Module 1. The role of micronutrients in the players' diet

Unit 1.1 The role of vitamins in the players' diet

1.1.1 Vitamins for football

Besides consuming the macronutrients (i.e., carbohydrates, fat and proteins), players must consume relatively small amounts of certain micronutrients (i.e., organic vitamins and inorganic minerals) in the diet to maintain their health (Rodriguez et al., 2009; Thomas et al., 2016). Micronutrients play an important role in processes such as energy production, bone health, immune function and protection against oxidative damage. The micronutrients also assist the synthesis and repair of muscle tissue during recovery from football exercise and injury (Rodriguez et al., 2009). It is important to understand the vitamins contained in food, the role they play in the body and how best to incorporate them into the diet. This will provide you with the required knowledge to advise on good dietary choices and address any dietary deficiencies should they be identified.

In addition to being found in foods, micronutrients are available individually or in a variety of combined preparations, referred to as dietary supplements. It is common for some players to consume large quantities of vitamin and mineral supplements in the mistaken belief that they will help prevent infection or injury, speed recovery, or improve performance. In reality, vitamin and mineral supplementation may improve the nutritional status of players who consume marginal amounts of micronutrients from food and may improve performance in players with deficiencies (Clarkson, 1991). It is also important to note that no evidence suggests that doses of vitamins and minerals in excess of the recommended daily allowance will improve performance (Fogelholm, 1994). Thus, it is advised that players do not purchase their own dietary vitamin or mineral supplements, but to use only those provided/recommended by their sports nutritionist/dietician or the team doctor.

Did you know?

Terminology: "recommended daily allowance" is abbreviated and commonly referred to as the RDA.

1.1.1.1 Assessment of vitamin status

The vitamin status of the player may be assessed by two common methods. Direct assessment is typically achieved by the analysis of blood samples. Full guidance and best practice in blood sampling and analysis will be covered in later courses. In summary, this method requires the collection of blood by a trained professional (medical or qualified phlebotomist). The blood must be appropriately prepared for analysis, stored and transported correctly. It is important to identify and use a reputable laboratory for analysis, who is experienced in completing this analysis and can provide calibration reports from their analytical machinery. In addition, procedures should be agreed and documented about the disposal of the samples following analysis. Finally, results from the tests should be shared via secure methods, with identifying details of the individual player protected. The blood analysis usually provides a blood cell count and a metabolic panel, where micronutrients of interest are displayed against the physiological normative range.

An indirect method of vitamin status involves the analysis of the player's diet. This can be achieved by following the history of the player's daily energy intake and analyzing it with appropriate nutrition software, which will provide the vitamin intake versus the recommended daily allowance. The pros and cons of dietary assessment are covered in later courses. Nonetheless, this method only provides a "snap-shot" into the player's overall vitamin intake.

There is a recommended daily allowance for each vitamin. The RDA value is based on the quantity of vitamin needed to achieve the minimum requirement to prevent clinical deficiency. The vitamin RDA is calculated by the known nutritional needs of a "healthy" population. There is little evidence that the RDA for football players is different to that of the general population. However, there could be some exceptions, as discussed below. The players with the highest risk of not meeting the vitamin RDA are those who consume a very low energy intake diet or who make poor food choices. For example, when players consistently fail to consume fruit or vegetables in their diet or eat the same food day in, day out.

A simple rule is for players to add "color" to their plate at mealtimes. This can simply be the inclusion of vegetables with their dinner. Snacking on fruit or raw vegetables during the day should also be encouraged. Offering seasonal and/or "new" vegetables during mealtimes shows the player there is choice in their daily diet and helps keep menus appealing throughout the year.

At present, we are unable to quantify the additional micronutrient requirements for football players. Nevertheless, an adequate intake of vitamins and minerals can, in general, be achieved by a moderate to high energy intake from a varied diet of nutritious foods (Williams 2005; Yavari et al., 2015). Thus, most players are likely to meet micronutrient RDA requirements automatically as a consequence of increased energy intake to support training and matches (van der Beek, 1991). Studies have reported that there are no significant differences between the micronutrient status of athletes in comparison to sedentary controls (Volpe, 2007). The consensus amongst sports nutrition scientists is that a varied and balanced diet with adequate energy intake should supply sufficient micronutrients for optimal performance. However, there may be a few exceptions. For example, experience shows that not all players eat varied diets of adequate energy intake and some may require help to improve both the quality and quantity of their food selections. To this end, the micronutrients that may require extra attention will be discussed. Unit 1 will discuss vitamins and unit 2 will discuss the role of minerals in a player's diet.

1.1.1.2 Vitamins

All known vitamins have important functions in most metabolic processes. The vitamins in a player's diet are classified as fat-soluble or water-soluble. In other words, vitamins which are dissolved by fats and by water. The presence of dietary fat and water impacts the absorption of the fat-soluble and water-soluble vitamins in the intestines. All vitamins must be acquired from the player's daily diet. The exceptions are vitamin D, which can be synthesized by exposure of the skin to sunlight, and vitamin K, which can be synthesized from bacteria in the large intestine. Vitamin D will be discussed separately. Vitamins do not provide a source of energy to the body, but many do have important roles in energy metabolism. Deficiencies in vitamins may impair body functions and compromise the player's health. The function of the vitamins will be summarized below, followed by dietary sources and recommended daily allowance.

Table 1. Water-soluble and fat-soluble vitamins

Vitamins	
Water soluble	**Fat soluble**
• Vitamin B_1 • Vitamin B_2 • Vitamin B_3 • Vitamin B_6 • Vitamin B_{12} • Biotin • Pantothenic acid • Folic acid • Vitamin C	• Vitamin A • Vitamin D • Vitamin E • Vitamin K

Source: own elaboration.

1.1.1.3 Fat soluble vitamins

The fat-soluble vitamins are vitamin A, vitamin D, vitamin E and vitamin K. These vitamins are absorbed in fat globules that travel through the lymphatic system of the small intestine into the peripheral circulation. The fat-soluble vitamins can be stored in the body. Thus, players should be warned against excess consumption of fat-soluble vitamins. Toxic concentrations may cause ill health and obvious impaired physical performance.

Vitamin A is essential for vision in dim light and is necessary for skin, growth as well as bone formation and immune function. An excess of vitamin A in the diet (usually through excess supplementation) will cause nausea and headaches. The RDA is 0.9 mg or males and 0.7 mg for females. Dietary sources include milk, butter, cheese, egg yolk, carrots, dark green vegetables and tomatoes.

Did you know?

Beta-carotene is a colored pigment in fruit and vegetables, which gives it its yellow and orange color. Once ingested, the body converts beta-carotene into vitamin A.

Vitamin E is an antioxidant vitamin (discussed below) which protects cell membranes from damage. An excess of vitamin E in the diet will become evident through headaches, fatigue and diarrhea. The RDA is 15 mg for both males and female players. Common dietary sources include vegetable oils, nuts, vegetables and cereal products.

Vitamin K is essential for the formation of proteins involved in blood clotting. It is a vitamin that does not need to be ingested via the diet as it is produced by bacteria in the large intestine. Dietary sources include dark green leafy vegetables, cabbage, spinach and cauliflower. The RDA is 120 μg for males and 90 μg for female players.

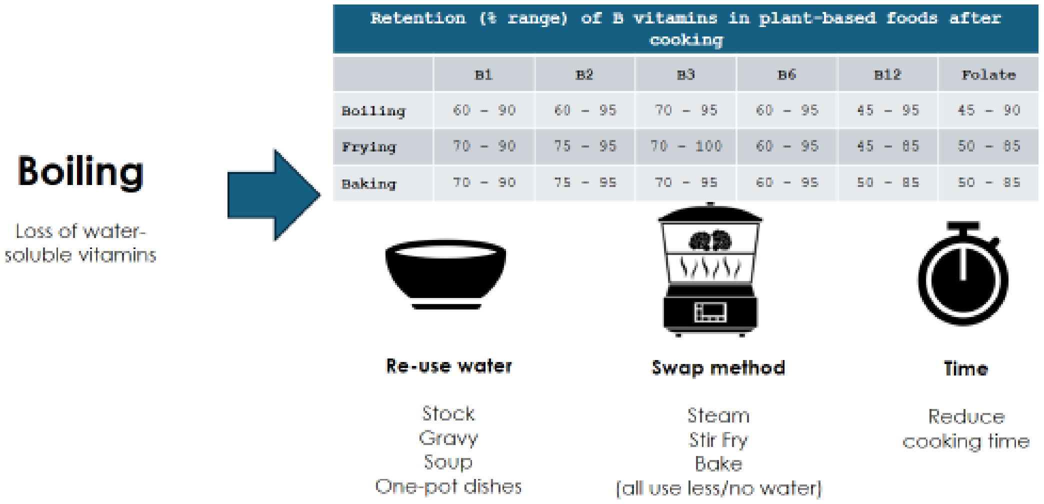
Did you know?

μg is the symbol for the metric measurement microgram, which is one thousandth of a milligram.

1.1.1.4 Water soluble vitamins

The water-soluble vitamins dissolve in water. Water-soluble vitamins are not stored in the player's body, and thus need to be consumed regularly in the daily diet. The player's body will absorb the vitamins required, and any excess will be excreted in urine. However, certain water-soluble vitamins, when consumed in large supplemental doses, may have some negative side effects. In contrast to the fat-soluble vitamins, water soluble vitamins may be destroyed by heat or lost in water when cooked. This is typically observed when players are "learning" to cook, or in very busy club kitchens where the vegetables are boiled for a long time. This does not just make the vegetables lose flavor and texture, but also nutritional value (Coe and Spiro, 2022). Thus, care should be taken in the preparation of foods containing water-soluble vitamins. Additionally, raw, steamed or roasted fruit and vegetables are good snack options for players. Some practical suggestions to reduce the loss of water soluble vitamins are displayed in figure 1.

Figure 1. Practical tips to preserve water soluble vitamins during cooking



Retention (% range) of B vitamins in plant-based foods after cooking						
	B1	B2	B3	B6	B12	Folate
Boiling	60 – 90	60 – 95	70 – 95	60 – 95	45 – 95	45 – 90
Frying	70 – 90	75 – 95	70 – 100	60 – 95	45 – 85	50 – 85
Baking	70 – 90	75 – 95	70 – 95	60 – 95	50 – 85	50 – 85

Source: own elaboration based on Coe and Spiro, 2022.

Vitamin C is considered an antioxidant vitamin (see below), it facilitates the absorption of non-heme iron, and it is also involved in the formation of collagen protein (tendons and ligaments). There are no toxic effects when ingested at lower doses. The RDA is 90 mg for males and 75 mg for females. Higher doses of up to 200 mg may be considered when players present a common cold, to reduce the duration of symptoms. Common dietary sources include fresh citric fruits and green vegetables.

Did you know?

Iron in food is referred to as "heme" or "non-heme" iron. The difference being that "heme-iron" is attached to a heme protein. Heme-iron is found in animal foods. Iron found in plant foods is not attached to heme protein and is referred to as a non-heme iron.

The B vitamins are involved in a variety of roles in the body. In summary, they form co-enzymes required for energy metabolism, such as NAD and FAD, and they function as co-enzymes for the formation of DNA and RNA. The RDA for vitamin B1 is 1.2 mg for males and 1.1 mg for females, vitamin B2, 1.3 mg for males and 1.1 mg for females. The RDA for vitamin B3 is higher, 16 mg for males and 14 mg for females. The RDA for vitamin B6 is 1.3 mg for both males and females and vitamin B12 is 2.4 µg for both males and female players. In general, good dietary sources for all B vitamins are meat, poultry, eggs and whole grain cereal products (U. S. Department of Agriculture, Agricultural Research Service, 2019) (table 2).

Table 2. B vitamins classification, name, RDA, deficiency and common dietary sources

	Name	RDI	Blood Reference Range	Deficiencies	Sources
B1	Thiamin	1mg	66 – 200 nmol/L (TDP)	<70 nmol/L TDP	Peas, bananas, oranges, nuts, wholegrain bread, **liver**
B2	Riboflavin	1.3mg	174 – 471 nmol/L (FAD) **OR** EGRac < 1.2	EGRac ≥ 1.4	Milk, eggs, **mushrooms**, plain yogurt
B3	Niacin	16.5mg	Dependent on biomarker used	Urine	Meat, fish, wheat flour, eggs, peas, **mushrooms**
B5	Pantothenic acid	-	-	-	Chicken, beef, **liver**, kidney, egg, **mushroom**, avocado
B6	Pyridoxine	1.4mg	>20 nmol/L PLP	<10 nmol/L PLP	Pork, chicken, turkey, fish, peanuts, oats, banana, kale
B7	Biotin	-	133 – 329 pmol/L (Serum)	Urine	Low levels in food, produced by bacteria in gut
B9	Folate	200ug	>7 nmol/L (Serum) >300nmol/L (RBC)	<10nmol/L (Serum) <340nmol/L (RBC)	Broccoli, leafy green veg, peas, chickpeas, **liver**
B12	Cobalamin	1.5ug	140 – 1000 pmol/L (Serum)	< 150 pmol/L	Fish, **liver**, red meat, eggs, poultry, milk, cheese, yogurt

Source: U. S. Department of Agriculture, Agricultural Research Service, 2019.

Table 3. Impact of cooking method on B vitamin retention in plant-based foods

Retention (% range) of B vitamins in plant-based foods after cooking

	B1	**B2**	**B3**	**B6**	**B12**	**B9**
Boiling	60 – 90	60 – 95	70 – 95	60 – 95	45 – 95	45 – 90
Frying	70 – 90	75 – 95	70 – 100	60 – 95	45 – 85	50 – 85

Baking	70 – 90	75 – 95	70 - 95	60 - 95	50 - 85	50 - 85

Source: own elaboration.

1.1.1.5 Football-specific considerations

Antioxidants and inflammation

The antioxidant vitamins, vitamins C and E are involved in protecting cell membranes from oxidative damage (Rodriguez et al., 2009; Powers et al., 2014). Exercise has been linked with an increased production of reactive oxygen species capable of causing cellular damage (Powers et al., 2010). A sudden increase in training stress (such as an increase in volume or intensity), or a stressful environment (training in hot conditions or at altitude) is believed to increase the production of these reactive oxygen species (ROS) leading to an increase in markers of cellular damage. Supplementation with antioxidant vitamins such as vitamin C or vitamin E is often suggested to increase antioxidant status and provide protection against this damage (Taghiyar et al., 2013).

However, the literature on the effects of antioxidant supplementation on antioxidant status, cellular damage and performance is complex and confusing (Powers et al., 2011). Some, but not all, studies show that acute supplementation during periods of increased stress may provide bridging protection until the player is able to adapt his or her own antioxidant status to meet this stress. The available literature provides little evidence that antioxidant supplementation enhances physical performance or reduces muscle damage from intense exercise (Powers et al., 2004). Whether on-going supplementation is necessary, or even desirable, for optimal training adaptations and competition performance of football players is also unknown. Furthermore, the increase in free radical production during a period of intensified training acts as signal for adaptation, and therefore, ingesting antioxidant vitamins may actually interfere with the desired adaptation (McArdle and Jackson, 2000).

There is emerging evidence that “antioxidants” and other food components may indirectly influence the recovery process. Eccentric muscle contractions, synonymous with football, have been shown to increase muscle damage, inflammation, delayed onset of muscle soreness and reduced muscle function (Bowtell et al., 2011). This response is potentially triggered by inflammatory cytokines (Davis et al., 2007). This is a normal and healthy process. However, in some circumstances, the response may be excessive and limit recovery. In this case, food components that modulate the inflammatory process may be considered for ingestion during the acute recovery process (Nedelec et al., 2013). Studies have shown some beneficial effects of omega-3 fatty acids (Tartibian et al., 2009), curcumin (Davis et al., 2007) and tart cherry juice (Connolly et al., 2006; Howatson et al., 2010) in the recovery process due to their anti-inflammatory and/or antioxidant effects.

Although these data show promising results, it should be noted that not all results were obtained from human experiments, effects on functional outcomes are not always clear and long-term effects have not been evaluated. In any case, anti-inflammatory and antioxidant supplementation should be carefully dosed, as the inflammatory process and redox reactions trigger exercise adaptations. Thus, chronic high or poorly timed dosages of antioxidant vitamin supplementation may be detrimental to long-term training objectives (Baar, 2014). Furthermore, it is important to note that training up-regulates antioxidant and anti-inflammatory defenses (Gomez-Cabrera et al., 2008). Thus, the anti-inflammatory effects of food and supplementation are likely to be less in well-trained players. The use of functional foods or food ingredients to enhance recovery is an exciting area of research, but clearly, more studies are required to be able to determine optimal timing, ingredients, dose and judging long-term effects (Res, 2014).

Vitamin C supplementation has not been reported to be ergogenic, but prolonged intense exercise or periods of fixture congestion may increase the players' requirement for vitamin C. This is because physical performance and immune function may be compromised with vitamin C deficiency (Moreira et al., 2007). The ingestion of 200 mg of vitamin C per day should sufficiently saturate body tissues and enhance the absorption of iron. In addition, the co-ingestion of 50 mg of vitamin C with gelatin may also be beneficial in connective tissue remodeling (Monsen, 2000). Players at risk of poor vitamin C intakes are those following low fat diets, restricting energy intakes or consuming low quantities of vegetables, fruits and whole grains (Rodriguez et al., 2009).

1.1.1.6 Vitamin D

Vitamin D is a unique vitamin in that it can be synthesized in the skin via sunlight exposure, with less than 20 % of daily needs typically coming from dietary sources. Vitamin D is associated with numerous important biological actions relevant to the player including regulating bone health, muscle function and immune function (Tenforde et al., 2010; Close, 2015). Vitamin D has a receptor present in skeletal muscle. This finding led to increased interest and subsequent research on the potential role of vitamin D in regulating muscle function and training adaptations (Close et al., 2013; Beaudart et al., 2014; Morton, 2014). The study of vitamin D is of particular relevance to football, following observations that professional football players exhibit vitamin D deficiency in the winter months (Morton et al., 2012; Close et al., 2013). Players at risk of low vitamin D status are those who live at northern latitudes and frequently train indoors (Meier et al., 2004; Farrokhyar et al., 2015). Under these conditions, players are not exposed to an appropriate wavelength of ultraviolet radiation for cutaneous production of pre-vitamin D3 to occur (Webb and Holick, 1988; Webb et al., 1988). In comparison to Caucasians, studies have found that black and Hispanic players may be at elevated risk of vitamin D deficiency, with darker skin color reducing synthesis. Nonetheless, paradoxically these players present a lower risk of osteoporosis, rapid bone loss and associated fractures (Owens et al., 2018).

The average daily intake of vitamin D in the diet is approximately 100–250IU (1 ug = 40 IU), which is less than the current RDA of 400IU (UK) and 600IU (North America) (Collins et al., 2021). To promote muscle adaptations as well as maintain both bone and immune health, it has become common for players to supplement their diet with vitamin D3 (cholecalciferol) to correct for deficiencies during the winter, when exposure to natural sunlight is diminished (He et al., 2016). Although not conclusive, studies have reported that dietary supplementation of vitamin D in a cohort of youth professional football players (who exhibit severe deficiency (i.e. 25[OH]D < 12 nmol/L)) is associated with improvements in sprint and jump performance (Close et al., 2013).

There are clinical implications of both vitamin D deficiency, but also toxicity. For this reason, it is highly advised that players' baseline serum 25 (OH)D levels are measured using reliable and valid techniques (such as tandem mass spectrometry) prior to dietary supplementation interventions (Module 2). The expected magnitude of serum 25 (OH)D increase is inversely proportional to basal levels (Close et al., 2013). Hence, a one-size-fits-all approach to supplementation is not appropriate. Thus, players and practitioners should be aware that high doses of dietary supplementation in players presenting high basal levels will increase the risk of toxicity.

Accordingly, depending on the individual player's baseline concentration an appropriate supplementation method should be adopted. If the player presents serum concentrations <75 nmol/L, then an oral 5000 IU/d is an effective protocol to increase concentrations >75 nmol/L. If the player presents vitamin D deficiency (<30 nmol/L), and particularly severe deficiency (<12.5 nmol/L), 10.000 IU/d may be effective to increase concentrations rapidly within 4 weeks, which may then be sustained with 5000 IU/d (Morton, 2014; Close, 2015). In players where a deficiency is not present, subsequent supplementation is unlikely to provide a health or performance benefit, and it may lead to toxicity — it is therefore not recommended. In a study completed at FC Barcelona, it was found that team players training outdoors with supplementation had higher total vitamin D concentrations than those players training indoors with supplementation (Valtueña et al., 2021). Therefore, as sports nutritionist, you should be aware of how the vitamin D requirements may change over the season and those players most at risk of deficiency. It is recommended that any dietary supplementation of vitamin D should only be undertaken in partnership with the team's sports physician.

1.1.1.7 Practical advice

As a general goal, players should be encouraged to consume five portions of fruit and vegetables per day. When assessing the players' dinner plate, encourage them to include "color," i.e. green, yellow, purple, red, and avoid "beige" plates. If there is resistance of the player to include fruit and vegetables in their diet via meal-time options, other methods can be adopted. For example, including fruit into protein "smoothies" post training may improve the taste and variety of smoothie options, as well as improving the nutrient density of the recovery shake. Another approach is to work with the chef/catering staff to improve the nutrient profile of the menus provided at the club (Course 4).

Summary

- Players should consume a wide variety of foods (fruit, vegetables, dairy products and cereals) to ensure adequate vitamin intake in the diet to maintain health.
- Vitamins can be classified as fat-soluble and water-soluble.
- Ingesting excessive "antioxidant" vitamins is not advised.
- Dietary supplementation of vitamin D may be considered for players with clinically measured low vitamin D status.

Unit 1.2. The role of minerals in the players' diet

1.2.1 Minerals

Minerals are inorganic elements that are required for many body functions including the skeleton, muscle and enzyme activity. Thus, minerals are essential for the player's health and the physical efforts required of football training and matches. The amount of mineral available to the player's body will depend on three factors: 1) the absorption from food; 2) the uptake or release of minerals from body tissues; and 3) losses through sweat, urine and faeces.

The available evidence suggests that football specific activities per se, will not lead to mineral deficiency. Furthermore, mineral supplementation will not improve football performance, except where a pre-existing deficiency is corrected (Fogelholm, 1994). Nevertheless, the main minerals of interest which may be low in the diet of players are iron, magnesium and calcium (McDonald and Keen 1988; Lukaski, 2004). At present mineral status may be assessed either directly from body tissues (blood analysis) or indirectly from dietary analysis. Deficiencies in minerals are often a consequence of low energy intakes and may be more prevalent in female players (Monsen, 2000; Rodriguez et al., 2009; ACSM, 2016). Overall, there is no justification for mineral supplementation for all players. Instead, each player should be individually assessed.

Did you know?

A mineral is an inorganic (non-living) element found in nature that is usually related to those elements that are solid. For football nutrition, a mineral can be considered as an essential element for life processes.

1.2.1.1 Iron

Iron is an essential micronutrient in the players' diet that contributes to several central processes of direct relevance to football performance. For example, iron is fundamental to the production of red blood cells, which are required for oxygen transport, and therefore, the aerobic capacity of a player. Inadequate iron status can reduce exercise capacity via sub-optimal levels of hemoglobin, and perhaps iron-related enzymes involved in energy production (Haas and Brownlie, 2001).

Reductions in the hemoglobin levels of distance runners first alerted sports scientists to the issue of the iron status of athletes (Ricci et al., 1988). Iron losses can result from a host of mechanisms during exercise such as hemolysis, hematuria, sweating and gastrointestinal bleeding (Peeling et al., 2008). A difficult issue is to determine "true" iron deficiency from alterations in measures of iron status caused by exercise. Thus, it is possible to over-diagnose "low" iron status based on a single measure of hemoglobin and ferritin levels (Taniguchi et al., 1991). A common failure in the interpretation of results is to ignore increases in blood volume that result from training. The increased blood volume will "dilute" the contents of the blood. This hemodilution, often termed "sports anemia", will not impair football performance (Balaban, 1992; Sacirovic et al., 2013).

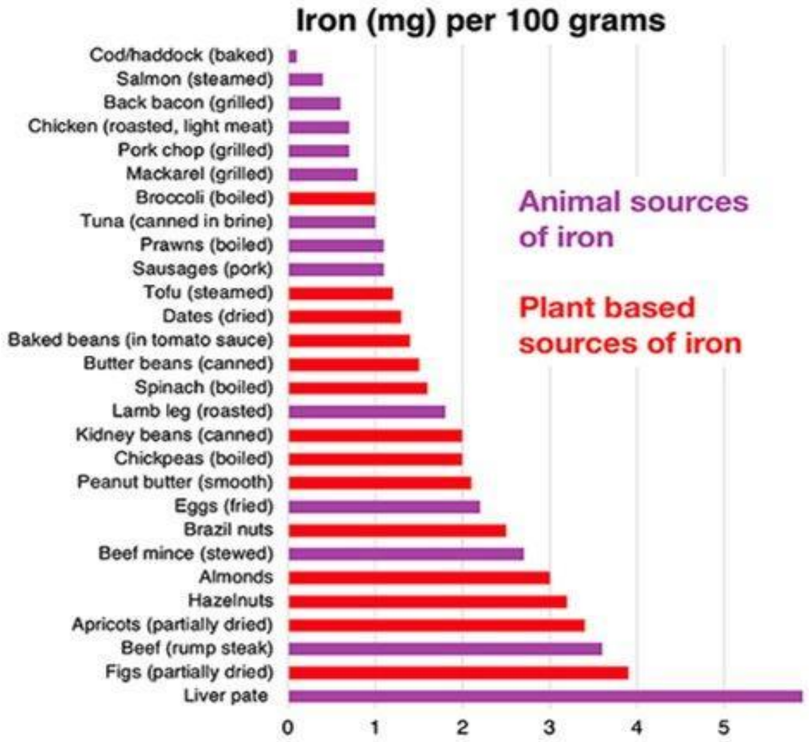
Nevertheless, players are at risk of iron deficiency. The causes of low iron status in players will be similar to those of the general population. Specifically, a low intake of bioavailable iron in the diet or increased iron requirements or losses. Iron requirements may be increased in some players due to growth needs, or to increased losses of blood and red blood cell destruction. The most common risk factor among players is a low energy and low iron diet. Other groups that are at high risk of iron deficiency include female players, "restricted" eaters, vegetarians and players eating high carbohydrate/low meat diets (Mann et al., 2002; Kim and Nattiv, 2016).

Iron is found in two forms in a range of plant and animal foods (figure 2):

- one form is heme iron, which is found only in flesh or blood containing animal foods,
- the other form is organic iron, found both in animal foods and plant foods.

The main distinguishing factor between the two forms of iron is its bioavailability. Heme iron is relatively well absorbed from single foods and mixed meals (15-35 % bioavailability), whilst the absorption of non-heme iron from single plant sources is low (2-8 %).

Figure 2. Dietary sources of heme and non-heme iron. Daily recommended intake adult ~16 mg/day: 9 mg men – 15 mg women EFSA 2015



Source: Tarnowski, n.d., https://lc.cx/zl7bWs

The bioavailability of non-heme iron, and to a lesser extent, heme iron may be influenced by the simultaneous consumption of other foods. Iron absorption can be enhanced by factors including vitamin C, peptides from fish and meat, alcohol and food acids. Factors that inhibit iron absorption include polyphenols, calcium and peptides from plant sources such as soy protein (Lane and Richardson, 2014). Thus, predicting the iron status of a player may not necessarily be achieved by assessing their total dietary intake. This is because of the aforementioned interactions of different nutrient intake at meal times impacting bioavailability. It has been reported that both heme and non-heme iron absorption is increased in those individuals who are iron-deficient or have increased iron requirements, perhaps as an adaptive response. It is important to recognize that recommendations on iron bioavailability are based on studies that have not used football specific populations. Therefore, we assume that results from "iron" studies are applicable across healthy populations.

Low iron status, classified by serum ferritin levels lower than 20 ng/mL, should be considered for further assessment and intervention. Present evidence does not indicate that low iron status without anemia will reduce football specific performance. Players with low iron status, or experience a rapid decline in iron status, will be more susceptible to fatigue and their ability to recover after training and matches will be compromised. In theory, these players should respond to strategies that improve iron status or prevent a further decrease in iron stores (DellaValle and Haas, 2014).

Table 4. Haematological assessments of iron deficiency and iron anemia. Values are different for males (M) and female (F) players

	Normal	Deficiency	Anemia
Serum ferritin (µg/L)	>35 (F) >110 (M)	<35	<12
Haemoglobin (g/L)	120-155 (F) 135-175 (M)	115-119 (F) 125-134 (M)	<115 (F) <125 (M)

Source: own elaboration based on Peeling et al., 2008.

A skilled practitioner is needed to accurately interpret the results and assess iron status (table 4). Oral iron supplements are a common approach used to address an iron deficiency. Although oral iron supplements come in various forms (pills/liquid), ferrous sulphate tablets are the most common approach. As a guide, ingesting 60-200 mg/day of elemental iron in conjunction with natural sources of vitamin C to enhance absorption may be considered (for dietary supplementation guidelines, see Module 2). Iron supplementation recovers depleted iron stores and an iron-rich diet is needed to maintain the increase in iron stores. Full recovery is slow and can take as long as three months. Blood levels should be collected at appropriate times (Jamurtas et al., 2015) and reviewed after 10-12 weeks. Additional iron supplementation may cease when measurements return to usual ranges.

Nevertheless, high-iron doses should not be taken unless iron deficiency has been identified. To this end, the management plan should aim to increase the intake of bioavailable iron, and appropriate strategies to reduce any unwarranted iron loss. Many players self-prescribe iron supplements. However, this practice does not provide the player with the opportunity for adequate assessment of iron losses and expert dietary counseling from a professional. As a sports nutritionist you should be aware of the symptoms of excessive iron consumption, which may manifest as players experiencing an upset stomach, constipation and nausea. In more extreme situations, players may also vomit, have debilitating stomach pains and suffer diarrhea.

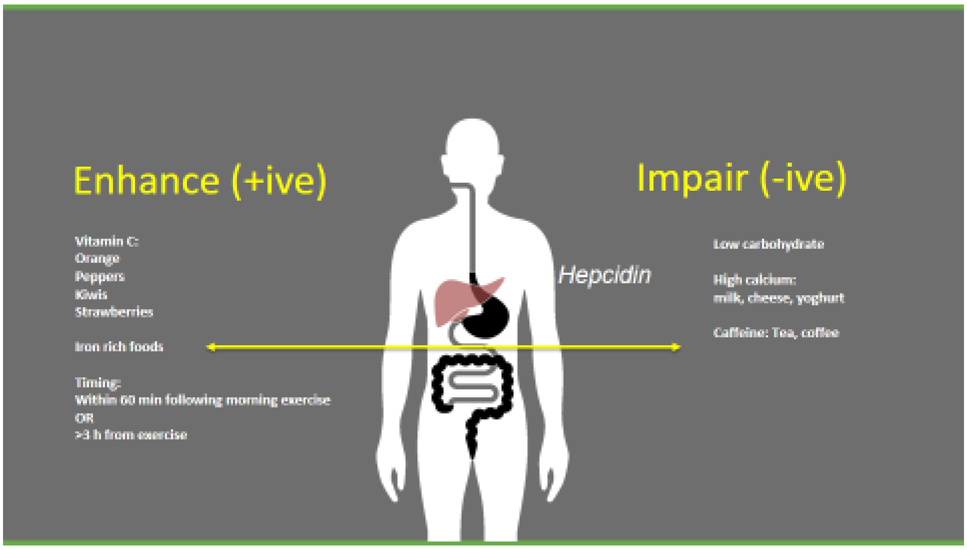
Did you know?

Hepcidin is an iron-regulating hormone made in the liver.

Hepcidin controls the level of iron by reducing dietary absorption and inhibiting iron release from the cells in the body.

There are several practical approaches to improve a player's iron status, which should be explored prior to any dietary supplementation. Generally, taking this approach leads to longer term beneficial dietary changes. First, a player's overall energy intake should be assessed, ensuring appropriate intake of carbohydrate (as discussed in Course 2) (McKay et al., 2020). Next, you should observe and determine the combinations of foods that a player eats. Simple modification of foods around meal time occasions can have a big impact on the players capacity to absorb iron (figure 3). One common scenario is that players drink coffee with their breakfast or lunch. Replacing this high caffeine beverage with a hot drink alternative is a good option for players with low iron status.

Figure 3. Dietary factors to enhance or impair iron absorption into the body



Source: own elaboration.

Finally, the timing of iron rich food ingestion can be modified. Specifically, the time of day in which iron-containing foods are eaten and the proximity of iron intake to training can be considered. This is because iron absorption has been shown to be increased in the morning in comparison to the afternoon, when consumed within 30 min of exercise (McCormick et al., 2019).

Furthermore, players can optimize the uptake of iron from a single meal by ingesting iron rich foods within 30 min after training. This recommendation is based from observations that iron absorption is reduced by 36 % when iron was consumed 2 hours post-exercise compared to a resting control trial. This ingestion regime was planned to coincide with the 3 hours peak in hepcidin concentrations post-exercise (Barney et al., 2022). Therefore, the advice to optimize iron absorption from dietary intake would be for players to consume iron-containing meals in the morning and within 30 min after daily training.

1.2.1.3 Magnesium

Magnesium has been reported to be involved in carbohydrate, protein and fat metabolism and to play a role in neuromuscular, immune and hormonal functions (Lukaski, 2004). Magnesium status has been reported to be related to aerobic capacity (Lukaski et al., 1983). However, prolonged intense exercise is associated with a reduction in serum magnesium concentrations (McDonald and Keen, 1988; Terink et al., 2016). The magnesium levels in the plasma are tightly regulated. Therefore, it is important to assess overall diet as blood work may not initially indicate a deficiency. Magnesium deficiency may have an impact on performance by increasing the oxygen requirement of sub-maximal exercise (Rodriguez et al., 2009).

Due to the role of magnesium for nerve transmission and muscle contraction, dietary supplementation (100-520 mg elemental magnesium daily) has been suggested as an intervention to prevent muscle cramps (Moretti, 2021). However, the role of magnesium supplementation for preventing or treating muscle cramps remains unclear due to the lack of clinical evidence. Furthermore the available studies indicate no effect of magnesium supplementation on performance (Newhouse and Finstad, 2000; Finstad et al., 2001). Thus, at this time the simple advice is for players to avoid deficiency by being encouraged to regularly consume good food sources of magnesium such as nuts, peas and seafood.

Nonetheless, it is important to note that magnesium is an emerging dietary consideration for football players. This is because an eight year study reported that 22 % of Olympic athletes were deficient in magnesium at one time point. These observations are of direct relevance to football as athletes with a history of Achilles or patella tendon pain had significantly lower magnesium levels than average (Pollock et al., 2020).

Calcium

Calcium is important for players bone tissue (growth, maintenance, repair), transmission of nerve impulses and muscle contraction (Rodriguez et al., 2009). The concentration of serum calcium is well regulated independent of acute calcium intake. Bone (the skeletal system) is the largest store of calcium in the body. This store of calcium can be mobilized when the intake of dietary calcium is inadequate. Consistent or frequent loss of calcium from the skeletal system may lead to the demineralization of bone tissue. Thus, diets that are low in calcium increase the risk of low bone mineral density and subsequent fractures (American Dietetic and Dietitians of Canada, 2003; Tenforde et al., 2010). Weight-bearing exercise is considered to be one of the best protectors of bone health.

Women soccer players have been found to have higher bone mass and lumbar spine and hip bone mineral density than age and body weight-matched controls (El Hage, 2013; El Hage et al., 2014; Plaza-Carmona et al., 2016). Nonetheless, low bone mineral density has been reported in female athletes, notably distance runners. Thus, players in women's teams should be considered a high-risk group, especially if experiencing menstrual disturbances (Papageorgiou et al., 2018). This is because a serious outcome of menstrual disturbances in female athletes is the high risk of either direct loss of bone density, or failure to optimize the gaining of peak bone mass during early adulthood (Varley et al., 2017). Individually, or in combination, the problems involved in the female athlete triad (disordered eating, menstrual dysfunction and reduced bone status) can directly impair football performance (Module 4). Significantly, the female triad may reduce the players' career span by increasing their risk of illness and injury, including stress fractures (Okamoto et al., 2010), with long-term problems extending to an increased risk of osteoporosis in later life.

Optimal nutrition is important to correct factors that underpin the menstrual dysfunction, as well as those that contribute to sub-optimal bone density (Papageorgiou et al., 2018). Adequate energy intake and the reversal of disordered eating or inadequate nutrient intake are important. A team approach involving sports physician, sports dietician, psychologist or psychiatrist, coach and family may be needed to treat the player with disordered eating or eating disorders.

Adequate calcium intake (700 mg/d for female and 1000 mg/d for males) is important for bone health, and requirements may be increased to 1200-1500 mg/day in female players with impaired menstrual function (Papageorgiou et al., 2018). Strategies to meet calcium needs must be integrated into the total nutrition goals of the player. Where adequate calcium intake cannot be met through dietary means, usually through the use of low-fat dairy foods or calcium-enriched soy alternatives, dietary calcium supplementation may be considered (table 5).

Did you know?

Trace mineral are those minerals required in very small quantities. Trace minerals are abundant in vegetables, meat and dairy foods.

Table 5. Food sources of calcium. The RDA is 700-1000 mg/day

Food and serving size	Approximate calcium content (mg)
Glass (200 ml) whole or skimmed cows' milk	240

Glass (200 ml) calcium enriched soy milk	240
Hard cheese (e.g. cheddar) 30 g serving	220
Yoghurt (120 g)	200
Soy yoghurt (100 g)	206
Broccoli (2 spears)	34
Kale (67 g)	100

Source: own elaboration based on U. S. Department of Agriculture, Agricultural Research Service, 2019.

1.2.1.4 Sodium, chloride and potassium

Sodium is an essential electrolyte for cell function, body fluid and blood pressure regulation, blood volume and pH (Stachenfeld, 2014). Players may require more than the upper intake recommended for both sodium (2.3 g/d) and chloride (3.6 g/d) (Rodriguez et al., 2009). This is because some players will experience greater losses of sodium and chloride as a consequence of greater concentrations in sweat or high sweat rates (Maughan and Murray 2001; Maughan et al., 2005; Maughan and Shirreffs, 2007). Although there is wide variation across individuals and activities, players can lose as much as 5 g sodium in sweat during a single high-intensity training session or match (American College of Sports et al., 2007; Baker et al., 2016). Thus, during prolonged football match play or training, sodium ingestion can play a role to assist with body fluid maintenance and electrolyte balance (Baker et al., 2005). Post-exercise, replenishment of sodium loss is advised for rapid rehydration (Chapter 2).

Replacing sodium lost through sweat during football exercise can be achieved by including salt (sodium chloride) in the player's post-match meal. This can be achieved by including salty foods such as pretzels or simply slightly salting their food.

Potassium is important in the regulation of fluid and electrolyte balance, nerve transmission and active transport mechanisms (Rodriguez et al., 2009). The concentration of potassium in extracellular fluid (4-5 mmol/l) is much lower in comparison to the intracellular fluid (150-160 mmol/l) (Maughan and Murray, 2001) and losses during exercise are far lower than that of sodium. Potassium is widely available in foods as it is an essential constituent of all living cells. Thus, to replenish potassium, players should include fresh vegetables, fruits, nuts and whole grains in their diet (Rodriguez et al., 2009). Bananas and apricots are potassium-rich foods and good options to consume post football exercise as they also provide a source of carbohydrate to replenish glycogen.

1.2.1.5 Mineral losses in sweat

The mineral losses during training and matches will depend on the sweat composition of the player, together with the player's sweat rate. There is a large inter-player range in sweat composition, as well as sweat rate, which may result in significantly different requirements for mineral replacement. Sodium and chloride are the major minerals lost in sweat, other minerals are only lost in small quantities (table 6). The range in sodium chloride (salt) losses in FC Barcelona's male first team was ~2–5 g/hour during intense training in hot conditions (Rollo et al. 2021). This observation highlights how replenishment of minerals differs between players.

Table 6. Sweat mineral composition

Mineral	mmol/L
Sodium	20-80
Potassium	4-8
Calcium	0-1
Magnesium	>0.2
Chloride	20-60

Source: own elaboration.

1.2.1.6 Other minerals: function, RDA and dietary source

Although there is not specific need for football players, the following list is to provide a brief introduction to other minerals for your information and understanding.

- Phosphorus

Phosphorous is a major mineral present in bone and teeth. It is an essential component for cells in the body. The RDA for phosphorous in adult players is 550 mg/d. Good dietary sources include protein rich foods such as milk, meat, eggs and fish.

- Zinc

Zinc is a trace mineral. It is essential for growth and repair of body tissues and it is a key component of enzyme activities. The RDA for zinc is 7 mg/d for females and 9.5 mg/d for males. Good dietary sources of zinc include milk, cheese, eggs, whole grain cereals and pulses. The role of dietary zinc ingestion for immune function will be covered in later modules.

- Copper

Copper is a trace mineral, it is a component of enzyme systems and enables the effective use of iron. The RDA for copper is 1.2 mg/d. Good dietary choices include shellfish, nuts and green vegetables.

- Selenium

Selenium is an antioxidant and protects the cell membrane from damage. The RDA is 0.075 mg/d for men and 0.060 mg/d for females. The dietary source for selenium is nuts, eggs, fish and cereals.

Other minerals include fluoride, chromium and iodine. The purpose for this unit is not to exhaust the list of minerals, but simply to ensure that you are aware of their function and the importance of the varied diet to ensure an adequate intake as part of a player's overall energy intake.

1.2.1.7 Practical considerations

Similar to the advice for vitamins, players should aim to meet their mineral needs by ingesting a diet rich in fresh fruit and vegetables, whole grains, nuts, seeds, dairy and meat/fish. The danger is that busy lifestyles, heavy training and frequent travel may result in players missing meals. The avoidance of meals reduces the intake of minerals in the diet, and if combined with poor food choices may result in deficiencies. The task for the sport nutritionist is to educate the players around ingesting adequate energy intake and the consequences of not meeting energy needs is an increased risk of mineral (and vitamin) deficiency. In addition, the nutritionist should be aware of high-risk groups such as players aiming to lose body mass or body fat, as well as women players (Module 4). Finally, the dietary guidelines for increasing mineral intake should be integrated with the players' other nutritional goals.

Table 7. Example of dietary supplementation for micronutrient deficiencies

Medical supplements for nutrient deficiencies	Supplement
Medical supplement are used to treat clinical issues, including diagnosed nutrient deficiencies.	Iron
	Calcium
Requires individual dispensing and supervisión by appropriate sports dietician / medical proffesional.	Multivitamin / mineral
	Vitamin D

Source: own elaboration.

Dietary supplements should be used in specific situations using evidence-based protocols. They should be used by some players to directly contribute to optimal performance. Supplements should be used in individualized protocols under the direction and monitoring of an appropriate sports nutrition/medicine/science practitioner (Module 2).

Summary

- Minerals are essential for the health and performance of the player.
- Football is known to increase mineral loss from the body.
- The RDA for mineral intake can be achieved by the ingestion of fresh fruit, vegetables, salads, meats and nuts as part of meeting the player's overall daily energy intake.
- Specific dietary intervention and potential dietary supplementation are required where a deficiency has been identified.

- Iron absorption can be enhanced by modifying the timing of intake and combining the intake of iron-rich foods with vitamin C.

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