

3.2 Body composition in football

THE PLAYER'S BODY

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 players body. Body fat has several vital roles such as storage and source of energy, structural material of cells (such as the cell membranes), and also 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 $\leq 5\%$ 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

PLAYER 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, Hackett et al. 2016) and cardiac disease (Koene, Prizment 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, Blanchet-Collet 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, Naughton 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, Ruano 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, Kang et al. 2013, Kemper, van der Sluis 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 immune function and ultimately performance (Nieman 2000, Moreira, Mortatti 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 muscle phenotype which may not be optimal for football performance (Tesch & Larsson, 1982).

The assessment and monitoring of both a player's fat and muscle are important considerations with regard to football performance. Consistent messaging throughout academy, development and professional squads is an important process to educate players how to eat for health, performance and body composition management.

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 can range between 7 and 19% (Wittich, Oliveri et al. 2001, Reilly, George et al. 2009) (Table 6). Less data is available on elite female football players (Mala, Maly et al. 2015). Based on available research and our own data (FCB, unpublished observations) female body fat

percentage ranges from 16-24% (Sedano, Vaeyens et al. 2009, Delestrat, Baker et al. 2013). 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, since higher levels of muscle mass normally achieved by some players as a part of physical training could overestimate levels of fat mass predicted by this index.

Table 6: 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: Retrieved from Reilly et al., 2009.

BODY MASS MANAGEMENT

A common objective for many players is to lose body fat while gaining or maintaining muscle mass, although the time 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 may be a more appropriate approach (Garthe, Raastad et al. 2011). Although this method may take longer to achieve weight loss goals (Donnelly, Blair et al. 2009, Garthe, Raastad et al. 2011), it may reduce the risk of the diet negatively impacting on daily performance and feelings of mood/motivation of the player (Achten, Halson 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. 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).

The energy density of food is determined by measuring the amount of energy (kcal) for a given quantity (g) of food (Table 1). 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.

Table 7: 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: Retrieved from (Manore 2019)

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, McClung 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, Mitchell et al. 2010, Thomas, Erdman 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, Moore et al. 2007, Carbone, McClung et al. 2012, Philips 2013). It is recommended that the appropriate quantity of protein is ingested at routine meals spaced throughout the day (Moore, Robinson 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, Breen et al. 2005). Conversely, this may hinder those players attempting to

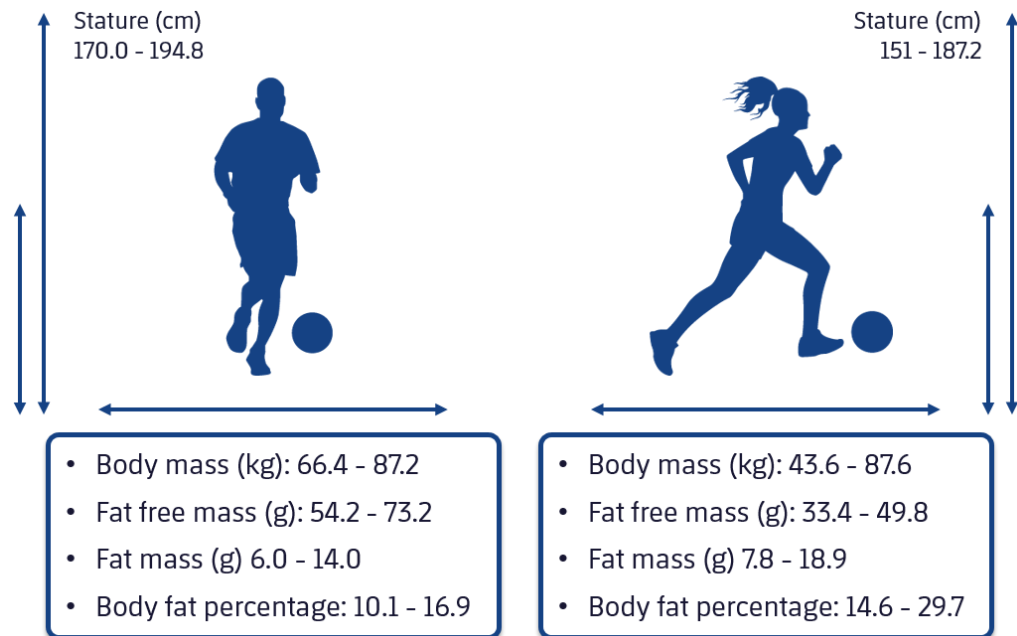
gain lean body mass. In this circumstance, similar quantities and timing of protein intake is advised whilst increasing energy intake to promote a positive energy balance.

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, Kukuljan 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 sub-optimal 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, Kukuljan 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, Saris et al. 1989, Dahlstrom, Jansson 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, Hirschberg 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, Sundgot-Borgen et al. 2013). Nevertheless, those athletes who have higher amounts of body fat are also part of this high risk group and sports 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 4 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 4: Range in anthropometrical and body composition of elite male and female football players at FCB (2016-2017)



Source: Prepared by the author.

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. The purposes of body composition analysis are 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 (Davenport 1917). 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, Lees 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, Nimphius et al. 2014). As such, body composition analysis can also help identify significant muscular imbalances which are generally regarded to

increase the risk of injury.

A professional footballer's 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.

KEY POINT

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

METHODS TO ANALYSE PLAYER BODY COMPOSITION

An extensive range of methods to assess body composition currently exist. High precision technologies considered as reference values for body composition include X-ray computed tomography (Ashwell, Cole et al. 1985), magnetic resonance imaging (Ross, Leger et al. 1992), hydrostatic weighing (Donnelly, Brown et al. 1988) and DXA (Nana, Slater 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 your body fat percentage using your 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 "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, Lohman 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, Olds et al. 2006).

The skinfold method has been described in full previously (Marfell-Jones, Olds 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, Olds et al. 2006). Values are then expressed as a sum of the thickness of the anatomical sites assessed, together with circumference measurements (Ackland, Lohman et al. 2012). Despite standardisation, the skinfold method requires skilled personnel and can lack the accuracy practitioners and athletes require (Ackland, Lohman 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. However, guidelines for standardisation and best practice for skin fold measurements are detailed below:

Skin fold guidelines

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 5 (Stewart, Marfell-Jones, Olds, & De Ridder, 2011): (Norton, Olds, Norton, & Commission, 1996; Stewart et. al., 2011):

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.

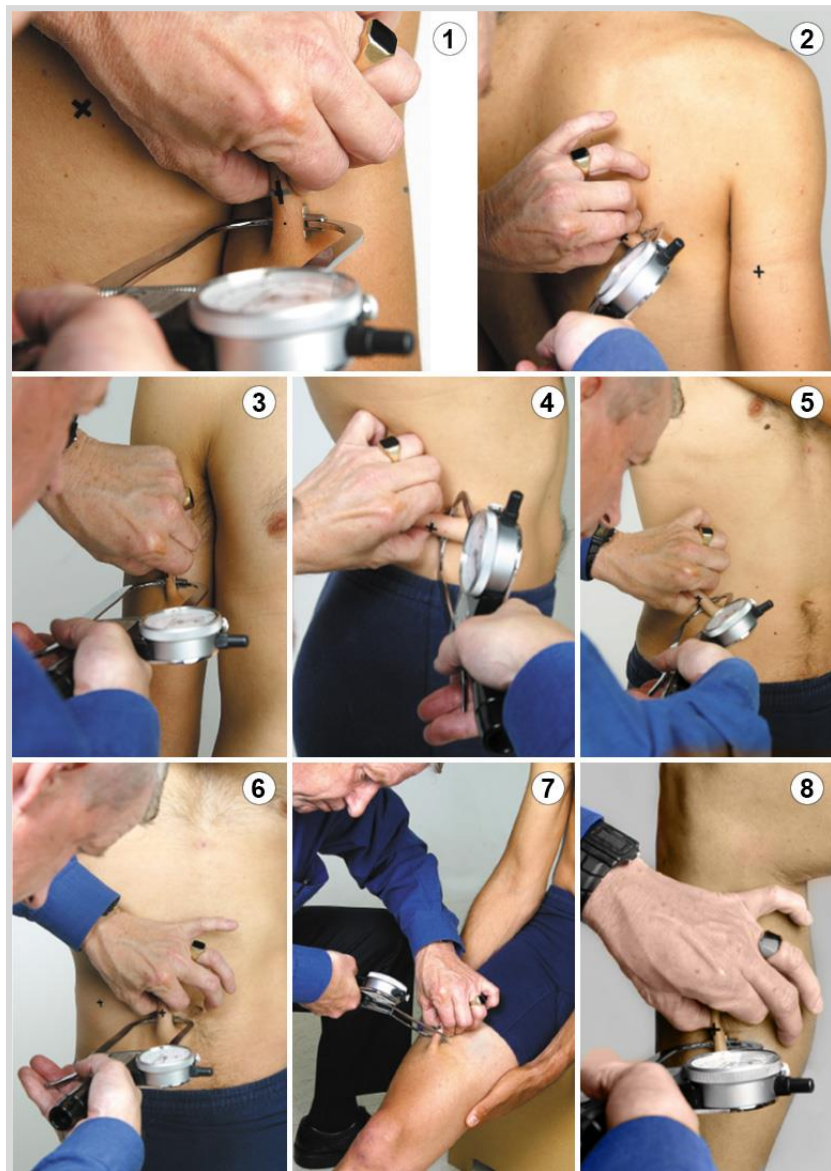
Supraspinatus: taken at the intersection point of 2 lines; that which runs from the anterior axillary edge to the upper anterior iliac spine, and the other that results from the forwards projection of the iliac crest mark. It runs in a medial, descending direction, at approximately a 45° angle from the 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 5: Measurement locations for skinfolds



Source: Retrieved and adapted from Marfell-Jones, Olds 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, Schenk et al. 2011, Mascherini, Gatterer et al. 2015, Fassini, Nicoletti 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, Davies, Jagger et al. 1990, Beertema, van Hezewijk 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 (Cornish, Thomas et al. 1993, Shafer, Siders 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, Randell 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 & Wagner, 2004). Eating and drinking, dehydration, exercise, and the menstrual cycle are all factors that can alter the outcome of the evaluation (Heyward & 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, Yanguas et al. 2014, Nescolarde, Yanguas 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, Schenk et al. 2011). With a diverse range of functionality, BIA may become an ever-increasing popular choice within football clubs.

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, Blake 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, Scafoglieri et al. 2010, Nana, Slater 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, Scafoglieri 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, Scafoglieri et al. 2010, Nana, Slater et al. 2014). Therefore, Table 6 summaries the recommended procedures for any small changes in body composition to be confidently detected and correctly interpreted (Nana, Slater et al. 2015, Nana, Slater et al. 2016).

Table 8: Best practice protocol for undertaking whole body composition assessment by DXA in athletes and active people

General		Implications		
- 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).		- 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	- 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	Clothing should also be free of chlorine and salt since these factors may alter attenuation ratios and subsequent estimates of body composition. USG may be 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).

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 suggests 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: Retrieved 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, Stellingwerff et al. 2010, Meyer, Sundgot-Borgen 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.

Tabla 9: 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 euhydrated		x	x
Players should complete the assessment fasted (≥ 5 h)		x	x
Standardised positioning	x	x	x
Use the same equipment/technology for each subsequent measure	x	x	x

Source: Prepared by the author.

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 routine player weight / body composition assessment 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. Conversely, privacy and confidentiality are more appropriate for high-risk groups or individuals "struggling" with either high or low body mass/fat.

Values of body composition should be recorded over time and where possible 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 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 at the club. Finally, routinely recording body composition provides key baseline data to

inform the nutritional and recovery programme for those players returning from injury.

SUMMARY

- The players body composition can be divided into fat free mass and fat mass.
- The players 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.
- In general, elite male players body fat percentage ranges between 10-16%. Individual threshold values are encouraged rather than squad requirements.
- The routine assessment of body composition should be correlated against relevant makers of the players health and physical performance.

Disclaimer: Ian Rollo is an employee of the Gatorade Sports Science Institute, a division of PepsiCo, Inc. The views expressed in this course are those of the authors and do not necessarily reflect the position or policy of PepsiCo, Inc.

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