Miller et al., 2012). Of note, poorly educated players, both male and female, typically attempt to lose body fat by very low energy intakes (Erp van-Baart et al., 1989; Dahlstrom et al., 1990). Consequently, these players are reported to be twice as likely to experience upper respiratory tract infections in comparison to those individuals maintaining energy balance (Hagmar et al., 2008). Excessive training, chronic low energy, low nutrient intake and psychological distress are often involved in fat loss strategies and may cause long-term damage to health, well-being, and ultimately performance. A report by the International Olympic Committee’s Medical Commission detailed concerns that athletes engaging in inappropriate strategies to reduce body fat such as severe food restriction are at risk of damaging their health (Meyer et al., 2013). Nevertheless, those players who have higher amounts of body fat are also part of this high risk group and sports nutritionists/dietitians should be aware of this in order to conduct screenings for metabolic risk factors when necessary (Steffes et al., 2013). Under this scenario, a periodized strategy for body fat loss should be applied. Often, “ideal” physiques for individual players in football are based on a rigid set of characteristics of successful peers. However, this process fails to take into account the considerable variability in the physical characteristics of sports people, even between elite players within the same team. To this end, figure 5 highlights the range of body composition determined by dual-energy x-ray absorptiometry (DXA), of both professional male and female football players successfully playing for FC Barcelona.

Figure 5. Range in anthropometrical and body composition of elite male and female football players at FCB (non-published: internal data)



Source: own elaboration.



Body composition analysis

Many football clubs routinely monitor the body composition of their players. Often, body fat is expressed as a percentage of total body mass. Body composition analysis has been typically used in football to assess a player's physical development over time, monitor energy availability status and also assess the impact of specific training or nutrition regimes. It is important to note that a player's physique is heavily determined by inherited characteristics, for example, the height of a player will be determined through genetic predisposition. Although a genetic component will also exist, a player's body composition can be modified through the influence of their training program and diet. Thus, importantly with regard to physical performance, changing body composition, and specifically controlling the amount of body fat, is one variable that a player can directly control.

Finally, a common consequence of a favoured foot for kicking the ball can result in asymmetry in the lower extremities in footballers (Rahnama et al., 2005). Muscle imbalances of 3 % in the lower limbs have been reported to correspond to an 8 % difference in strength between legs in Australian rules footballers. This imbalance was found to lead to inaccurate kicking, whereas greater levels of symmetry, relative lower-body strength and muscle mass were associated with improved kicking accuracy (Hart et al., 2014). As such, body composition analysis can also help identify significant muscular imbalances that are generally regarded to increase the risk of injury.

If a professional footballer's opts into assessments, body composition is usually measured at the beginning of the preseason period and then monitored at regular intervals during the season, typically every 1-2 months. In addition, assessment of body composition is appropriate before and after specific training/nutrition programmes or immediately following an injury, which alters daily energy expenditure. The methods and frequency of body composition assessment will differ depending on the resources at the team's disposal, as well as their preferences. Nevertheless, independent of the method, it is imperative for appropriate standardisation prior to and in completion of the assessments to ensure meaningful changes can be tracked over time. Finally, measurements of physique should only be carried out by appropriately qualified, trained and experienced staff (e.g. ISAK accredited anthropometrist, qualified DXA technician), utilising suitable measurement equipment and processes.



Key point

Independent of the body composition assessment method, it is imperative to ensure appropriate standardisation both prior to and upon completion of the assessments, so that meaningful changes can be tracked over time.

Methods to analyse player body composition

An extensive range of methods to assess body composition currently exists. High precision technologies considered as reference values for body composition include X-ray computed tomography (Ashwell et al., 1985), magnetic resonance imaging (Ross et al., 1992), hydrostatic weighing (Donnelly et al., 1988) and DXA (Nana et al., 2013). However, the widespread use of most of these technologies is prevented due to their limited availability, expense and practicalities within a football club.

For example, Hydrostatic weighing (also known as underwater weighing) calculates body fat percentage using underwater body weight. When completed correctly, hydrostatic weighing is a very precise method for measuring your body fat percentage, and it is often regarded as a “gold standard” for body composition analysis. However, for hydrostatic weighing assessments, a specific facility with a hydrostatic weighing pool and qualified staff are required. In addition, the duration of assessment is often longer than that of other body composition assessment techniques. Thus, in general, the three main methods used to assess body composition in football players are skinfolds, bioelectrical impedance analysis (BIA) and DXA.

Skinfolds

A position statement on body composition was published in 2012 under the auspices of the International Olympic Committee’s Medical Commission, providing a guide for practitioners working in sport (Ackland et al., 2012). In summary, provided the person administering the test is trained, the skinfold method was reported as a reliable ‘in the field’ measurement. Therefore, it is perhaps not surprising that the measurement of subcutaneous adipose tissue thickness is the most commonly used method for assessing body composition. This method is typically performed using callipers to measure a skinfold at specific anatomical sites (Marfell-Jones et al., 2006).

The skinfold method has been described in full previously (Marfell-Jones et al., 2006). In brief, the skinfold site is approached by the finger and thumb at 90° to the surface of the skin. The skinfold is raised with parallel sides. The calliper is positioned 1 cm laterally from the peak of the fold and at the midpoint along the fingernail of the index finger. The calliper



is released and a reading accurate to 0.1 mm is recorded after 2 s. This measure is completed at the eight sites defined by the protocol of the International Society for the Advancement of Kinanthropometry (ISAK): triceps, subscapular, biceps, iliac crest, supraspinal, abdominal, front thigh and medial calf (Marfell-Jones et al., 2006). Values are then expressed as a sum of the thickness of the anatomical sites assessed, together with circumference measurements (Ackland et al., 2012). Despite standardisation, the skinfold method requires skilled personnel and can lack the accuracy practitioners and athletes require (Ackland et al., 2012). It is advised that nutritionists, physiologists or any person responsible for body composition assessment complete the required training before completing skin-fold analysis.

A meta-analysis including 73 studies reporting body composition in football reported the mean sum of 6 and sum of 8 skinfolds of 52.2 and 60.00 mm, respectively. The percentage and kilograms of fat mass and kilograms of fat free mass based on these values varied depending on the formula applied (Sebastiá-Rico et al., 2023).

It is important to emphasise that physique management targets should be individualised to each player. Nonetheless, studies describing the anthropometric characteristics of elite male and female football players provide reference values. These values provide context and comparison across playing positions as well as sexes for the sports nutritionist. As such, reference values from professional players in the Italian league are displayed in table 8 (Petri et al., 2024).

Table 8. Anthropometric characteristics of elite football players (mean +/- SD)

Note:*=different from male players; #=different from female players; §=different from the general male population; ^=different from the general female population.



| Variable | Males (N = 184) | Females (N = 173) |
|--------------------------------------|--------------------|----------------------|
| Age (y) | 24.3 ± 4.3 | 25.2 ± 5.1 |
| Stature (m) | 183.9 ± 6.2 #,§,^ | 169.2 ± 6.1 *,§,^ |
| Body mass (kg) | 79.2 ± 12.1 #,§,^ | 62.4 ± 6.6 *,§ |
| Body mass index (kg/m ²) | 23.3 ± 1.3 #,§,^ | 21.8 ± 1.7 *,§,^ |
| Circumferences | | |
| Relaxed arm (cm) | 29.0 ± 1.8 #,§,^ | 26.4 ± 1.8 *,§,^ |
| Contracted arm (cm) | 32.5 ± 1.8 #,§,^ | 28.0 ± 2.0 *,§ |
| Waist (cm) | 75.9 ± 6.4 #,§,^ | 69.2 ± 3.8 *,§ |
| Hip (cm) | 93.4 ± 7.9 §,^ | 94.0 ± 4.8 §,^ |
| Thigh (cm) | 54.8 ± 2.8 #,^ | 53.6 ± 3.6 *,§ |
| Calf (cm) | 37.5 ± 2.0 #,^ | 35.9 ± 2.2 *,§ |
| Skinfolds (SKF) | | |
| Biceps (mm) | 2.9 ± 0.5 #,§,^ | 4.4 ± 1.7 *,^ |
| Triceps (mm) | 6.5 ± 2.1 #,§,^ | 12.6 ± 3.5 *,§,^ |
| Subscapular (mm) | 7.5 ± 1.3 #,§,^ | 9.4 ± 2.8 *,§,^ |
| Suprailiac (mm) | 6.6 ± 2.3 #,§,^ | 9.8 ± 4.7 *,§,^ |
| Supraspinal (mm) | 6.2 ± 2.1 #,§,^ | 8.3 ± 3.2 *,§,^ |
| Abdominal (mm) | 8.7 ± 2.8 #,§,^ | 13.6 ± 5.3 *,§,^ |
| Thigh (mm) | 8.6 ± 2.9 #,§,^ | 19.4 ± 5.0 *,§,^ |
| Calf (mm) | 4.1 ± 1.4 #,§,^ | 7.8 ± 4.9 *,^ |
| Sum of the 8 SKF (mm) | 51.3 ± 9.4 #,§,^ | 81.8 ± 19.7 *,§,^ |
| Breadths | | |
| Humerus (cm) | 6.7 ± 0.6 #,§,^ | 6.1 ± 0.5 *,§ |
| Femur (cm) | 9.8 ± 1.0 # | 9.3 ± 0.8 *,§,^ |
| Somatotype | | |
| Endomorphy | 1.8 ± 0.5 #,§,^ | 3.2 ± 0.9 *,§,^ |
| Mesomorphy | 3.8 ± 1.5 § | 3.3 ± 2.6 §,^ |
| Ectomorphy | 2.8 ± 0.8 §,^ | 2.7 ± 0.9 §,^ |

Source: own elaboration based on Petri et al., 2024.

Skin fold guidelines

Guidelines for standardisation and best practice for skin-fold measurements are detailed below.

Before carrying out measurements, the assessor should have obtained relevant qualification. The skin fold qualification ensures that the assessor gains sufficient experience and provides evidence of the required skill to complete the measurements.



- Ensure equipment (calliper) is clean and of an appropriate quality.
- Mark the location of the skinfold by identifying the correct anatomical landmarks.
- Ensure the skinfold is taken exactly at the reference point.
- When assessing a site, pinch a double layer of skin and subcutaneous adipose tissue with the thumb and index finger. Apply the calliper 1 cm below the fingers that support the skinfold.
- Hold the calliper at 90° to the surface of the measuring site.
- Assess skinfold sites consecutively, not successively. That is, first take a measurement of all the skinfolds, before repeating the measurements a second and third time.
- Record the reading of the value of the skinfold two seconds after applying pressure with the callipers.
- Aim to standardize the time of data collection. It is advised that assessments are not completed after a training session, competition, a sauna session, after swimming or taking a shower; these factors may increase the thickness of the skinfolds.

To allow a comprehensive understanding of this method, a detailed description of anatomical marks for skinfold measurements are displayed in figure 6.

Site: anatomical location.

Triceps or tricipital: vertical skinfold parallel to the longitudinal axis of the arm, taken on the rear face, at the middle point of the acromial-radial distance. The arm should be relaxed, the articulation of the shoulder with a slight external rotation, and the elbow straight down the side of the body.

Subscapularis: 2 cm from the inferior angle of the scapula, an oblique skinfold is taken downwards and laterally, at approximately a 45° angle from the horizontal.



Biceps or bicipital: vertical skinfold parallel to the longitudinal axis of the arm, taken on the front face, at the middle point of the acromial-radial distance. The arm should be relaxed, the articulation of the shoulder with a slight external rotation, and the elbow straight down the side of the body.

Iliac crest: skinfold directly above the iliac crest, at the midaxillary line. It runs gently downwards, from the back to the front of the body.

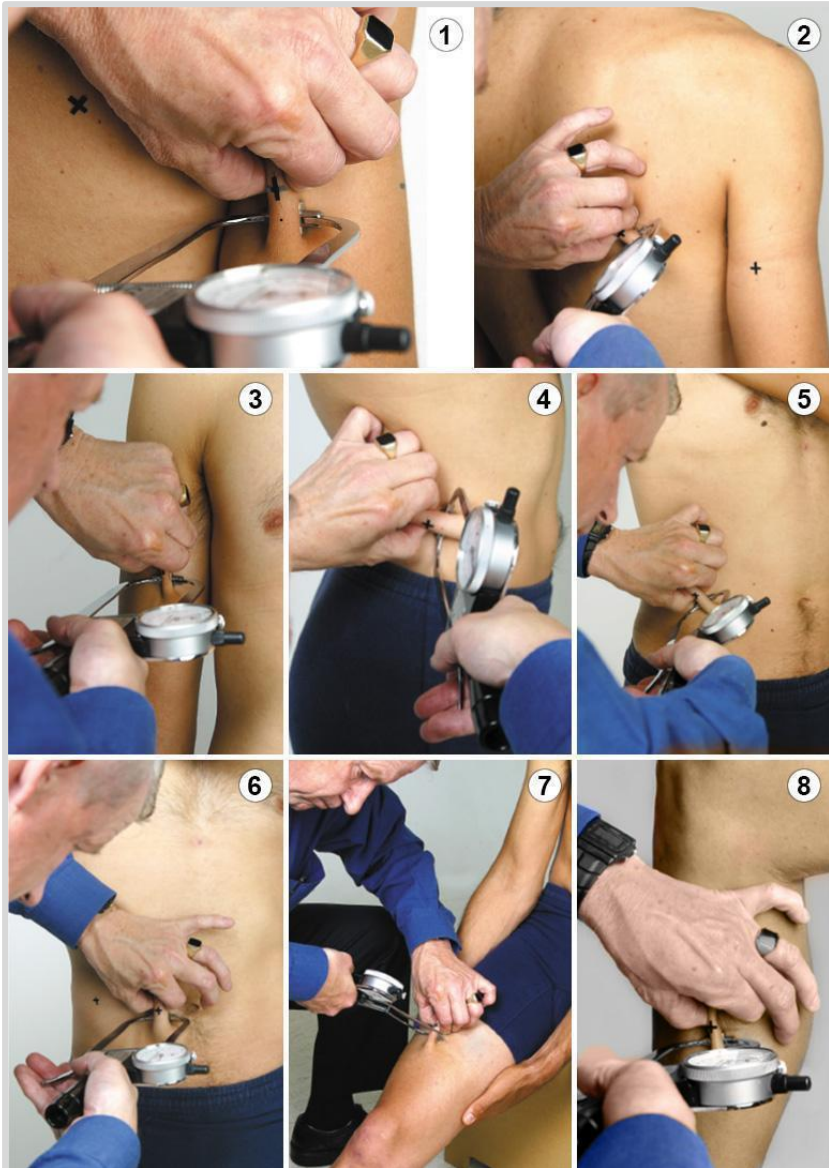
Supraspinatus: taken at the intersection point of 2 lines; that which runs from the anterior axillary edge to the upper anterior iliac spine, and the other that results from the forwards projection of the iliac crest mark. It runs in a medial, descending direction, at approximately a 45° angle from the horizontal.

Abdominal: vertical skinfold, parallel to the longitudinal axis of the body, approximately 5 cm to the right of the belly button. It is important that neither the fingers nor the calliper are placed in the belly button.

Front thigh: the subject sits on the front edge of the box, with the trunk erect and the knee extended. The skinfold runs vertically, parallel to the longitudinal axis of the thigh, at the middle point of the distance between the inguinal skinfold and the upper edge of the knee, along the mid-line of the thigh.

Mid-calf: the subject is standing, with the right foot on the box, the right knee bent at approximately 90°. The skinfold is vertical and is taken in the medial (internal) part of the calf, at the part of greatest girth.

Figure 6. Measurement locations for skinfolds



Source: own elaboration based on Marfell-Jones et al., 2006.

Key: 1, tricipital skinfold; 2, subscapularis skinfold; 3, bicipital skinfold; 4, iliac crest skinfold; 5, supraspinatus skinfold; 6, abdominal skinfold; 7, front thigh skinfold; 8, mid-calf skinfold.

Bioelectrical impedance

The bioelectrical impedance analysis (BIA) technique offers a method to non-invasively assess the fluid distribution and body composition of football players (Gatterer et al., 201; Mascherini et al., 2015; Fassini et al., 2016). The BIA works by passing an electrical current through the player's body. The resistance to that current, as a result of the specific resistivity and volume of fat free mass, which acts as conductor, is measured. Total body



water is also calculated and the value can be used to estimate percentage body fatness (Kushner and Schoeller, 1986; Beertema et al., 2000). The BIA machines vary in size and mobility. Advances in the technique have resulted in devices using both single and multiple frequencies of electrical current, with multiple frequencies reported to improve accuracy (Shafer et al., 2009). The BIA method has been reported to have a strong absolute agreement with DXA for measurement of body fat percentage (ICC=0.87, 95% CI 0.46, 0.95) (Carter et al., 2013). Body mass scales with electrodes positioned on hand held paddles and, on the foot, plates, are a typical method of applying the electrical current to the extremities of a player's body. The advantages of BIA are that the assessment can be "self-led" by the player, the duration of analysis is quick, 1-2 minutes, and the results are available instantly.

There are different types of BIA analysers: a) full body is the traditional BIA method involving a four-way system, with electrodes in hand and foot; b) hands, and c) feet. Although the last two have the advantage of lower cost, their prediction error is greater than the full-body BIA (Heyward and Wagner, 2004). Eating and drinking, dehydration, exercise, and the menstrual cycle are all factors that can alter the outcome of the evaluation (Heyward and Wagner, 2004). This is because the results will be influenced depending if the player is dehydrated or hydrated as it is the fluid in a person's body which transmits the current through the various tissues. Therefore, it is very important to standardize the conditions under which the evaluations are carried out and to follow them rigorously in each evaluation to maximise the precision of the results.

It is noteworthy to mention that BIA has recently been investigated as a diagnostic tool for the assessment of soft tissue injuries in professional football players. Specifically, a single frequency phase-sensitive analyser at 50 kHz was used to obtain baseline measures and compared against post-traumatic types of injuries (Nescolarde et al., 2014; Nescolarde et al., 2015). In addition, BIA has been used to successfully assess changes in body water acutely during major football championships, with total distances covered significantly correlated to the percentage drop in fluid at the end of games (Gatterer et al., 2011). With a diverse range of functionality, BIA is a popular choice within football clubs due to the ease of transport and speed of use (Sebastiá-Rico et al., 2023).

Dual-energy x-ray absorptiometry

Dual-energy x-ray absorptiometry (DXA) is a clinical method with the primary purpose to assess bone mineral density (Ryan et al., 1993; Barry and Kohrt, 2008). An additional function of a DXA machine is to assess body composition. This technology has become a commonly used method within elite football clubs, providing a relatively precise estimate of fat mass, bone mineral content and lean mass.



Full details of DXA technology and standardisation procedures have been reported previously (Clarys et al., 2010; Nana et al., 2016). In brief, players are positioned in a standardised position on the DXA bed. An X-ray beam passes in a posterior to anterior direction through the bone and soft tissue upward to a detector. Fat mass and fat-free mass are differentiated by the ratio of X-ray beam attenuation at the lower energy relative to that at the higher energy. Therefore, these properties of differential attenuation of X-rays make the DXA approach to study body composition to be based on a three-component model in which fat, bone mineral and lean soft tissue are distinguished (Plank, 2005). Consideration for using DXA in players should include the history of high levels of ionising radiation exposure (i.e. medical treatment following injury). In female players, it is recommended that a pregnancy test be completed prior to assessment to avoid any risk of unnecessary exposure to ionising radiation.

The popularity of DXA is most likely due to scans being relatively quick and easy to perform, the radiation dose it generates is minimal and it provides precise and attractive data to feedback to the players. Other interesting characteristics are that it requires minimal cooperation from the subject being evaluated and minimal technical skills from the evaluator. It is important to note that DXA also has limitations and strict standardization procedures should be adhered to if meaningful changes are to be identified (Clarys et al., 2010; Nana, Slater et al. 2014).

Recent reviews have concluded that when using DXA as a method, details of the machine and software, subject positioning protocols, and analysis protocols should be reported and adhered to. This is because the error in DXA measurement of fat mass and muscle mass is approximately 1 kg. Furthermore, water consumption or the change in the state of hydration of the body could affect the lean tissue mass results. However, several studies indicate that normal variations in hydration (1 % to 3 % of body weight) have little effect on the ability of DXA to detect changes in body composition. In fact, a 5 % increase or decrease in hydration levels causes a variation of only 1 % to 2.5 % in the estimation of body fat percentage by DXA (Heymsfield, 2005). Although this may be better than most other techniques, small differences of interest to the practitioner and player during routine monitoring may still be difficult to detect (Clarys et al., 2010; Nana et al., 2014). Therefore, table 9 summaries the recommended procedures for any small changes in body composition to be confidently detected and correctly interpreted (Nana et al., 2015; Nana et al., 2016).



Table 9. Best practice protocol for undertaking whole body composition assessment by DXA in athletes and active people

| General | | Implications | | |
|--|---------------|--|--|--|
| <ul style="list-style-type: none"> - DXA assessments should be undertaken in conjunction with Surface anthropometry to better understand the relationship between the two measurements. - Near nude body mass should also be measured on a calibrated scale for a quick and simple reliability cross-check against DXA – derived estimate of total mass. - Longitudinal monitoring of athletes should be undertaken using the same DXA machine and, ideally, the same technician - Each facility is encouraged to calculate their machine – and population- specific technical error of measurement (e.g. % coefficient of variation, least significant change). - The frequency of measurement of whole body composition in an individual should be determined according to the likelihood that any change exceeds the measurement error, as well as local limitation of radiation exposure (e.g., requirements of Human Ethics Committees or Radiation Safety authorities). | | <ul style="list-style-type: none"> - High subject and technician burden (early mornings) - Limited number of scans per morning (difficult to scan large groups) - Limits use of DXA machine for monitoring body composition to mornings (high expense for short periods of use) | | |
| Stage | Type of error | Point of error | Best Practice Protocol | Notes |
| Prescanning | Technical | Subject's clothing | Minimal clothing (e.g.; underwear and wire- free crop to with jewelry removed). | Minimal clothing provides better visualization of subjects' positioning on the scanning bed (spine alignment and limb placement). |
| | Biological | Subject presentation | <ul style="list-style-type: none"> - Fasted with no fluid intake on morning of scan - Optimized hydration status (collect upon waking urine specific gravity on assessment morning to check) - Bladder voided | <p>Clothing should also be free of chlorine and salt since these factors may alter attenuation ratios and subsequent estimates of body composition.</p> <p>USG maybe useful for longitudinal monitoring of body composition. Although unclear, major alterations in hydration may be at least help explain incongruent body composition estimates. Other unknown sources of error may include menstrual cycle, glycogen stores, gastrointestinal gas/ content or use of supplements that affect intramuscular solutes (e.g. creatine, β – alanine).</p> |



| Stage | Type of error | Point of error | Best Practice Protocol | Notes |
|----------|---------------|---|--|--|
| Scanning | Technical | Machine's inherent "technical noises" | Undertake routine quality control and quality assurance system in place to detect any "drift" in the system. | Each facility is encouraged to calculate their own machine's technical reliability from repositioning of subjects (e.g. % coefficient of variation), to assist in inferring if a real change has occurred |
| | | Technician's position of subject on the scanner | Standardized positioning technique with the possible use of positioning aids. | Food and hand positioning aids are designed to standardize the positioning of the subject on the scanning bed and to maximize the consistency of scans within – and between- subjects. Our experience suggest that they aid subject comfort in maintaining the desired scanning position and improve the apparent reproducibility of results |
| | Technical | Manual demarcation of segmental lines on the body | Check regional analysis by the software . Have standardized regional composition analysis protocol | |
| | | Consistency of scans within – and between- subjects | Ideally, have one technician undertake and analyze the scan over time. | The experience of the technician may affect the consistency of scans. If possible, calculate the intra – and intertechnician variability specific to the laboratory- |

Source: Adapted from Nana et al., 2014.

Novel methods of body composition assessment continue to be developed, of these, ultrasound shows some promise. Although ultrasound research is in its infancy, the method may offer a valid and more accurate alternative to skinfolds and more expensive measures of assessment (Pfeiffer et al., 2010; Meyer et al., 2013). Nevertheless, despite adhering to strict standardization procedures, errors will be present independent of the method. Therefore, all body composition results need to be interpreted under the scrutiny of the limitation of the method used. Care is recommended when comparing results from the same methodology used by different research groups or teams.

Table 10. Standardisation of body composition assessment



| Body composition standardisation | ISAK | BIA | DXA |
|---|------|-----|-----|
| Completed by same qualified experienced professional | X | | X |
| No activity or exercise before assessment | X | x | X |
| Players should be hydrated | | x | X |
| Players should complete the assessment fasted ($\geq 5h$) | | x | X |
| Standardised positioning | x | x | X |
| Use the same equipment/technology for each subsequent measure | x | x | X |

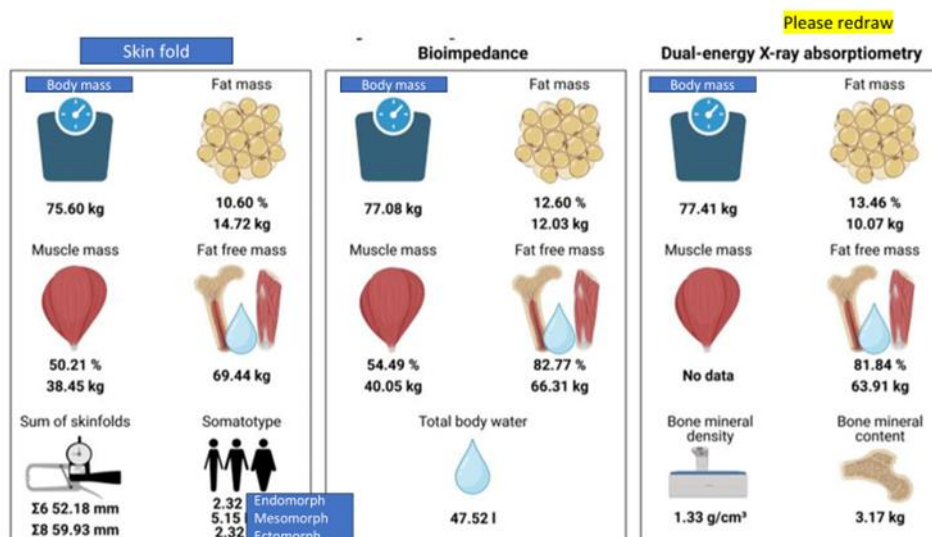
Source: own elaboration.

Application

Research suggests that a player's key influencer is their coach. With that regard, implementing nutritional strategies should not be isolated to the "club nutritionist". Instead, behaviour modification will be most effective when all staff surrounding the player in a team understands the importance of energy balance and nutritional strategies. This can be achieved by small-group nutrition workshops, specifically designed handbooks and more recently, digital materials. Involving the coach or having coaching staff present at player's [body composition assessments](#) can have a large impact on a player's adherence to a nutrition program. This simply highlights the importance placed on nutrition and body composition. However, this practice should be completed with respect to the specific circumstance and occasion. Privacy and confidentiality are important for all players, perhaps even more so for high-risk groups or players "struggling" with their physique. The results of body composition and physique communication should be scheduled in a private environment, with minimal delay post-measurement to allow for timely reflection. Unsolicited or offhand comments or discussions without context are inappropriate. The discussion relating to the players physique should focus on constructive reflection and provide realistic actionable strategies for change when appropriate. Any intervention associated with physique change should be framed against achievable, functional health and performance outcomes. Furthermore, suggested interventions for physique change should be supportively discussed between the player and other relevant stakeholders within the sports medicine department.

By working with other disciplines in the sports medicine department, changes in body composition can be correlated against markers of player health and performance. For example, body fat percentage or sum of 8 skin folds may be correlated against symptoms of upper respiratory tract infections over the season. This insight may then be used to provide a threshold value for the following season. Values of body fat percentage or lean mass may also be assessed against players' physical performance such as 10-15-meter sprint speed, distances covered at high speed during a game and markers of fatigue during a game. These performance outcome variables can serve as great motivating factors for the player as well as highlight the importance of nutrition within the sports medical and coaching departments. Finally, recording body composition provides baseline data to inform short and long term goals of the nutrition and conditioning programme for those players returning from injury.

Figure 7. Guidance values for professional male football players body composition differentiated by skin fold, bioimpedance and DXA



Source: own elaboration based on Sebastiá-Rico et al., 2023.



Summary

- The aim of player physique management is to ensure long-term health and wellbeing in the pursuit of performance.
- The player's body composition can be divided into fat free mass and fat mass.
- The player should have the choice to “opt in” for body composition assessments.
- The player's body composition can be assessed using a variety of methods, the most common of which include skin fold, bioelectrical impedance and dual x-ray absorptiometry.
- The appropriate standardisation should be applied to the specific method used to assess body composition.
- Individual threshold values are encouraged rather than squad requirements.
- The routine assessment of body composition should be correlated against relevant makers of the player’s health and physical performance.



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