

Module 2. Sports nutrition for the Injured player and player recovery

Unit 2.1 Sports nutrition for the injured player

Unfortunately, football players are likely to experience an injury at some point during their playing career, independent of competitive level, age and gender (Tipton, 2010; Wall et al., 2015). An injury in football can be defined as any physical complaint sustained by a player during a match or training session, irrespective of the need for medical attention or time loss from football activities (Valle et al., 2016).

Football injuries can be classified into two categories. A “medical attention” injury is one that results in a player receiving medical attention, whereas a “time loss” injury is one that leaves the player unable to participate in subsequent training or matches (Fuller et al., 2006). There are many types of injury that are sustained in football, including muscle, connective tissue and skeletal injuries. The most common injuries in football are muscle injuries, the main cause of which is trauma. Trauma to the muscle may be inflicted either directly (typically by an opposing player) or indirectly (via a muscle strain). The aim of this unit is to introduce common injuries in football and to provide guidance on nutritional strategies to support the “returns to play” process.

Did you know?

When experiencing direct trauma, the muscle is injured by a heavy extrinsic compressive force. When the player experiences an indirect trauma, the muscle is injured as muscle fibres are exposed to an excessive intrinsic tensile force.

Muscle injuries

In professional football, muscle injuries account for 31-46 % of all injuries (Ekstrand et al., 2011a; Ekstrand et al., 2011b). Most muscle injuries (~90 %) affect the muscle groups of the lower limbs, i.e. hamstrings (37 %), adductors (23 %), quadriceps (19 %) and calf muscles (13 %) (Valle et al., 2016). Over the course of a season, a team may experience 37 % of players missing training or matches due to muscle injuries (Ekstrand et al., 2011b). It is important to note that half of these injuries will be minor —causing absences of less than a week. In these circumstances, a specific nutrition intervention is unlikely to be required. However, the other half of injuries will be severe, resulting in absences of more than four weeks. Beyond player availability and team success, injuries also have significant financial ramifications. For example, in the English Premier League, the financial cost of 32 days lost due to a hamstring injury has been calculated at £209,000



(JTL 2017). Therefore, nutritional strategies to reduce the risk of injury, as well as accelerating the players' return to play, is of great relevance.

The incidence of injury in elite players has been reported to range between 25-35 per 1,000 match hours, and 6-7 per 1,000 training hours (Ekstrand et al., 2011b). In matches, 43 % of all muscle injuries have been reported to occur during the first and final 15 minutes of a game (Rahnama et al., 2002). These observations reflect the intense nature of the opening stages and the possible effect of fatigue in the final stages of a match. Football specific activities lead to fatigue. Fatigue can be experienced both in-game and post-match. Those factors that are associated with fatigue include dehydration, glycogen depletion, muscle damage and neuromuscular fatigue. The intrinsic and extrinsic factors which may contribute to the magnitude of competitive exercise-induced fatigue are listed in table 1. Increasing the number of matches played per week and reducing the duration of recovery between matches contributes to an elevated risk of muscle injury (Bengtsson et al., 2018).

Table 1. Examples of extrinsic factors and intrinsic factors, which may contribute to the magnitude of exercise-induced player fatigue

Extrinsic factors	Intrinsic factors
Match score/result	Training status
Quality of the opponent	Age
Match location	Gender
Playing surface	Muscle fibre type
Environment temperature	Previous injury history
Financial rewards	Nutritional status



Source: own elaboration.

Did you know?

Increasing the volume and intensity of football-specific play exposes the player to greater physical loads, as well as the number of tackles, increasing the risk of muscle injury (Bacon and Mauger, 2016; Malone et al., 2016).

The phases of injury

Following an injury, a similar pattern of healing is typically observed which involves four stages; degeneration, inflammation, regeneration and fibrosis (Prisk and Huard 2003; Jarvinen et al., 2013). When players get injured their “return to play” can be categorised into two phases: the acute injury phase and functional recovery phase. The acute injury phase (also known as the immobilisation phase) may be defined as the moment the injury occurs to the start of active mobilisation of the injured area. The duration of the acute injury phase will range from hours to several days, which is dependent upon the severity of the injury. The functional recovery phase may be defined as the structured and deliberate activation of the injured muscle. The primary goals of functional recovery are to prevent muscle atrophy, recover muscle hypertrophy and return the functionality of movement (Jones et al., 2004). The duration of the functional recovery phase will depend on the severity/classification of the injury (Valle et al., 2016), and the effectiveness of the care received during both phases.

Nutrition for return to play

Nutrition advice for the injured player has historically been neglected within professional football. This is because physical rehabilitation is prioritised and sports nutritionists have not been involved in return to play discussions. When a player experiences an injury, the medical and coaching teams objective is to return a player to the pitch (available for selection) safely but as quickly as possible. It is here that sports nutrition strategies may be used to optimise the rehabilitation process and speed the players return.

Although differences in the nutrition strategy for the acute and functional recovery phases exist, both phases have the same four primary nutritional goals, which will be discussed below.

- Manage the inflammatory response.
- Attenuate muscle atrophy and encourage muscle repair.
- Modify dietary intake to player’s energy demands.
- Routine physique assessment to monitor changes and adapt the dietary strategy accordingly.



First, it is important for the sport nutritionist to understand that both the acute injury and functional recovery phases offer opportunities to engage with the player. This is because the time out due to injury will allow the player greater time for more formal dietary consultations. The sports nutritionist may witness players who have been reluctant to engage with sports nutrition beginning to show an interest in the nutrition process. If done right, the nutritional advice given, and the player-nutritionist relationship, should remain post-injury (Rollo et al., 2021). Experience shows that sport nutrition support during an injury often results in players who have been reluctant to engage with sports nutrition becoming invested for the rest of their careers, having experienced the benefit of the support.

In some circumstances, where a player has suffered a serious injury, players can become disillusioned. In this situation, it can be common for players to lose focus from performance nutrition and switch to comfort eating. Comfort eating is characterised by periods of binge eating, particularly in the acute injury phase. This behaviour is not conducive in speeding return to play, and an excessive shift in positive energy balance may result in the player accumulating excess body fat. To this end, following initial consultation with the player, a diet plan should be generated. The diet plan should be built depending on the food preferences and schedule of the player. In periods of immobilisation or inactivity, a nutrition plan will provide the player with a structure to their daily routine and can provide ownership towards the recovery process (Rollo et al., 2021).

1. Manage the inflammatory response

Most injuries rapidly trigger inflammatory processes that initiate wound healing and soft tissue or bone repair. Initial consideration should be given to the players dietary status ensuring sufficient energy and no dietary deficiencies in calcium, vitamins D and C, zinc, copper and manganese, all of which may impair the initial healing process (Collins et al., 2021). It is important to note that reducing of post injury inflammation has not been shown to attenuate tissue deconditioning, and furthermore is likely to be detrimental to the healing process (Collins et al., 2021). While further research is needed to inform recommendations, the available evidence does not support the use of nutritional strategies that may limit injury-induced inflammation. This is particularly important in the acute injury phase.

2. Attenuate muscle atrophy and encourage muscle repair

Given the role of dietary protein in muscle protein turnover, it is crucial that following a muscle injury, protein intake is optimised both in terms of attenuating muscle atrophy, as well as promoting repair. Observations from laboratory-based studies have shown that limb immobilisation not only reduces muscle protein synthesis, but also induces a degree of anabolic resistance to protein (Wall et al., 2013). It has been shown that increasing the



absolute daily protein intake to 2-3 g/kg body mass (BM) prevented the loss of lean mass even during reduced total calorie intake (Mettler et al., 2010). Therefore, elevating the player's total protein consumption beyond their current intake and possibly up to 3 g/kg BM may be considered for an injured player. It is advised that the total intake of protein be distributed equally throughout the day, with approximately 0.4g/kg BM provided at each meal (Stokes et al., 2018). Interestingly, an equal distribution of protein is something football players commonly fail to achieve. Protein (whey or casein) ingestion prior to sleep (30-40g) has been shown to improve overnight muscle protein synthesis (Module 1).

Did you know?

The protein content of milk is approximately 80 % casein and 20 % whey.

It is a priority for injured players to increase protein intake. However, a common observation from professional football is that protein intake may decrease during injury. This is because players cease to consume protein shakes following their routine gym and field-based training sessions. This is an important "watch out" for the sports nutritionist during injury and highlights the importance of nutrition education during early nutrition consultations.

A second nutritional strategy that may help to prevent skeletal muscle atrophy involves supplementation with fish oils. Ingesting 5 g of fish oil (providing 3 g EPA and 2 g DHA) daily for two weeks was reported to prevent muscle atrophy during limb immobilisation in active female participants. The fish oil supplementation was reported to maintain muscle mass by increasing myofibrillar muscle protein synthesis (McGlory et al., 2019). However, research suggests that a minimum of 2 weeks supplementation with 5 g of fish oil per day is required to achieve increases in muscle n-3 polyunsaturated fatty acid lipid composition (McGlory et al., 2014). Considering this, it is essential for the sports nutritionist to commence this strategy immediately following the injury. The recommended dose of 5 g is in excess of anything that the player may achieve in their daily diet. Therefore, supplementation will be necessary with due consideration given to supplement safety and batch testing detailed in previous modules.

Dietary supplementation with creatine monohydrate has also been proposed as an effective dietary strategy during muscle injury. Whilst creatine loading has not been shown to successfully preserve lean muscle mass during immobilisation (Backx et al., 2017), it has been reported to improve the recovery of muscle mass following immobilization (Op 't Eijnde et al., 2001). Therefore, should players not already be taking it, the sports nutritionist may consider completing a "creatine loading" regime with the player as soon as the injury occurs. The addition of creatine to the players' diet can be achieved by adding creatine monohydrate to the players' morning smoothies or daily protein shakes.



Low vitamin D concentrations are associated with an attenuation of muscle regeneration, both *in vitro* and *in vivo* (Owens et al., 2015). For muscle regeneration players should aim to achieve concentrations of 75 nmol/L. Data in Premier League football suggests that many players are below this threshold during the winter months (Morton et al., 2012), and should therefore, consider daily supplementation with 2000 IU per day of vitamin D. Given that vitamin D deficiencies may take several weeks to correct, a practical strategy would be to regularly assess each player's vitamin D concentration throughout the season in case a muscle injury occurs (Owens et al., 2018).

Did you know?

The term *in vivo* refers to an experiment performed on a living organism, such as a human. The term *in vitro* refers to an experiment performed in a laboratory, which is completed within a test tube or laboratory dish, usually using microorganisms outside their natural environment.

During the injury period it is advisable to reduce, if not eliminate, alcohol intake. Some players have been known to increase their alcohol intake when unmotivated or seeking distraction from not being involved in daily football activities (Tipton, 2015). Beyond the potential for excessive energy intake, alcohol post-exercise has been shown to reduce myofibrillar protein synthesis even when co-ingested with protein (Parr et al., 2014), potentially impairing recovery. It should be emphasised that the alcohol intake used in experimental studies was high (12 standard drinks). It remains to be determined if an attenuation of protein synthesis occurs with more moderate alcohol ingestion. Nevertheless, it is advised that alcohol intake is avoided during the injury due to the potential to suppress the anabolic response in skeletal muscle and increased likelihood of poor dietary choices.

3. Modify dietary intake to player's energy demands

The different phases of injury provide a continuum of altered nutritional needs depending on stage and duration of injury (Collins et al., 2021). During the acute injury phase, it is likely that the players' daily training schedule will be changed or reduced. For sports nutritionists it may be intuitive to reduce the players' energy intake to match the change in energy expenditure. However, this approach may fail to account for the energy expenditure of the players during the acute injury phase and the energy required to fuel the repair process. In a study on Premier League football players, the energy expenditure of an injured player (ruptured anterior cruciate ligament) was reported to be 3,178 Kcal (Anderson et al., 2019). This value of energy expenditure is only marginally lower than the 3,500 Kcal reported from a different player in the same team during a 2-match week (Anderson et al., 2017).



Energy expenditure could be higher during the acute injury phase as a result of the increased energy expenditure of healing (Frankenfield, 2006), combined with the daily early-phase rehabilitation that will be taking place. A case study in a Premier League footballer demonstrated that a large reduction in carbohydrate and total calories resulted in a substantial loss of lean body mass (5.8 kg), which took 8 weeks to regain (Milsom et al., 2014). Such losses in lean mass would not promote accelerating the players return to play. Therefore, drastic reductions in energy intake should be discouraged when players are injured. This advice is to ensure enough energy for repair and to maintain lean muscle mass.

4. Routine physique assessment to monitor changes and adapt the dietary strategy accordingly.

Within professional football, physique management programs regularly assess players body fat and lean muscle mass. There are a variety of methods commonly used for the assessment of body composition, the strengths and weaknesses of each method were discussed in previous courses. The two most common methods include dual-energy X-ray absorptiometry (DXA), and skinfold assessment using International Society of Anthropometry and Kinanthropometry (ISAK) accredited practitioners.

The assessment of body composition is a valuable tool in the return to play process, allowing not only for body fat to be routinely assessed (which will help to evaluate if the player has the correct energy balance), but also to monitor changes of lean muscle mass (table 1). Should DXA be used, it is possible to assess changes in specific regions, i.e. the injured limb versus non-injured limb. The advantage of skinfold measures is that assessments can be performed with greater frequency (weekly), which can help to keep players on track as well as providing valuable consultation time with the player. It is important that players do not become too focused on preventing any increase in body fat, as this may compromise recovery. The sport nutritionist should use player consultations to explain and frame the data correctly, providing appropriate education and support as the player returns to play.

Connective tissue injury

In comparison to muscle, the science of nutritional interventions to improve soft tissue function is in its early development (Khatri et al., 2021). The physiology of tendons and ligaments is different to muscle (Kjaer et al., 2009) due to their limited blood flow. Instead, tendons and ligaments are dependent on nutrient delivery through bulk fluid flow (Baar, 2015). Thus, nutritional interventions to improve connective tissue function may be different and independent to those designed for muscle. Studies *in vitro* have reported that providing the amino acid proline with vitamin C may improve collagen synthesis (Paxton et al., 2010).



The ingestion of gelatine has been reported to be effective in increasing circulating concentrations of the collagen amino acids glycine, proline, hydroxyproline, and hydroxylysine (Shaw et al., 2016). These amino acids are those used in the structure of tendons and ligaments. Furthermore, the ingestion of gelatine (15 g ingested with 50 mg vitamin C) one hour prior to exercise increased blood markers (amino-terminal propeptide of collagen I) related to increased collagen synthesis (Shaw et al., 2016).

Gelatine is a promising nutritional intervention to improve both the function of connective tissues and speed the recovery from musculoskeletal injuries. Nevertheless, more research is needed, especially investigating this intervention in those populations who experience a high incidence of ligament injury, such as female players (Celebrini et al., 2012; Celebrini et al., 2014; De Ste Croix et al., 2015).

Did you know?

The term collagen hydrolyzates is used to describe collagens that have been broken down into small peptides and amino acids in the presence of collagenases and high pressure.

Ingesting collagen amino acids is associated with improving joint functionality and reducing joint pain (Khatri et al., 2021). However, the exact mechanisms are still to be determined. The ingestion of 30 g of whey or collagen protein during recovery from resistance exercise did not increase muscle connective protein synthesis rates during the early stages of postexercise recovery in both male and female recreational athletes (Aussieker et al., 2023). Therefore, ingestion timing may be a key factor. The sports nutritionists should aim to provide 15 g of collagen plus vitamin C, 1 h before rehabilitation exercise. Feedback and dialog with the player is required to determine if this strategy remains as they enter back into full time training.

Concussion

The awareness of concussion (traumatic brain injury) in football is growing. This is due to institutes dedicated to understanding, preventing and treating concussion (for example: Sports Legacy Institute and Boston University; Alzheimer's Disease Center), as well as popular media reporting the concern of parents of juvenile players participating in football. The incidence rate for concussion has been reported to be 1 per 1000 playing hours for men and 3 per 1000 player hours for women (Dvorak et al., 2007; Muñoz et al., 2015; Drobic et al., 2016). Thus, in comparison to muscle injuries, the incidence of concussion in football is low (Faude et al., 2017). Nevertheless, players, coaches, and medical staff should be aware of the signs, symptoms, and evaluative techniques of concussion (Delaney et al., 2002; Broglio et al., 2010).



A concussion is characterised by any alteration in cerebral function caused by a direct or indirect force transmitted to the head (Delaney and Frankovich 2005; Delaney et al., 2014; Partridge, 2014). It is important that both players and staff recognise the symptoms of concussion, which may include one or a combination of:

- a brief loss of consciousness,
- light-headedness,
- cognitive and memory dysfunction,
- vertigo,
- tinnitus,
- blurred vision,
- concentration difficulties,
- amnesia,
- headache,
- nausea - vomiting,
- sensitivity to light,
- loss of balance.

In February 2021, the law of the game was changed to allow the referee to stop a match for a potential concussion injury to a player. The medical staff of that player's team are allowed to enter the field to make an assessment. A separate doctor located in the stadium will review video footage of the incident. The team doctor will have as much time as is required to make an on-pitch clinical assessment of the player. If there are clear symptoms of concussion, or the video provides clear evidence of concussion, the team will be permitted to replace the player with an additional permanent concussion substitution. The substituted player will not be allowed to return to the field of play. Each team is permitted to use a maximum of two concussion substitutions in a match.

Delayed symptoms of concussion may also be evident through fatigue, personality changes, depression, lethargy and sleep irregularities (Aubry et al., 2002; Delaney and Frankovich, 2005). Full pathology of concussion is beyond the scope of this module. However, any player who experiences concussion or has a history of concussion should report this to their medical team.



There is little evidence regarding nutrition interventions and concussion. To date, nutrition recommendations are based on results from rodent studies which have provided antioxidant and anti-inflammatory compounds (Mills et al., 2011; Tipton, 2015) as well as recent studies investigating the remodelling and restorative processes of long term cognitive function (Pu et al., 2016). Based on the available literature, firm nutritional guidelines cannot be made. Although various dietary supplements may be considered, the two main compounds currently under investigation and of interest are omega 3 fatty acids and creatine (Ashbaugh and McGrew, 2016).

High dosages of omega 3 fatty acids (5 g per day) may improve the short term outcomes following concussion (Lewis, 2016). This may be achieved via neurite growth, increased neurite branching, and subsequent synaptogenesis, resulting in enhanced synaptic function and improved neuronal repair after head injury (Kim and Spector, 2013). Furthermore, supplementation with omega 3 fatty acids prior to sustaining a concussion may protect against reduced plasticity of neurons and impaired learning (Wu et al., 2011). Omega 3 fatty acid ingestion has been reported to normalise levels of proteins associated with neuronal circuit function and locomotor control after sustaining a concussion (Wu et al., 2011).

Creatine monohydrate supplementation can increase the brain's creatine stores (Candow et al., 2023) and can improve cerebral energetics (Pan and Takahashi, 2007; Turner et al., 2015). This may result in improved cognition, communication, self-care, personality, and behaviour (Sakellaris et al., 2006), whilst significantly reducing the magnitude of symptoms such as headaches, dizziness and fatigue following traumatic brain injury (Sakellaris et al., 2008). Although further research is required, creatine may serve as a neuroprotective supplement following concussion (Dolan et al., 2019). The sports nutritionist should work with the medical team to identify those players with a history of concussion or higher risk of concussion to determine if low dose creatine supplementation (3g per day) is warranted during the season. If not supplementing with creatine for performance purposes, loading protocols (20 g a day for 5 days) may be considered for players following a concussion.

Interdisciplinary approach

The process and duration required for a player to return to training and matches following a time loss injury is complex and will depend on the classification of injury (Valle et al., 2016). An effective way to speed the players' return to play is for the club's medical team to adopt an interdisciplinary approach. To facilitate this, members of the multidisciplinary team should understand the relative importance, perspectives and contributions of the other disciplines (Rollo et al., 2021). Thus, it is crucial that the sport nutritionist integrates with the entire support team. For example, the nutritionist should speak with the medical staff about the intensity of the rehabilitation programme and gain as much information as possible on training load from the conditioning staff. During the return to play process,



nutrition support and guidance is critical. However knowing when to intervene and when to 'back-off' is a softer skill which may be learnt either through experience or sought through guidance from other professionals (e.g. sports psychologist). Working with a football player during a time of injury requires an understanding of the player and their personality. During the return to play process weekly meetings with the sports nutritionist, physical trainer, sport psychologist and medical doctor are recommended to facilitate the player's recovery. Examples of an interdisciplinary approach integrating sports nutrition and sports psychology principles is displayed in table 2.

Table 2. Examples of how sports nutrition and sports psychology may synergistically support the injured player

Injured player considerations	Sports Nutrition / Sports Psychology interdisciplinary example
Acute injury phase	Dietary intake and supplementation plan as an action to achieve sense of control over the injury situation
Physique management	Routine body composition analysis provides short-and-long term goal setting targets
Inactivity	Meals providing structure to day, avoid episodes of reduced self-worth and binge eating
Social isolation /inclusion	Inclusion of players on team eating occasions and having players complete rehabilitation alongside teammates who are training to maintain sense of identity
Role models	Establish a "mentor" programme between injured player and role model who successfully overcame similar injury Sharing of previous experience of both



	sports nutrition and sports psychology strategies that “helped” the player return to football will help facilitate rehabilitation adherence
Readiness	<p>Nutrition provided prior to exercise and education enhances players' understanding of their body to facilitate confidence and enhance psychological readiness (confidence, emotions, risk appraisals, approach-avoidance motivations)</p> <p>Players gain confidence following consistent pre-exercise nutrition strategies</p> <p>Education also serves to inform about best sources of information (avoid unqualified advice from internet/social media)</p>

Source: own elaboration based on Rollo et al., 2021.

Summary

- The process and duration required for a player to return to training and matches following a time loss injury is complex and will depend on the classification of injury.
- Four sports nutrition priorities are the following.
 1. Manage the inflammatory response.
 2. Attenuate muscle atrophy and encourage muscle repair.
 3. Modify dietary intake to the player's energy demands.
 4. Routine physique assessment to monitor changes and adapt the dietary strategy accordingly.
- Ingesting gelatine (15 g + Vit C) one hour before exercise may be considered to support connective tissue remodelling.



- The sports nutritionist should be a member of the interdisciplinary team, responsible for the players' return to play.

Unit 2.2 In-season sports nutrition recovery strategies

At the final whistle, the player's body enters a phase of recovery, during which energy supplies are restored (glycogen), fluids are replaced (sweat) and repairs are made in the musculoskeletal system. Although appropriate nutrition strategies are required to speed recovery and adaptation following each training session or match, there may be specific times during the season where additional dietary strategies should be considered. For example, professional football players may be required to play up to three matches in a week, for several weeks in a row. Often periods of fixture congestion coincide with critical times of the season, i.e. playing for cups, league titles or avoiding relegation. Playing multiple matches in a week, combined with factors such as frequent travel, may negatively influence a player's physical performance (Rollo et al., 2010).

Successful recovery from training and matches is a complex process. The numerous factors, which influence recovery are not independent, but interact. In professional football, the allocation of financial resources will determine the facilities, as well as access to experienced sports medical/science professionals to lead the recovery programme. The objective of in-season recovery is to maintain a player's physical and mental readiness to perform in the next match. Optimal recovery provides the benefit of allowing players to maintain high-level training and match performance. Conversely, inadequate recovery may result in sub-optimal performance and increased risk of illness and injury.

Nutrition is one of many variables that can impact a player's recovery. Others include sleep (Module 1), travel, training load and physical therapies (Nedelec et al., 2012; Nedelec et al., 2013). For the sports nutritionist, the priority is to deliver the fundamentals of sports nutrition. However, once the basics are in place, there are other dietary strategies, which could be considered during these intense in-season periods. The sports nutritionist should also seek opportunities to integrate sports nutrition strategies to complement the other recovery modalities being used by the players.

Muscle damage

Football-specific activities can result in exercise-induced muscle damage. Muscle damage in football can be caused by both mechanical and biochemical processes. The mechanical damage is a result of explosive and/or eccentric muscle contractions, which can disrupt the contractile properties of the muscle (Belcastro et al., 1998). Muscle contractions, such as those experienced during football, promote the production of free radicals in the active skeletal muscles. The magnitude of free radical production in the



working muscles will increase with both the intensity and duration of exercise (Powers et al., 1999). Free radicals are molecules with an unpaired electron in their outer shell. They are a highly reactive chemical species capable of damaging components of muscle such as proteins and lipids (Powers et al., 1999). This is referred to as exercise-induced oxidative stress.

The muscle damage experienced in football, whether mechanical or biochemical, triggers inflammatory responses (Michailidis et al., 2013). This inflammation may increase the perception of pain after exercise, commonly known as Delayed Onset Muscle Soreness (DOMS) (Ascensao et al., 2008). The DOMS experienced by the player typically peaks approximately 48 hours after exercise (Betts et al., 2009). This timeline of recovery response is problematic, especially mid-season when players may be required to perform every 72 hours and train in the days before.

Studies have reported that the rate of muscle glycogen resynthesis may be slowed following competitive high-intensity intermittent exercise, such as a football match. The reduced rate of glycogen synthesis after muscle-damaging eccentric contractions has been associated with reductions in GLUT 4 content and translocation, as well as reduced glucose uptake. Two days (48 hours) after a match, muscle glycogen stores have been reported to be lower than pre-match concentrations, despite the ingestion of a high carbohydrate diet (Bangsbo et al., 2006; Krstrup et al., 2011). It is known that football-specific movements, i.e. the frequent changes in direction and decelerations from sprints, have a high eccentric component. The impaired glycogen resynthesis is likely a consequence of the muscle damage caused by the eccentric contractions and the physical contact/collisions between players (Krstrup et al., 2011). This is particularly important because exercise with muscle damage may increase glycogen utilisation, thus making glycogen loading before exercise even more important (Hughes et al., 2013).

It has been reported that muscle damage-induced reduction in glycogen resynthesis is not alleviated by a diet high in carbohydrate and whey protein (Gunnarsson et al., 2013). This is despite certain amino acids having a potent effect on the secretion of insulin, which is a stimulator of glycogen resynthesis (van Loon et al., 2000). Nevertheless, recovery goals should also focus on the immune system, muscle building and injury repair. Therefore, players should still be encouraged to follow guidelines and eat nutrient-rich forms of carbohydrate foods and drinks during the recovery period to provide a range of valuable macro and micronutrients (Betts and Williams, 2010) (figure 1).

Figure 1. Recovery smoothies provide a great option to provide nutrient rich foods whilst delivering the key macronutrients





Source: own elaboration.

The basics

The priority for the sports nutritionist is to ensure that players are meeting the guidelines for macronutrient and fluid intake. Nutritional aspects of recovery covered in this course have focused on the macronutrients. Carbohydrates are required for glycogen restoration, to reduce fatigue and to support the players' physical and immune health. A low intake of carbohydrate during the days of repeated exercise will result in a gradual depletion of muscle glycogen stores and impairment of endurance exercise performance (Costill et al., 1971; Nevill et al., 1993). If competition or training is intense, this may increase the risk of injury (Achten et al., 2004; Halson, 2013; Nedelec et al., 2015). Proteins are required for adaptation and to promote muscle remodelling. Fluids and electrolyte ingestion are required to replace losses as a consequence of sweating. All these factors are fundamental in the recovery of the player and preparing them for the next match or training session. These sports nutrition recovery fundamentals are often referred to as the "3 Rs"—Rehydrate, Rebuild, Refuel. The "3-R's" will help players to sustain their level of performance over the duration of a competitive season.

Key point

The priority for the sports nutritionist is to make sure the players do the basics well.

Dietary antioxidants

To protect against free radical-induced damage, muscle fibres and other cells synthesise various endogenous antioxidant molecules as a mechanism to "scavenge" free radicals and prevent/limit oxidative damage. Of relevance to the sports nutritionist, these endogenous antioxidants can be supported by antioxidants obtained in the player's diet (exogenous antioxidants). The dietary antioxidants can assist the endogenous system to produce a network of protection against free radical-mediated damage. Good dietary sources of antioxidants include most fruit and vegetables. Thus, those players meeting

energy requirements through a variety of foods should be ingesting sufficient dietary antioxidants.

Did you know?

A free radical “scavenger” refers to the ability of the antioxidant to dispose of free radicals.

Vitamin E is a fat-soluble vitamin and protects cell membranes against free radical-mediated damage (Traber and Stevens, 2011). Under most dietary conditions, the concentration of vitamin E in tissues is relatively low. However, vitamin E deficiency has been shown to impair muscular endurance and alter muscle contractile properties during exercise (in rodents) (Coombes et al., 2002). Vitamin E levels in the tissues can be elevated with dietary intake. As vitamin E is fat soluble, ingesting large doses is discouraged; excessive vitamin E can result in toxic levels and gastrointestinal distress. The Recommended Daily Allowance (RDA) of vitamin E is 15 mg/day (22 International Units). During intense periods of the season, vitamin E intake can be achieved by ingesting foods such as sunflower seeds, almonds, hazelnuts, and peanuts. A good way to incorporate these foods is to add them as toppings to the players' morning oats or yoghurts. Vitamin E is also found naturally in olive oil and sunflower oil.

Vitamin C (ascorbic acid) is a water-soluble vitamin. As an antioxidant, vitamin C performs two key functions. First, vitamin C can directly scavenge free radicals. Secondly, vitamin C plays an important role in recycling vitamin E. Therefore, vitamin C and E work together to protect the cell against radical-mediated damage (Traber and Stevens, 2011). The RDA for vitamin C is 90 mg for males and 75 mg for females. Specific dietary supplementation is not required, instead during periods of fixture congestion, the sports nutritionist should ensure players eat fresh citrus fruits and green vegetables daily.

Polyphenols are found in plants-based foods. There are many types of polyphenols that are involved in a diverse range of processes including growth, pigmentation, pollination and resistance to environmental stress (Bowtell and Kelly, 2019). Flavonoids are a large family of polyphenols. At present, the antioxidant properties of many naturally occurring flavonoids have not yet been investigated. Nonetheless, those flavonoids, such as catechins and quercetin, that have been studied have been shown to possess both anti-inflammatory and antioxidant properties (Bowtell and Kelly, 2019).

Carotenoids are natural pigments synthesised in numerous plants and are responsible for the bright colors found in many fruits and vegetables (Paiva and Russell, 1999). There are various types of carotenoids in the foods that we eat, and the majority of these carotenoids have antioxidant activity. Carotenoids are fat soluble antioxidants and, because of their location in cell membranes and their radical scavenging capacity,



carotenoids are efficient biological antioxidants to protect against free radical-mediated damage to cell membranes (Krinsky, 1998).

Did you know?

The balance between antioxidants and oxidants is commonly referred to as the redox balance.

Examples of dietary sources of polyphenols are the following.

- grapes
- caffeic acid–coffee
- gallic acid–tea
- seeds, whole grains, legumes
- cocoa
- green tea
- onions, apples, deep green vegetables
- parsley and other herbs
- citrus fruits
- soy products
- cherries and berries
- cocoa
- pomegranate
- mango

Did you know?

Providing the players with daily “smoothies” which contain fruits and raw vegetables is an effective way to boost the antioxidant content of a player’s diet.

Antioxidant impact on exercise and recovery

Free radicals, although involved in muscle damage, are also important signalling molecules for adaptations to occur in the skeletal muscle (Mankowski et al., 2015).



Therefore, ingesting large amounts of dietary antioxidants may blunt the adaptive processes that free radicals promote (Gomez-Cabrera et al., 2015). However, some studies have shown no detrimental effect of dietary antioxidants on endurance type adaptation to exercise. These contrasting results between studies may be due to a difference in baseline antioxidant status of participants, the type and quantity of antioxidants ingested, and varied exercise training (Mankowski et al., 2015).

In general, sustained long-term dietary supplementation with antioxidants is not recommended for football players and may be detrimental to training adaptations (Braakhuis and Hopkins, 2015). Therefore, dietary supplementation with antioxidants may be avoided when adaptation is a focus, such as during pre-season, but considered when recovery becomes the key objective (in-season). This is because studies have reported a beneficial effect of dietary sources of antioxidants, such as fruits and vegetables on recovery.

Concentrated beetroot juice is most commonly ingested for its potential to benefit performance but ingesting beetroot juice may also support aspects of exercise recovery (Zoughaib et al., 2024). Indeed, ingesting nitrate-rich beetroot concentrate can attenuate physical performance decreases in the days following matches (Abreu et al., 2023). In team-sport players, ingestion of beetroot juice in the 3 days following a repeated sprint test reduced the loss of muscle function and soreness (Clifford et al., 2016; Clifford et al., 2016). Furthermore, six days of concentrated beetroot ingestion (140 ml) improved high-intensity intermittent type exercise performance (Yo-Yo IR1) in trained football players, in comparison to a placebo (Nyakayiru et al., 2017).

Therefore, ingesting between 140 ml and 280 ml of concentrated beetroot juice (providing approximately 8.4-16.8 mmol of nitrate) in the days before and between matches could be integrated into in-season recovery strategies. This can be achieved by providing shots of beetroot juice at meal time occasions and with the pre-match meal on match days. In addition, nitrate-rich vegetables such as beetroot, rocket salad and spinach can also be added to the players' recovery smoothies, which will also increase the players' plasma nitrate and nitrite concentrations (Jonvik et al., 2016).

Did you know?

Concentrated beetroot juice has a unique flavour and may not be to all players' taste preferences. Protein shakes or smoothies provide a great vehicle to add additional nutrition interventions such as beetroot juice concentrate, or nitrate rich vegetables to help mask the taste.

There is also emerging evidence that antioxidant rich fruits such as tart cherry (Connolly et al., 2006), pomegranate (Ammar et al., 2018) and blackcurrant (Godwin et al., 2017) may benefit player recovery. Of particular interest is tart cherry, which has been reported to



reduce markers of inflammation, decrease perceptions of soreness, and improve redox balance compared with placebo after exercise (Bell et al., 2016; Levers et al., 2016). In one study, semi-professional male soccer players consumed 30 ml of tart cherry concentrate for five days prior to and three days after an adapted version of the Loughborough Intermittent Shuttle Run Test (LIST). In comparison to the placebo, indices of performance (running, jumping) recovered faster, and muscle soreness (DOMS) ratings were lower following the ingestion of tart cherry. In addition, the ingestion of tart cherry concentrate attenuated the acute inflammatory response (Bell et al., 2016). These results would indicate that the sports nutritionist can consider preparing the players for periods of fixture congestion by introducing tart cherry ingestion, 5 days prior to the first fixture of the week.

Did you know?

Tart cherry concentrate can be added to the player's diet in various ways such as within morning yoghurts pots, protein shakes or milk-based drinks prior to sleep.

Although antioxidant ingestion is a promising in-season recovery strategy, further research is required to provide definitive guidelines for the impact different antioxidants may have on player recovery. Overall, ingesting a well-balanced diet including fruits and vegetables will achieve an adequate level of antioxidants. It is important to emphasise that to-date there is no evidence that eating fruit and vegetables will blunt any football-induced exercise adaptations (Close et al., 2016). The ingestion of food is favourable to dietary supplementation. However, it is not always possible to ingest the quantities of food required to deliver an efficacious dose of a functional ingredient (Close et al., 2022).

Curcumin

Curcumin is a component of the spice turmeric and is often used in clinical settings to reduce inflammation (Santos-Parker et al., 2017). The mechanism by which curcumin exerts its effect may be related to its ability to inhibit inflammation (Menon and Sudheer, 2007). Dietary supplementation with curcumin may therefore be of interest to players seeking an alternative to anti-inflammatory medications to reduce inflammation and muscle soreness. To increase the bioavailability of curcumin, it is important to co-ingest it with black pepper. Studies have shown that the bioavailability of curcumin may be increased twenty fold by co-ingesting the curcumin with piperine, a compound found in black peppercorns (Patil et al., 2016).

In one study that provided 5 g of curcumin a day, participants reported reduced sensations of pain associated with DOMS (Nicol et al., 2015). Correspondingly, systemic markers of muscle damage were reported to be reduced by 48 %, when 400 mg a day of highly bioavailable curcumin was ingested 2 days before and 4 days after a high-intensity, muscle damage-inducing protocol (McFarlin et al., 2016).



In football, the daily ingestion of 270 mg of curcumin has been shown to reduce inflammation during the pre-season period in professional women's players (Choi et al., 2023). Whilst during the season, when professional players consumed 60 mL of a turmeric drink twice per day, biomarkers of inflammation and subjective measures of muscle soreness were reduced post-match in comparison to the ingestion of a placebo (Clayton et al., 2023).

Although most studies have investigated daily doses of curcumin, acute ingestion protocols immediately post exercise may also have an impact on attenuating muscle soreness (Tanabe et al., 2019). In a study in male professional football players, the ingestion of 500 mg of curcumin ingested within 36 hours after a match, attenuated DOMS and muscle function deficits (Abbott et al., 2023). However, ingesting acute lower doses (150 mg) may not be sufficient to achieve such recovery benefits (Tanabe et al., 2024). These results support that ingesting curcumin may alleviate the degree of inflammation and may reduce some of the performance deficits associated with post match fatigue/exercise-induced muscle damage.

Did you know?

Players can ingest curcumin in their diet by adding turmeric to daily meals. Turmeric is typically included in many curry dishes and the sports nutritionist should work with the club chef on how best to incorporate the ingredient into the meal plans. However, many studies provide a dose of curcumin that would be difficult to achieve through dietary means. Therefore, the sports nutritionist should follow dietary supplementation guidelines detailed in previous courses, if considering this intervention.

Fish oil

Omega-3 polyunsaturated fatty acids are essential fatty acids that are consumed in the players' diet through the ingestion of foods such as cold-water fish and fish oils, where they are highly concentrated. Omega-3 fatty acids have been reported to have anti-inflammatory properties and so could be considered as a nutrition strategy for in-season recovery (Rawson et al., 2018).

This concept is supported by studies that report eccentric, exercise-induced DOMS was reduced following the ingestion of 3 g of omega-3 a day for 7 days (Jouris et al., 2011). However, not all studies have reported this, and the eccentric resistance exercise models used in studies to induce DOMS are unlikely to be relevant to football players (Gray et al., 2014, Mackay et al., 2023).

Although there is limited information on the effect of n-3 polyunsaturated fatty acids on football players, dietary supplementation could also offer practical means of enhancing



post-match recovery (Ranchordas et al., 2017). One study investigated the influence of adding omega 3 to a protein recovery beverage (whey protein, leucine and carbohydrate) over a 6-week period. The additional fish oils equated to approximately 1 g per day. In this study, football players were monitored for physiological markers of recovery 3 days following eccentric exercise, which consisted of knee extensor resistance exercise. It was reported that players who ingested the additional fish oils had lower subjective muscle soreness and markers of muscle damage in comparison to those players who ingested carbohydrate/protein alone. However, it is important to note that although perceived soreness was improved, there was no difference in muscle function or football-specific performance between groups (Philpott et al., 2018).

Cramping

It is highly likely that football players will experience muscle cramp at some stage during their career. Players experience a temporary, intense and painful, involuntary contraction of skeletal muscle. Cramp may be defined as a “painful, spasmodic contraction of the skeletal muscle that occurs during or immediately after muscular exercise” (Schwellnus et al., 1997). In football, players may experience cramps at any stage during exercise, although it appears most prevalent towards the end of the 90 minutes, and especially if the match enters extra time. This is evident when you watch a match and players typically drop to the ground and request a teammate or physical trainer to stretch the afflicted muscle.

Anecdotally, risk of cramping is increased in fatigued players or when players compete multiple times in a week. Furthermore, cramp appears more prevalent when the match duration goes beyond the duration to which players are conditioned, or played in an environment to which players are not acclimated. The occurrence of exercise associated muscle cramps are due to a combination of unique intrinsic and extrinsic factors rather than a singular cause (Miller et al., 2022).

Unfortunately, exercise associated muscle cramping is notoriously unpredictable. The sports nutritionist should be aware that there will likely be a host of cramp remedies that will be offered by either the coach, teammates or family members. Much of this advice will be based on previous experiences or anecdotal hearsay. It is important to note that the precise mechanisms responsible for cramps are unknown. There are different types of cramp, and so they are likely to be stimulated by different mechanisms. There is evidence that some cases may be associated with disturbances of water and salt balance, while others appear to involve sustained abnormal spinal reflex activity secondary to fatigue of the affected muscles. The evidence in favour of a role for hypohydration comes largely from medical records obtained in large industrial settings, although it is supported by one large-scale intervention trial and by field trials involving a small number of athletes (Maughan and Shirreffs, 2019).



Interestingly, the ingestion of pickle juice in situations where players report cramps has become a popular nutrition intervention. The hypothesis being that the electrolyte rich fluid is able to rapidly replenish any electrolyte imbalance in the muscle (Abreu et al., 2020). However, if we consider the digestion and absorption of fluids, covered in previous modules, any such effects of pickle juice more likely due to a central response. Potentially, pickle juice triggers a reflex in the mouth, which reduces the motor neuron activity, responsible for muscle innervation in the brain (Miller et al., 2010). Nonetheless, the key point is that the ingestion of pickle juice will not prevent players cramping. However, pickle juice may reduce the duration of cramping symptoms. Whether this intervention would be superior to simply ingesting a readily available carbohydrate-electrolyte beverage is still to be determined.

To this end, for the sports nutritionist, the prudent advice would be to avoid fatigue in the skeletal muscle through the ingestion of carbohydrate, ensuring the player is hydrated and replacing electrolyte losses between training and matches.

Recovery interventions

Recovery strategies are a fundamental component of the players health and performance. The recovery process completed during the season presents frequent opportunities for the sport nutritionist to engage with the player, as well as the sports medicine department. Recovery interventions and their effects on fatigue, muscle injury, recovery and performance are well documented (Altarriba-Bartes et al., 2020). Thus, where possible sports nutrition recommendations should be taken in context and used synergistically with other effective recovery approaches such as foam rolling, ice baths, sleep, compression garments and massage.

To speed player recovery and reduce muscle soreness clubs may utilise various physical therapies. Common therapies involve the use of water (hot and cold) and cryotherapy. Cryotherapy and ice baths have become common strategies that are used by football teams. As cryotherapy has a vasoconstrictive effect, there has been concern that glycogen resynthesis could be impaired by using these interventions. This would be a result of a reduction in blood flow to the muscle, reducing the availability of glucose.

Immersing the whole body or lower body in cold water (10-15 °C) for 5-15 minutes, following exercise is used to reduce the players perception of muscle soreness and to speed the restoration of physical performance (Bailey et al., 2007). Ten minutes of lower limb cold water immersion (8 °C), following exhaustive exercise, has been reported to not impair glycogen restoration, in comparison to being seated at rest, when appropriate quantities of carbohydrate were ingested (Gregson et al., 2013). Thus, cryotherapy may not impact glycogen resynthesis.



The impact of post exercise cold water immersion of the muscle adaptive response has been investigated in male athletes (Fuchs et al., 2020a). In this study participants completed a single resistance-type exercise session followed by water immersion of both legs for 20 min. One leg was immersed in cold water (8 °C), whereas the other leg was immersed in thermoneutral water (30 °C). Participants ingested 20 g of protein post exercise. It was found that cold-water immersion during recovery reduced myofibrillar protein synthesis rates and, as such, is likely to impair muscle recovery. Interestingly, a follow up study by the same research group reported that postexercise hot-water immersion (46 °C) during recovery from a single bout of resistance-type exercise did not further increase muscle protein synthesis rates compared to thermoneutral water immersion (Fuchs et al., 2020b).

The available literature highlights the balance that should be considered when planning in-season recovery programs. Although cold water immersion may reduce muscle protein synthesis, the intervention still benefits players' perception of muscle soreness and recovery. Therefore, this recovery intervention is still valid during specific periods of the season. When completing water therapies the players are a captive audience, allowing recovery beverages to be easily provided.

Overview

The risk of impaired performance and injury is significantly increased when playing multiple matches in a week during a competitive season. Under these circumstances (a recovery period under 72 h) it is recommended to increase the emphasis on optimal nutritional recovery strategies. This can begin by the restoration of muscle glycogen after exercise, achieved by ingesting approximately 60 g of carbohydrate per hour during the first 2-3 hours (Ivy et al., 1988; Rollo, 2014). Protein intake is recommended immediately post-exercise (~20-30 g), together with appropriate volumes of fluid to rehydrate (Laitano et al., 2014). Overall, a nutrient-dense diet consumed throughout the day, in combination with a selected sports nutrition strategy (tart cherry, dietary nitrate, curcumin, omega 3), can support the players in-season recovery objectives. Players should always seek professional advice before adopting dietary supplementation strategies with the intent to improve recovery in season.

It is important for the sports nutritionist to recognise that the recovery strategy adopted by a club will depend on the expertise of the practitioner (e.g., coach, trainer, sports nutritionist, sports psychologist) responsible for the players recovery. Therefore, the sports nutritionist should aim to understand this approach and integrate nutrition as appropriate. Ideally, the sports medical team should be educated on the benefits of nutrition so that strategies can be reinforced. The sports nutrition options listed in this module may be considered both as a squad wide intervention or ideally on an individual player basis. It is recommended not to use all suggested dietary interventions at once. Instead, being targeted on one or two approaches, at specific times in the season may



have a greater impact. This will also help in players' understanding why they are eating specific foods and allow a better evaluation of the effectiveness of a dietary intervention. As such, recovery programs should take a player-centred approach. Players should be empowered to understand and lead in the planning of their own recovery schedules. How the sports nutrition strategy is framed/explained to the player will have a powerful influence on its effectiveness and player adherence.

Summary

- Muscle damage in football can be caused by both mechanical and biochemical processes.
- The main factors, which can speed a player's recovery are sufficient rest and nutrition.
- The fundamental nutrition recovery strategies involve carbohydrate, protein and fluid.
- Introducing specific sports nutrition strategies (beetroot juice, tart cherries, omega-3 fatty acids, curcumin) may be advantageous during the season when recovery is paramount, such as when a player is required to play multiple matches in a week.



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