2.1 The days and weeks before

2.1.1 The important role of glycogen

This module is all about match day. How do you prepare for match day and what does a player need to do on match day. It will combine some of the science we discussed (especially in the section about recovery) but also discuss some of the practical aspects. Sometimes there is significant evidence in literature and the recommendations are fairly clear but the practical application can be very complicated. At that point one can argue how relevant or how useful these guidelines are if they are actually very difficult to achieve in real life. The counter argument will be that if the player is really determined to influence his or her performance then it should be trying to meet these guidelines as closely as possible.

The physical demands of football have been described in several papers. An elite football player typically covers 10-13 km in a 2 x 45 min match, with ~ 600m of this being covered at full sprint speed. Over the duration of the match, heart rate is maintained at ~85% of maximum (70%VO_2max) (Bangsbo, Mohr, & Krustrup, 2006), equating to an energy expenditure of around 1,600 kcal (Bangsbo, Norregaard, & Thorso, 1991). On match days energy expenditure is around 3500 kcal at the elite level (Anderson, Orme, et al., 2017) and is likely to be around 3000 kcal at lower levels. This is comparable to efforts in many endurance sports. However, performance is determined not only by running ability, but also by ball possession, skill performance and cognitive functioning (timing, reaction time, decision making). Analysis of data from all German Bundesliga teams across the season 2012/13 (306 matches) showed that match running performance alone was not significantly correlated with the final points accumulated. Rather, success corresponded to the relationship between match running performance and technical/tactical skills involved with ball possession (Hoppe, Slomka, Baumgart, Weber, & Freiwald, 2015).

Minimising fatigue relative to the opposing team is an important strategy in modern football, since most goals are conceded in the last few minutes of each half and are attributed to fatigue. Although fatigue reduces both skill and running performance (Bangsbo et al., 2006; Bangsbo et al., 1991; Mohr & Krustrup, 2013; Mohr et al., 2010; Russell & Kingsley, 2011), appropriate nutrition can address many underpinning factors and particularly the two main contributors: carbohydrate depletion and dehydration.

Preparation for a match usually starts with the recovery from the previous match.

> A football match has been shown to reduce muscle glycogen significantly or even deplete it. In a classic study, Saltin (1973) showed that muscle glycogen concentrations were 96, 32 and 9 mmol/kg wet weight muscle before, at halftime and after a 90-minute match. Furthermore, it was shown that a reduction in muscle glycogen content correlated with total distance covered and less sprints. If glycogen is increased through an increase in the amount of carbohydrate in the diet, players can run faster and further (Bangsbo, Nørregaard, & Thorsøe, 1992). Clearly, replenishment of carbohydrates should be the main focus of recovery and exercise capacity. Research has been performed on the type, amount and timing of carbohydrates and the addition of protein for optimal muscle glycogen recovery. (Res, 2014, p. 1).

But in order to develop the best strategies to optimise glycogen restoration, it is important to have an understanding of the mechanisms underlying glycogen synthesis. This is discussed in more detail in the module on recovery, but this section contains a quick recap.

> The effect of muscle glycogen content on fatigue resistance is most apparent during prolonged (>1 h) exercise, but also established during high-intensity intermittent exercise. Accordingly, high pre-exercise muscle and liver glycogen concentrations are believed to be essential for performance. Muscle glycogen content is approximately 300– 400 mmol glycosyl units/kg dw in untrained subjects, and increased in trained subjects, who have up to 800–900 mmol glycosyl units/kg dw (Pernow & Saltin, 1971). During exercise, the rate of glycogen utilization is in the order of 0.6 to 3.6 mmol glycosyl units/kg dw/min at 50% and 100% VO_2max, respectively, and can increase to 30–50 mmol glycosyl units/kg dw/min during maximal dynamic or static contractions. (Ortenblad & Nielsen, 2015, pp. 34-35).

Thus, it is not difficult to imagine that over the course of say 90 min or less, muscle glycogen stores can become depleted.

Although the mechanisms behind the performance decrements with low glycogen are not completely understood, there are probably two main reasons why muscle glycogen is so important to performance. First, it is simply an energy source, like fuel in a car.

However,

> in addition to providing a substrate for ATP production, glycogen availability (especially the intramyofibrillar storage pool) has also been shown to directly modulate contractile function. Recent studies from Ørtenblad and colleagues (Ortenblad & Nielsen, 2015) have demonstrated the preferential utilization of the intramyofibrillar storage pool during exercise in a manner that also correlates with impaired Ca2+ release from the sarcoplasmatic reticulum. (Impey, 2017, p. 26).

Skeletal muscle fibres are highly organized cells where organelles and inclusions are arranged in order to obtain an efficient excitation-contraction (E-C) coupling and its resulting energy production and delivery. In the last few years it has become apparent that glycogen particles are stored in different locations serving different tasks. In particular, the intramyofibrillar particles seem to be important for Ca^{2+} release from the sarcoplasmatic reticulum and, in turn, normal E-C coupling (Ortenblad & Nielsen, 2015).

2.1.2 Optimising glycogen stores

Although there is still a lot to learn about the exact mechanisms of how glycogen affects performance, there is consensus about the fact that muscle glycogen is a key factor. Therefore, it is important to start exercise with relatively high glycogen concentrations and to avoid low glycogen concentrations at all cost.

In order to optimise glycogen synthesis it is important to understand the factors that affect it:

1. The availability of glucose; this includes
    a. the ingestion
    b. gastric emptying
    c. the absorption
    d. the extraction of glucose (or other sugars) by the liver, and
    e. blood flow

2. The transport of glucose into the cell, which in turn depends on

    a. Prior exercise (exercise stimulates glucose uptake for 1–2 hours post-exercise and increases insulin sensitivity),
    b. Insulin concentration (high insulin stimulates glucose uptake), and
    c. Muscle glycogen content (low muscle glycogen stimulates glucose uptake); and

3. The activity of enzymes (in particular glycogen synthase), which also depends on insulin concentration (high insulin stimulates glycogen synthesis)
4. The extent of muscle damage and inflammation. Through yet unknown mechanisms this seems to slow down muscle glycogen resynthesis (Costill et al., 1990; Doyle, Sherman, & Strauss, 1993; O'Reilly et al., 1987; Widrick et al., 1992; Zehnder, Muelli, Buchli, Kuehne, & Boutellier, 2004). (Jeukendrup & Gleeson, 2018, https://bit.ly/2UENOq7).

As a result of the changing activity of these enzymes and the effectiveness of these transport mechanisms, two phases can be distinguished in the process of glycogen synthesis after exercise

1. The initial insulin-independent, or rapid phase and
2. The insulin-dependent, or slow phase. (Jeukendrup & Gleeson, 2018, https://bit.ly/2UENOq7).

From a practical point of view, it means that we should use the hour following exercise to start replenishing muscle glycogen, but in preparation for a match, the overall carbohydrate intake is going to be the key factor.

Making sure muscle glycogen stores are full on the day of the match is a function of carbohydrate intake on the one hand and carbohydrate use on the other hand, and the latter is of course dependent on training. Especially when two matches are played within a seven day period it may be challenging to replenish muscle glycogen.

> Krustrup et al. (2011) showed that even when players were given a carbohydrate-rich diet, it took up to 72 hours before glycogen stores were fully replenished. Many years earlier, Jacobs, Westlin, Karlsson, Rasmusson and Houghton (1982) had already shown incomplete recovery after 48 h with a daily carbohydrate intake of 8 g/kg body mass in professional players. In contrast to these football-specific studies, well-trained endurance athletes have been shown to be able to supercompensate muscle glycogen in just 24 to 36 h (Bussau, Fairchild, Rao, Steele, & Fournier, 2002). (Res, 2014, p. 1).

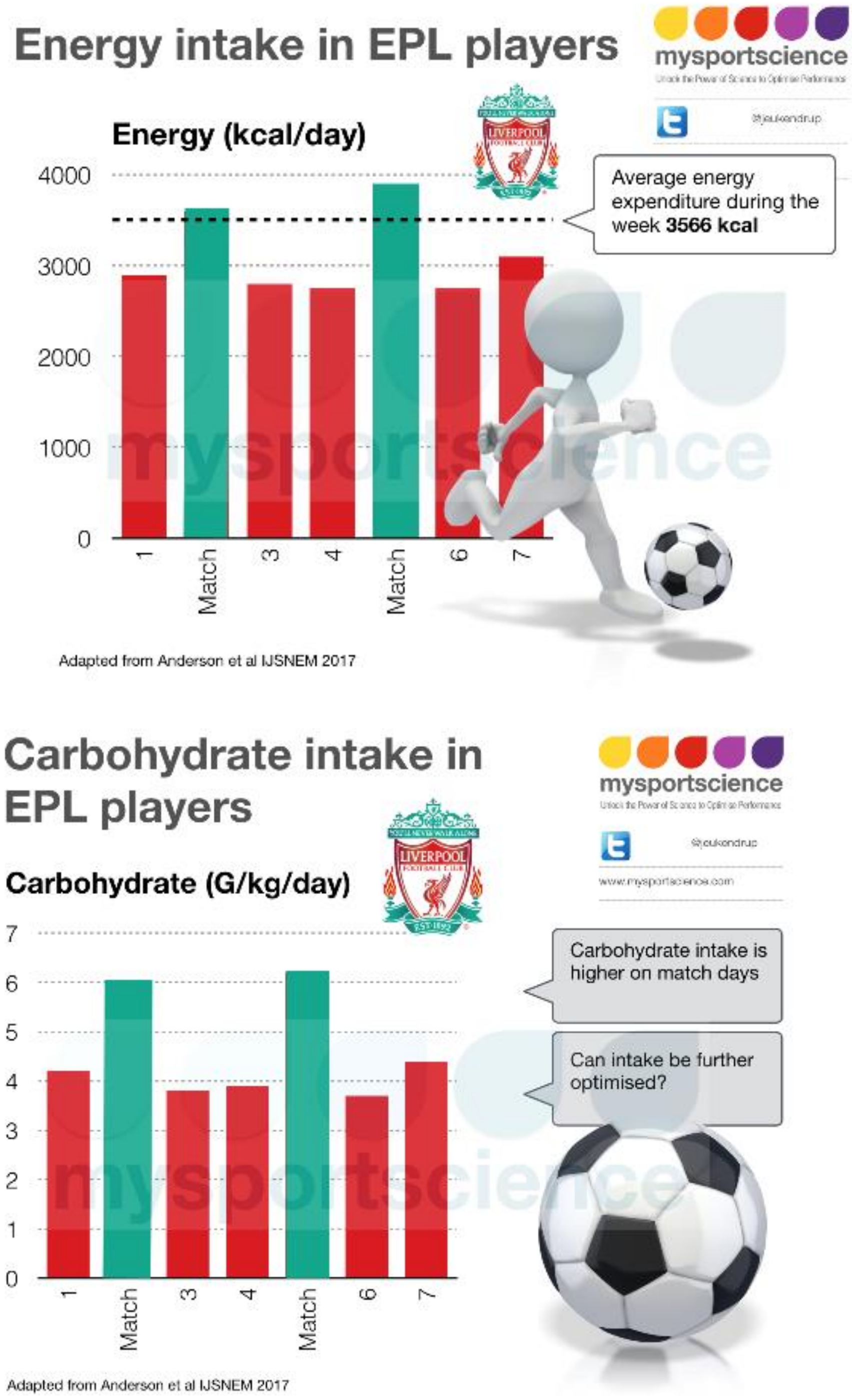
The cause of the discrepancy is unclear, but it may be explained by two important factors:

1. The better trained and the higher the aerobic capacity the greater the capacity to synthesize glycogen. Therefore, well trained endurance athletes may be at an advantage even compared with elite football players.
2. It is also possible that inhibition of glycogen resynthesis due to muscle damage as a result of the eccentric component of football may play a role.
3. The level of carbohydrate intake.

A general recommendation for football players is a carbohydrate intake of 3-8 g of carbohydrate /kg body weight, when it fits with the individual total energy intake goals. The recommended amount of carbohydrate per day is also dependent on the physical activity level on those days. On a rest day 3-5 g/kg would be more appropriate and on days with some training 6-7 g/kg would be more appropriate. On days or hard training or matches, carbohydrate intake should be closer to 8 g/kg. In the module on periodized nutrition we will return to this topic.

It is clear that many football players will not meet these recommendations. In a study at Liverpool FC players consumed 4 g/kg on most days apart from match days when carbohydrate intake was 6 g/kg (Anderson, Naughton, et al., 2017) (Figure 1). One of the reasons why meeting the recommendations is challenging is the fact that a football player on an average training day will expend 3000 kcal. In the study by Anderson, Orme, et al. (2017) in English Premier League football players energy expenditure was 2956 ± 374 kcal during training days and 3789 ± 532 kcal on match days (Figure 1). Now, let's do some back of the envelope calculations: When a 70 kg player is consuming 7 g per kilogram bodyweight this is roughly 2000 kcal. This means that carbohydrates make up about 67% of the total energy intake. Protein usually makes up 15-20%, or the recommendation is about 1.6 g/kg/day (or 112 g for this player), this is almost 500 kcal. This leaves 13-18% or 450-550 kcal for fat-this is 50-60 g. This is well below the intake of the average person (in many European countries this is around 150 grams per day) and this means that a player who wants to optimise recovery will have a significantly different diet to the average person.

Figure 1: Energy intake and carbohydrate intake during a week in English Premier League players



Source: Infographic from Jeukendrup, January 9, 2017, https://bit.ly/2SHjSrl, based on Anderson, Naughton, et al., 2017.

The concept of glycogen loading, as is often used in endurance sports, may not apply to the football setting, because of the high frequency of matches. However, the underlying principles are still important: glycogen stores must be full, sufficient carbohydrate needs to be ingested; storage is more effective after muscle glycogen depletion. In football, however, this is achieved by making sure that carbohydrate intake on a daily basis is high enough to support high rates of glycogen synthesis.

One might ask: why do endurance athletes manage this intake well, and football players generally don't? There is one important difference between these two groups: the endurance athletes (cyclists and triathletes in particular) who manage this carbohydrate intake well generally have higher energy expenditure and thus their allowance for carbohydrate intake as well as fat intake is greater, and it becomes easier to manage. The smaller the energy budget, the harder it becomes to manage a high carbohydrate intake (in g/kg/day).

This should not discourage anyone from optimising the daily carbohydrate intake to what is best for performance. But we have to keep an eye on the practicalities of achieving this. It will require cooking low fat and providing most meals as lower fat options and increase carbohydrate content at the same time. Of course, all of this has to happen without changing the palatability of the meals.

2.1.3 Diet the days before

The main focus the days leading up to a match may be on optimising glycogen stores and as we discussed above these are some of the key recommendations for carbohydrate intake:

- Daily carbohydrate intake should be 5-8 g/kg/day depending on daily activity
- This should be achieved by lowering fat intake, but keeping protein intake relatively high
- The types of carbohydrate do not matter that much
- The timing of intake is important if recovery time is short, and glycogen restorations should be started by ingesting carbohydrate the first hour after exercise. If recovery time is long timing is less critical

There are a number of other factors to consider as well, but they are not as critical or urgent. Of course, in the lead up to a match, muscles (and other tissues) need to continue to recover and adapt after the last match or hard training, and optimising protein synthesis is part of this plan. It is important to realise that this is not different before a match or after a match. Protein synthesis is an ongoing process that depends mostly on two factors: exercise and protein intake. Protein synthesis can be optimised through a number of strategies that we discuss in more detail elsewhere in this course. In brief here are the most important factors regarding protein intake:

- Daily protein intake should be in the 1.4-1.6 g/kg range, but the absolute amount is less critical than some of the other factors below.
- Timing of protein intake is an important variable to consider in optimizing skeletal muscle recovery. It appears optimal to ingest protein in the post- exercise period in sufficient doses (~ 0.4 g gram per kg body weight per meal)
- Three to four meals distributed throughout the day. Eating fewer meals with more protein is not as good as eating this optimal amount.
- Ingesting a larger dose of protein (~ 0.6 gram per kg body weight per meal) before bedtime appears to augment both acute overnight muscle protein synthesis and chronic skeletal muscle adaptations.
- The protein content of the post-exercise meal should be predominantly in the form of rapidly digested high-quality proteins with a high essential amino acid and especially leucine content (2-3g per meal). Examples of high-quality protein sources are meat, milk and eggs.
- Other protein consumed during the day should be mostly lean high-quality protein containing all the essential amino acids in approximately equal proportions. This will predominantly be protein from animal sources including beef, ham, lamb, poultry and fish but can be supplemented with soy, beans, cheese, nuts and bread.
- Some protein can also be obtained from soy, beans, nuts and bread.
- Staying hydrated is important too and it would be a good idea to do a simple hydration check the day before the match. It will be informative, but it will also remind players of the importance. Such a check can be simply looking at urine colour or measuring urine osmolality or urine specific gravity or by measuring body weight to see if there is no sudden decrease from baseline. But hydration on match day will of course be most important. (Jeukendrup & Gleeson, 2018, https://bit.ly/2UENOq7).

Healthy foods

Especially when the fixture schedule is congested, and there are only 2-4 days between matches, food choices become more critical, and from a performance perspective, focus quickly shifts to macronutrient intake because this is how the largest performance effects might be obtained. Dietary micronutrients, fibres and phytonutrients receive less attention, because they will not have an immediate impact on performance. They do have an important role to play in maintaining overall health, so if we only focus on macronutrients, we may compromise long term health. On the flip side, when recovery is critical, we don't want to focus on fibre, for example, as this may be great for gut health, it is not great for rapid delivery of nutrients and has also been linked to gastro-intestinal distress (de Oliveira, Burini, & Jeukendrup, 2014). So, we need to give attention to healthy nutrition most days but perhaps focus on rapid delivery of carbohydrate and avoid foods that could cause gastro-intestinal problems the day before a match. We will discuss periodisation of nutrition in more detail in a different part of the course.

Less packaged/processed foods

In general, it is probably a good recommendation to eat fresh food and less processed and packaged foods. The recommendation about increasing carbohydrate intake whilst reducing fat intake (to avoid overeating) would also favour eating fresh and less processed foods. Processed foods tend to be energy dense and often high in fat. They also tend to be lower in micronutrients, fibre, phytonutrients, thus generally have a lower nutritional value.

Mood and diet

Although food is a way to get an edge from a physiological point of view, we must never forget that nutrition is much more than that. Nutrition choices are influences by many factors including social, economic, religious, geographical, seasonal and many other considerations. The social aspects of eating are important in this context as food also serves to help mood and an improved mood state may also have an impact on performance. This aspect cannot be forgotten. We eat food because it has a function, but we also eat food to feel good and be happy. Therefore, solutions must be found that serve both goals. Great tasting foods that deliver the nutrients required for optimal recovery and preparation.

2.1.4 Sleep

Sleep is generally recognised as a critical factor in athlete's performance. Certainly, insufficient sleep is believed to have detrimental effects on performance. Also, Compromised sleep might also influence cognition, learning, memory, pain perception, immunity and inflammation. Chronic partial sleep deprivation may result in changes in carbohydrate metabolism, protein synthesis, appetite, and food intake. These factors can ultimately have a negative influence on an athlete's nutritional, metabolic and hormonal status and could therefore potentially reduce athletic performance. (Jeukendrup, September 10, 2017, https://bit.ly/2hdsNQN).

Sleep is thought to affect both physiological and cognitive function with resulting effects on sports performance. Evidence suggests that athletes have lower quality of sleep as well as lower quantity of sleep, compared with the non-athlete, particularly during periods of intensified training. (Jeukendrup, October 26, 2015, https://bit.ly/2PyjMR6).

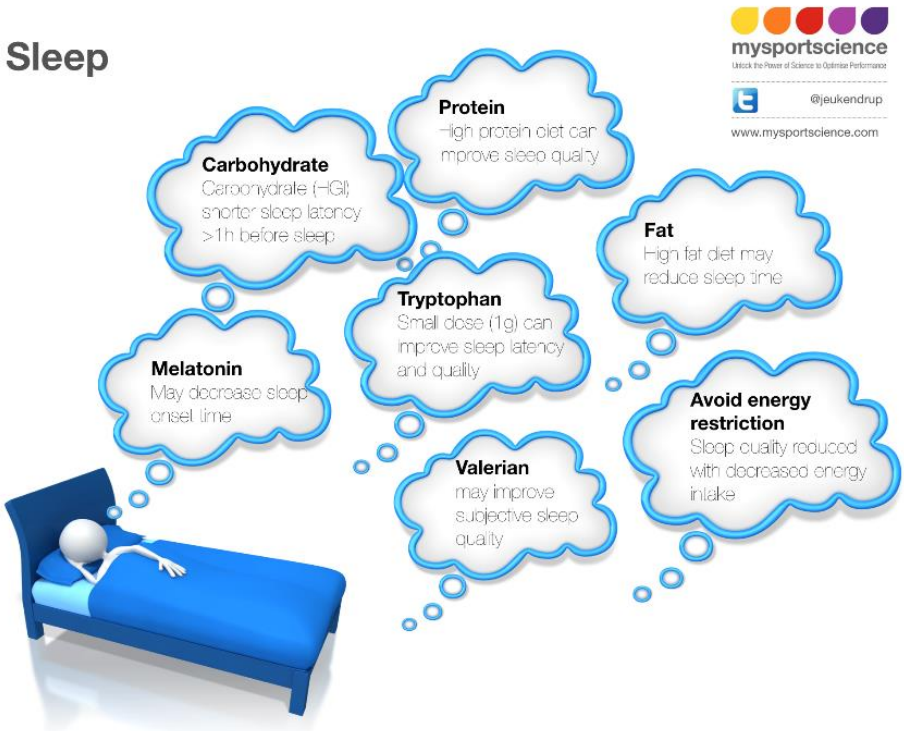
There are clearly a number of sleep hygiene measures that could be considered to improve sleep quality but also from a nutritional point of view there may be things to consider.

A number of neurotransmitters (e.g. 5-HT, gamma-aminobutyric acid, orexin, melanin-concentrating hormone, norepinephrine, and histamine) have been associated with the sleep-wake cycle. There are some nutritional interventions that can influence these neurotransmitters in the brain and so may thus influence sleep. For example, carbohydrate, tryptophan, valerian, and melatonin and others have been investigated as possible sleep inducers and represent promising potential interventions to improve sleep quantity and/or quality.

Synthesis of 5-HT in the brain is dependent on the availability of its precursor, the amino acid tryptophan (Trp). Trp is transported across the blood–brain barrier by a transport system that is shared by a number of large neutral amino acids (LNAA) including the branched chain amino acids (BCAA) leucine, isoleucine and valine. Thus, the ratio of Trp/LNAA in the blood is crucial to the rate of transport of

Trp into the brain. Ingestion of protein generally decreases the uptake of Trp into the brain, as Trp is the least abundant amino acid and therefore other LNAA are preferentially transported into the brain. The ingestion of carbohydrate, however, increases brain Trp as the rise in circulating insulin (as a result of the increase in blood glucose concentration) stimulates the uptake of LNAA into skeletal muscle, which results in an increase in free Trp in the circulation, an effect that promotes its uptake into the brain. (Jeukendrup, September 10, 2017, https://bit.ly/2hdsNQN).

Figure 2: Nutrition factors that might affect sleep



Source: Infographic from Jeukendrup, September 10, 2017, https://bit.ly/2hdsNQN

Several studies have investigated the effects of Trp supplementation on sleep (Silber & Schmitt, 2010), and the data suggest that Trp doses as low as 1 g can improve sleep latency (the time before falling asleep) as well as subjective sleep quality.

Melatonin is a hormone that influences the sleep-wake cycle and induces drowsiness, inducing a sleep promoting effect. When the retina of the eyes are exposed to light, melatonin secretion will be suppressed resulting in a wakeful state. Some nutritional interventions that increase Trp availability or reduce the plasma concentration of LNAA can also increase melatonin production and promote sleep. This can be achieved by several means:

- a high protein diet that contains more Trp than LNAA
- ingestion of carbohydrate (This may increase the ratio of free Trp to LNAA and facilitate the release of insulin, which promotes the uptake of BCAA into the muscle)

A supplement often associated with sleep is melatonin. Research investigating the use of melatonin for primary insomnia has demonstrated inconclusive results. A meta-analysis reported a reduction in sleep-onset latency of 7 min (the clinical relevance of this may be questionable. and concluded that while melatonin appeared safe for short-term use, there was no evidence that melatonin was effective for most primary sleep disorders (Buscemi et al., 2005).

Another recently investigated nutritional supplement is tart cherry juice which contains relatively large amounts of phytochemicals including melatonin. The ingestion of tart cherry juice has been shown to increase urinary melatonin, and when consumed for a one week period was shown to result in modest improvements in sleep time and quality (Howatson et al., 2012) compared with placebo.

Recent studies on the effects of carbohydrate ingestion on indices of sleep quality and quantity (reviewed by Halson, 2014) indicate that high carbohydrate meals consumed in the hour before bedtime improve sleep quality and reduce wakefulness. Solid compared with liquid meals tend to reduce sleep onset latency (time taken to fall asleep) up to 3 h after ingestion, and a high glycemic index (GI) meal significantly improves sleep-onset latency above that with a low GI meal if consumed 4 h (but not 1 h) before bedtime. A few studies have investigated more chronic manipulations of habitual dietary intake on sleep and these have suggested that diets higher in carbohydrate result in shorter sleep-onset latencies, diets higher in protein result in fewer wake episodes and diets high in fat may negatively influence total sleep time.

Valerian is a herb that binds to gamma-aminobutyric acid type A receptors and is thought to induce a calming effect by regulation of the nervous system. Results of a meta-analysis investigating the efficacy of valerian showed a subjective improvement in sleep quality (Fernandez-San-Martin et al., 2010). While valerian is one of the more common ingredients found in supplements claiming to promote sleep, side effects such as drowsiness, dizziness and allergic reactions can be observed.

Other suggested sleep aids have not been adequately investigated and are not supported by scientific evidence: passionflower, kava, St. John's wort, lysine, glycine, magnesium, lavender, skullcap, lemon balm, magnolia bark, and nucleotides. Many of these can be found in supplements that are claimed to improve sleep quantity and/or quality.

Practical recommendations to improve sleep via nutritional interventions include:

- High GI foods such as white rice, pasta, bread, and potatoes may promote sleep; however, they should be consumed more than 1 h before bedtime.
- Diets high in carbohydrate may result in shorter sleep latencies.
- Diets high in protein may result in improved sleep quality.
- Diets high in fat may negatively influence total sleep time.
- When total caloric intake is decreased, sleep quality may be disturbed.
- Small doses of tryptophan (1 g) may improve both sleep latency and sleep quality. This can be achieved by consuming a supplement or approximately 300 g of turkey.
- The hormone melatonin and foods that have a high melatonin concentration (e.g. tart cherries) may decrease sleep onset time.
- Subjective sleep quality may be improved with the ingestion of the herb valerian (Jeukendrup, September 10, 2017, https://bit.ly/2hdsNQN).

2.2 Match day

2.2.1 Meal(s) before the match

The goal of a meal before the match is primarily to replenish liver glycogen stores. The primary role of glycogen in the liver is to maintain constant blood glucose concentrations. Glucose is the main, and in normal circumstances the only, fuel used by the brain. The liver is often referred to as the glucoregulator or glucostat: the organ responsible for the regulation of the blood glucose concentration. An average liver weighs approximately 1.5 kg, and approximately 80 to 110 g of glycogen is stored in the liver of an adult human in the post-absorptive state. Glycogen is broken down in the liver to glucose and then released into the circulatory system. The liver has a much higher concentration of glycogen (per kilogram of tissue) than does muscle. Because of a much larger mass of muscle there is more glycogen stores in muscle (in absolute terms, 300 to 600 g in muscle versus 80 to 110 g in liver) but this does not take away that liver is very well suited to store glycogen. After an overnight fast, the liver glycogen content can be reduced to low levels (<20 g) because tissues such as the brain use glucose at a rate of about 6g/h in resting conditions. (Jeukendrup & Gleeson, 2018, https://bit.ly/2UENOq7).

Studies have demonstrated that athletes should have the last fairly large meal 3 to 5 hours before competition (Hargreaves, Hawley, & Jeukendrup, 2004). Even though this conclusion was based mostly on endurance studies, because of the role of glycogen during football, the same guidelines are used. In a football study, increased dribbling speed was observed when Briggs et al. (2017) studied the effects of (500 kcal versus 250 kcal, 60% carbohydrate) the size of the breakfast on performance in 7 English Premier League Academy football players. The players had their normal (relatively small) breakfast or a breakfast with added carbohydrate. The higher carbohydrate breakfast contained 77 g carbohydrate whereas the normal breakfast contained 39 grams (with similar amounts of protein and fat). They then played a simulated match with a number of skill tests. Although dribbling precision and success were unchanged, dribbling speed was improved with the added carbohydrate. Unsurprisingly, greater feelings of gut fullness were observed in B but no abdominal discomfort was reported.

Many other studies suggest that higher carbohydrate intakes before and during a match can delay fatigue (Holway & Spriet, 2011) and enhance the capacity for intermittent high-intensity exercise (Phillips, Sproule, & Turner, 2011; Russell, Benton, & Kingsley, 2012).

Especially if the pre-exercise meal is breakfast, it is important to have a relatively high carbohydrate intake because after an overnight fast when the liver is almost depleted of glycogen. The advantages of a meal in the hours before exercise are related to the increased carbohydrate availability in both muscle and the liver. In the 3 to 5 hours before exercise, although the majority of carbohydrate may be stored in the liver, some carbohydrate is also still incorporated into muscle glycogen. Ingestion of a carbohydrate-rich meal (containing 140 to approximately 330 g of carbohydrate) 3 to 5 hours before exercise increases muscle glycogen levels and improves exercise performance (Hargreaves et al., 2004). Such a meal could include carbohydrate sources such as bread and jam or honey, cereals, porridge, bananas, canned fruit, and fruit juice. Following is an example of a daily diet containing 150 g of carbohydrate representing at least 80% of the energy intake:

- Meal 1: one large bowl of porridge with skim milk, one banana, one glass (250 ml) of sweetened orange juice
- Meal 2: four slices of bread with jam or honey, one can of a soft drink
- Meal 3: 3 cups of rice made into a light stir fry with small amounts of lean ham or chicken, peas, corn, mushrooms and onion, and one glass (250 ml) of fruit juice. (Jeukendrup & Gleeson, 2018, https://bit.ly/2UENOq7).

The last larger meal should be 2.5-5 hours before a match. If only 2.5 hours is available the meal must be smaller; if 5 h is available the meal can be larger. Often the timing is dictated by logistics. In the hour before the game, there is a last opportunity to top up liver glycogen or to start fuelling for the game (for example the carbohydrate ingested 15 min before the game will be absorbed and become available during the game).

2.2.2 The hour before

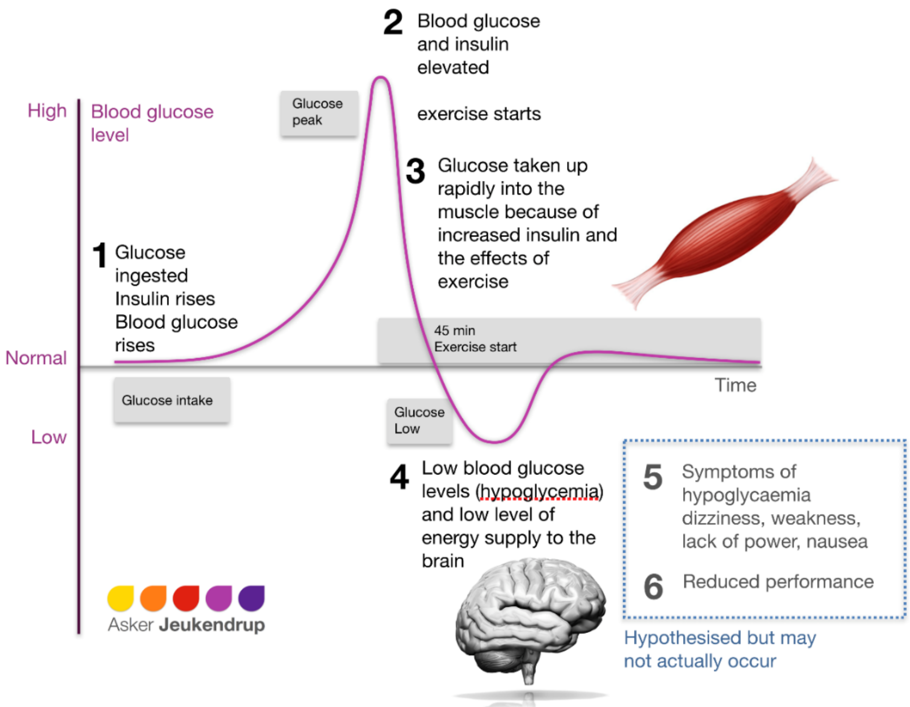
There has been a lot of debate about the ingestion of carbohydrate in the hour before exercise. Carbohydrate ingestion 30-60 min before a match results in a large rise in plasma glucose and insulin. With the onset of exercise, a rapid fall in blood glucose occurs, a phenomenon known as rebound or reactive hypoglycemia. Up to only a few years ago, athletes were often advised not to consume carbohydrate in the hour before exercise because this was thought to induce hypoglycemia and negatively affect performance. This view has gradually changed as will be discussed below. For a more detailed review of this topic the reader is referred to this review: (Jeukendrup & Killer, 2011). (Jeukendrup & Gleeson, 2018, https://bit.ly/2UENOq7).

Metabolic changes with pre-exercise carbohydrate ingestion

When carbohydrate is ingested in the hour before exercise, blood glucose as well as insulin concentrations will rise (Figure 3). This hyperinsulinemia stimulates glucose uptake. When exercise is initiated, contractile activity further stimulates muscle glucose uptake and the result is a rapid disappearance of glucose from the blood, causing a drop in the blood glucose concentration.

The exercise-induced increase in the normal liver glucose output is inhibited by carbohydrate ingestion (Marmy-Conus, Fabris, Proietto, & Hargreaves, 1996), despite ongoing absorption of the ingested carbohydrate. Enhanced uptake and oxidation of blood glucose by skeletal muscle may account for the increased carbohydrate oxidation after pre-exercise carbohydrate ingestion. In addition, in some studies, an increase in muscle glycogen degradation has been observed. (Jeukendrup & Gleeson, 2018, https://bit.ly/2UENOq7).

Figure 3: The concept of rebound hypoglycemia



Source: Jeukendrup, February 5, 2015, https://bit.ly/2QO2B2u

When carbohydrate is ingested in the hour before exercise blood glucose and insulin levels rise. When exercise is initiated, glucose uptake increases. Now, both insulin (at its peak) and exercise will stimulate glucose uptake, and as a consequence, a drop in blood glucose may be observed, and hypoglycemia may be the result. Hypoglycemia is associated with symptoms like dizziness, nausea, weakness, and shivering, none of which would be good for performance. However, research does not necessarily support this theoretical picture!

The increase in plasma fatty acids with exercise is attenuated after pre-exercise carbohydrate ingestion because of insulin-mediated inhibition of lipolysis (Horowitz, Mora-Rodriguez, Byerley, & Coyle, 1997). Even small increases in plasma insulin (e.g., after fructose ingestion) can result in a marked reduction of lipolysis. Fat oxidation is reduced not only because of the lower plasma fatty availability (Horowitz et al., 1997) but also because of inhibition of fat oxidation in skeletal muscle. Artificially increased plasma fatty acid availability did not completely return fat oxidation to levels seen during exercise in the fasted state (Horowitz et al., 1997). Some evidence indicates that the hyperinsulinemia and hyperglycemia reduce the uptake of FA into the mitochondria (Coyle, Jeukendrup, Wagenmakers, & Saris, 1997).

Factors that determine the glycemic response during exercise include

- the combined stimulatory effects of insulin and contractile activity on muscle glucose uptake,
- the balance of inhibitory and stimulatory effects of insulin and catecholamines on liver glucose output, and
- the magnitude of ongoing intestinal absorption of glucose from the ingested carbohydrate.

Because the metabolic effects of pre-exercise carbohydrate ingestion are a consequence of hyperglycemia and hyperinsulinemia, interest has developed in strategies that minimize the changes in plasma glucose and insulin before exercise. These strategies include the ingestion of fructose or carbohydrate types other than glucose that have a lower glycemic index, varying the carbohydrate load or the ingestion schedule, the addition of fat, and the inclusion of warm-up exercise in the pre-exercise period. In general, although these various interventions do modify the metabolic response to exercise, blunting the pre-exercise glycemic and insulinemic responses appear to offer no advantage for exercise performance.

The metabolic alterations associated with ingestion of carbohydrate in the 30 to 60 minutes before exercise have the potential to influence exercise performance. The increase in muscle glycogenolysis and suppression of fat metabolism could possibly result in earlier onset of fatigue during exercise as suggested in a study by Foster, Costill, and Fink (1979). Indeed, this early study reported a reduction in exercise performance. Since then, however, the overwhelming majority of more than 100 studies have shown either unchanged or even enhanced endurance exercise performance after ingestion of carbohydrate in the hour before exercise.

Interestingly in a series of studies (Jentjens & Jeukendrup, 2003; Moseley, Lancaster, & Jeukendrup, 2003) it was demonstrated that certain individuals may develop hypoglycemia when carbohydrate is ingested in the hour before exercise, although this was not a predictor of performance. Note that the causes of hypoglycemia in this situation are different from what happens after prolonged exercise when endogenous carbohydrate stores become depleted. Here it is primarily the result of the combined effects of insulin and exercise. Liver glycogen concentrations may be high. After prolonged exercise the cause of hypoglycemia is the fact that liver glycogen is depleted, plasma insulin concentrations are low.

Hypoglycemia seemed to be more prevalent when the carbohydrate was ingested 75 minutes before exercise compared with 45 minutes, and when it was ingested 15 minutes before exercise few people developed hypoglycemia (Moseley et al., 2003). Other studies have demonstrated that hypoglycemia can be completely prevented when carbohydrate is taken 5 minutes before exercise or during a warm-up.

In conclusion, despite the well-documented metabolic effects of pre-exercise carbohydrate ingestion, little evidence appears to support the practice of avoiding carbohydrate ingestion in the hour before exercise, if sufficient carbohydrate is ingested. Some people, however, may be more prone to develop hypoglycemia; therefore, it is recommended to determine individual practice based on experience with various pre-exercise carbohydrate ingestion protocols. (Jeukendrup & Gleeson, 2018, https://bit.ly/2UENOq7).

Practical messages

- Make sure that liver glycogen is topped up before the game
- This can be done by ingesting 150-330 g of carbohydrate in the 3-4 h hours before
- Allow enough time for digestion and absorption, so a match can be started without feeling full
- In the hour before a match there is a last opportunity to replenish liver glycogen and to start the fuelling “during” exercise. Especially when carbohydrate is ingested in the minutes before a match, this will carbohydrate will become available during the match
- Establish a routine for the team that players can get used to (or establish a routine at individual level where possible)

2.2.3 Warm up and half time

Research activities typically note performance benefits in protocols simulating football matches when carbohydrate is consumed during exercise at rates of ~30–60 g/h (Baker, Nuccio, & Jeukendrup, 2014; Baker, Rollo, Stein, & Jeukendrup, 2015; Russell, Benton, & Kingsley, 2014). Effects on performance indicators may be greater with higher carbohydrate intakes ($\geq$75 g) (Baker et al., 2014). However, it is also clear that football players often do no reach these intakes. For example, players in the English Premier League reported carbohydrate intakes of 32 g/h just before and during a match (Anderson, Naughton, et al., 2017). This may be attributed both to the match rules which limit intake to warm-up and half-time (see below), the fear or actual experience of gastrointestinal problems during high-intensity exercise or simply lack of awareness.

As mentioned above most published studies have reported improvements in soccer players' shooting, dribbling, and/or passing performance with ingestion of a 6-7.5% carbohydrate solution at an intake rate of 30-60 g/h. Currell et al [Currell, Conway, & Jeukendrup, 2009] found a significant improvement in dribbling and kicking accuracy with an intake of 55 g carbohydrate/h ingestion versus placebo. In the same study it was found that jumping to head a ball (which involves only a small cognitive component) was not influenced by carbohydrate feeding.

In general, there is a tendency for players' skill performance to decline during the latter stages of a game with placebo intake and carbohydrate ingestion can reduce this decline. For example, in a study using an intermittent running protocol there was a 14% reduction in passing performance from pre- to post-test with placebo ingestion and only a 3% reduction with 52 g carbohydrate/h (Ali & Williams, 2009).

At the moment there are few studies that have measured skill performance and measuring skill performance is notoriously difficult. Those measurements can have a large variation and are easily influenced by external variables. Therefore, they are more difficult to control. If a measurement has a lot of variation it is usually more difficult to detect the effect of an intervention (in this case carbohydrate feeding). I think that this is one of the main reasons why studies show variable results, with some shoring positive effects and some no effects of

> carbohydrate feeding. No studies to date have shown negative effects.
>
> Therefore, this is a strategy that should be explored more in soccer, especially at the highest level where small improvements in 11 players could make a difference. There are at least two good moments to ingest carbohydrate: just before the start of a game and at half-time. A target intake of 90 grams for a full game is a good start (45 g carbohydrate before and 45g at half-time) based on what we know from the few studies in the literature and from the work in endurance sports, but the reality is that there aren't enough studies to give very clear guidance on the optimal amount of carbohydrate. A very practical intake would be 2 times 25-30 grams (as this is the amount in a gel, a small energy bar or a banana). (Jeukendrup, May 27, 2015, https://bit.ly/2LcUdo1).

It has also become apparent that in addition to providing a substrate for the muscle and brain, carbohydrate consumed during exercise exerts central effects whereby receptors in the oral cavity detect carbohydrate ingestion and favourably alter the perception of effort (Carter, Jeukendrup, & Jones, 2004; Jeukendrup, April 16, 2013; Jeukendrup, July-August, 2013). This is different than providing fuel for the brain. In this case, there is a neural signal that immediately triggers certain areas of the brain.

> Several brain imaging technology (fMRI) studies have tracked changes in various areas of the brain with carbohydrate mouth sensing (Chambers, Bridges & Jones, 2009). In these studies, both sweet and non-sweet carbohydrates were shown to activate regions in the brain associated with reward and motor control. There is robust evidence that in situations when a high power output is required over durations of ~45-75 min, mouth rinsing or intake of very small amounts of carbohydrate play a non-metabolic role in enhancing performance by of 2-3%. (Jeukendrup & Gleeson, 2018, https://bit.ly/2UENOq7).

Although there is no football specific evidence, carbohydrate mouth rinsing has been shown to increase self-selected jogging speed with likely benefits in sprint performance during intermittent exercise (Rollo, Homewood, Williams, Carter, & Goosey-Tolfrey, 2015). In the future we may see studies that are more specific to football, but this approach is certainly promising if a practical solution can be found as a single rinse will have little effect and more rinses are likely required.

Implications for football are still unclear, but practical solutions which enable the use of carbohydrate mouth rinses during match play (e.g. mouth guards which also serve as carbohydrate delivery systems) could potentially enhance performance in situations where carbohydrate consumption is limited by gastrointestinal concerns. A recent article in the New York Times addressed this as players at the football world cup were seen rinsing their mouths with (carbohydrate) solutions (Longman, 2018).

Hydration can be another important factor during a match. Players are usually dehydrated to a smaller or larger degree after a football match (Nuccio, Barnes, Carter, & Baker, 2017) due to mismatch between sweat losses (governed by the intensity/duration of play and environmental conditions) and fluid intake (governed by match opportunities and individual hydration practices). In cool conditions, net fluid losses are typically within an acceptable range (1-2% BM) (Burke & Hawley, 1997), in which effects on running and cognitive performance (Nuccio et al., 2017) appear to be small and inconsistent. (Jeukendrup & Gleeson, 2018, https://bit.ly/2UENOq7).

For example, fluid ingestion had no effect on 15 m sprint performance during a Loughborough Intermittent Shuttle Test (LIST) protocol (Ali, Gardiner, Foskett, & Gant, 2011), although an earlier study by McGregor, Nicholas, Lakomy and Williams (1999) showed faster sprints with fluid ingestion during a 90 min LIST. Similarly, intermittent running capacity was not affected by mild dehydration in one study (Owen, Kregel, Wall, & Gisolfi, 1985), while another showed small improvements with drinking versus a water mouth rinse or no fluid (Edwards et al., 2007). Therefore, it is fair to conclude from the available evidence that current drinking practices are not a major concern for performance if they limit dehydration to moderate levels (up to 2.5% BM loss) in temperate conditions.

In hot conditions, however, greater fluid losses (e.g. match sweat rates of up to 3 L) could affect physiological responses and performance (Baker & Jeukendrup, 2014). How to deal with extreme environmental conditions is discussed elsewhere in the next module.

An elite football match played in a hot environment showed compromised performance of repeated sprint and jump activities, with pronounced reduction in high-intensity running toward the end of the match; this was attributed to training status and hyperthermia/dehydration (Mohr & Krustrup, 2013; Mohr et al., 2010). It is therefore likely that enhanced drinking strategies can prevent some of the larger effects on performance effects in hot environments (Mohr & Krustrup, 2013; Mohr et al., 2010). It is important to note that inter-individual differences in fluid losses and needs occur, requiring an individualised approach to prevent excessive dehydration (Holway & Spriet, 2011).

A number of practical issues determine opportunities for hydration and carbohydrate intake within a match. The Fédération Internationale de Football Association (FIFA) rules dictate that drinks (and other products) can only be ingested during stoppages. Stoppages for drinks or other medical reasons are decided by the referee, although during extreme hot weather tournaments, FIFA may decide to have scheduled drinking breaks. Generally, however, there are few drinking opportunities during a match and these opportunities are usually not scheduled and may not be available to every player (e.g. a player may be on the opposite side of the pitch). Clearly this makes the opportunities before the match and during halfme more important than in many other team sports. Both hydration and carbohydrate intake may require special attention in matches where overtime (2 x 15 min) is played. All match nutrition strategies, including the use of supplements (see specific section) should be practiced in training and minor matches.

Ergogenic aids

Nutrition supplements are the next thing to consider for match day. There are probably two types of supplements that could be used. Ergogenic aids that would help to increase the amount of work that can be performed (i.e. running performance, reduction in fatigue/delayed fatigue) or supplements that improve skill and cognitive aspects of performance. It is tempting to believe that nutrition supplements that deliver such compounds can boost performance. This section goes beyond the carbohydrate and protein supplements that support the point already made above. This section explores the supplements that are promising and have an evidence base in sports like football.

Running performance

There are a number of supplements that could, at least in theory, improve running performance in football. These supplements will be discussed in more detail elsewhere in this course, but here we will focus on the practicalities for match day. Besides carbohydrate (which does not have to be ingested as a supplement), the supplement with most evidence for improved performance is caffeine. Of course, caffeine does not have to be ingested as a supplement either but in football it often is the most practical solution. If players wanted to get the effects from coffee, however, this is possible too. The first step would be to work out the optimal dose for each individual, mostly by trial and error. Training can be used for this before trying caffeine in matches. On match day caffeine should be ingested 45-60 min before the start of the match, whether this is in the form of pills, capsules, sports nutrition products (most common form) or coffee. The target should be around 3 mg/kg but adjusted to the individual. If caffeine gum is used, this gum can be used during the warm up. Most gums require 3-5 min of chewing before all caffeine is released. Caffeine concentrations in blood will rise rapidly as a result of absorption in the oral cavity.

The other supplement that could be useful to take on match day, but is less practical is sodium bicarbonate. Studies have demonstrated improved buffering capacity with sodium bicarbonate and this could potentially improve repeated sprint performance. Specific studies in football are lacking at the moment but based on existing evidence in other activities, it is likely that this would exert small performance benefits. That is, if the ingested bicarbonate does not cause any side effects. The recommended dose is 300 mg per kg (0.3 g/kg) and this is a handful of salt that should be ingested in the 2 h before the match. This is where this supplement is not very practical. Some have ingested it dissolved in orange juice, others rely on capsules (the recommended method).

Another method to improve buffering capacity would be beta alanine. The mechanism is different, and therefore the effects of this method are likely additive to the effects of sodium bicarbonate. Bicarbonate increases the buffering capacity of the blood, drawing hydrogen ions out of the tissue; beta alanine will increase carnosine content, and this is an intracellular buffer. Carnosine content does not change overnight and a prolonged period of supplementation is needed to increase muscle carnosine concentrations. The recommended dose is 3-6 g/d for 3-4 weeks followed by a maintenance dose of >1.2 g per day. This means that it is a strategy suitable for the harder or more important part of the season (for example double weeks), but supplementation would need to be started 3-4 weeks earlier.

Because b-alanine may have side effects, especially at higher doses (tingling fingers and nose), it is recommended to practice and see if the potential performance effects outweigh the potential side effects.

The final supplements to consider are nitrates, which could be delivered in the form of foods (green leafy vegetables, beetroot) or in the form of concentrated beetroot juice (shots). The latter has been the most common and probably most practical form. Again, there is little research specifically to football, but there is some evidence with intermittent exercise. Performance effects may be small and may be even smaller in elite, very well trained players. Although studies suggest 3-6 day loading, 36 h nitrate loading may be more practical and acceptable amongst football players. The main limiting factor of this strategy will be taste and palatability issues with current nitrate products that are commercially available (i.e. beetroot juice or shots). It is therefore highly recommended that players experiment with nitrate supplementation prior to implementation.

Finally, creatine is a supplement that has been very popular for many years in strength sports; it's heavily researched and has a good evidence base, especially for performance in repeated sprints. It is recommended to load with 4 x 5 g creatine/d for 5-7 d followed by a daily maintenance dose of 3-5 g/d. Because creatine supplementation will suppress endogenous production, and because it takes a relatively long time before creatine returns back to normal levels, it is recommended to "cycle" creatine supplementation to specific stages of the season. This should be carefully planned at the start of the season.

Skills performance

Caffeine and carbohydrate are the dietary constituents for which the greatest number of reports describing improved skills and cognitive aspects of sports performance have been published. However, more work is needed to determine the optimal dose and timing of caffeine and carbohydrate intake needed to elicit maximal and consistent benefits in motor skills and cognitive performance. In fact, dose-response studies are needed for all dietary constituents, as the paucity of such studies represents a significant gap in the literature.

Overall, the body of literature reviewed suggests that study participants with impaired cognitive function states (e.g., sleep deprivation, mental stress, or exercise-induced fatigue) are more likely to experience acute benefits from caffeine or carbohydrate ingestion. There is currently a lack of evidence to substantiate the use of any other dietary constituents to benefit sports-related motor skill or cognitive performance. Many claims and suggestions have been made, that link other supplements to improved skill maintenance: branched-chain amino acids, cocoa flavanols, Gingko biloba, ginseng, guarana, Rhodiola rosea, sage, L-theanine, theobromine, and tyrosine. However, at present these supplements cannot be recommended to enhance motor skills or cognition for sports performance.

Carbohydrate and caffeine are the only dietary constituents that have decent evidence for their efficacy as an ergogenic aid in sport-specific skill tests. For other dietary constituents, researchers usually use motor skills and cognitive tests designed for the general population, and such tests have questionable relevance to sports settings. It is crucial that future efficacy studies develop and employ valid, reliable, and sensitive batteries of motor skills and cognitive tests.

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