

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%VO₂max) (Bangsbo, Mohr, & Krstrup, 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 & Krstrup, 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 Ca^{2+} release from the sarcoplasmic 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 sarcoplasmic 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:

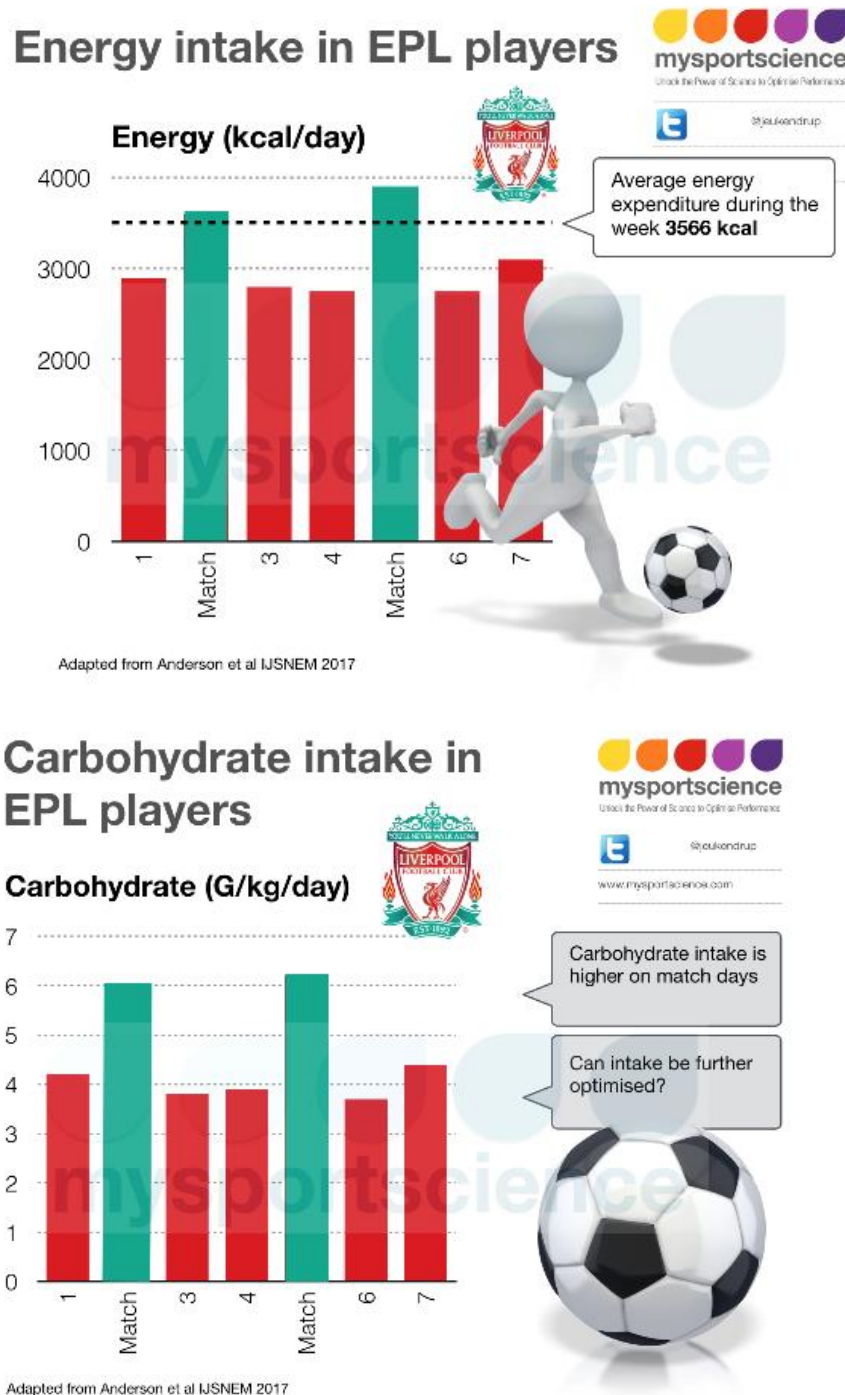
1. The better trained and the higher the aerobic capacity the greater the capacity to synthesize glycogen. Therefore, well trained endurance athletes may be at an advantage even compared with elite football players.
2. It is also possible that inhibition of glycogen resynthesis due to muscle damage as 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 of 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 influenced 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>).