

3.2 Nutrition Applied to Different Sports Specialties

3.2.1 Endurance Sports

In general, nutrition is considered a key determinant of endurance efforts, particularly those that exceed 90 minutes, approximately.

Fatigue during prolonged exercise is often associated with muscle glycogen depletion and decreased blood glucose. Hence, high concentrations of muscle and liver glycogen prior to exertion are considered essential for optimum performance; although it is unlikely that any of these factors on their own, in isolation, would limit prolonged exertion performance (Jeukendrup, 2011).

In addition to the depletion of the body's CHO, dehydration also impairs endurance performance (Sawka et al., 2007).

Diet on Pre-Competition Days

The purpose of CHO intake on pre-competition days is to fill body glycogen stores to the fullest.

Glycogen concentration in the musculoskeletal system of sedentary people is usually between 12 to 16 g/kg w.w. (5.45 - 7.27 g/lb).¹ (65 mmol to 90 mmol/kg w.w.) (29.54 - 40.9 mmol/lb), equivalent to an approximate total amount of 300 to 400 g of CHO. For trained people, glycogen concentrations are generally higher, at about 100-120 mmol/kg w.w. (45.45 - 54.54 mmol/lb) (Jeukendrup & Gleeson, 2004).

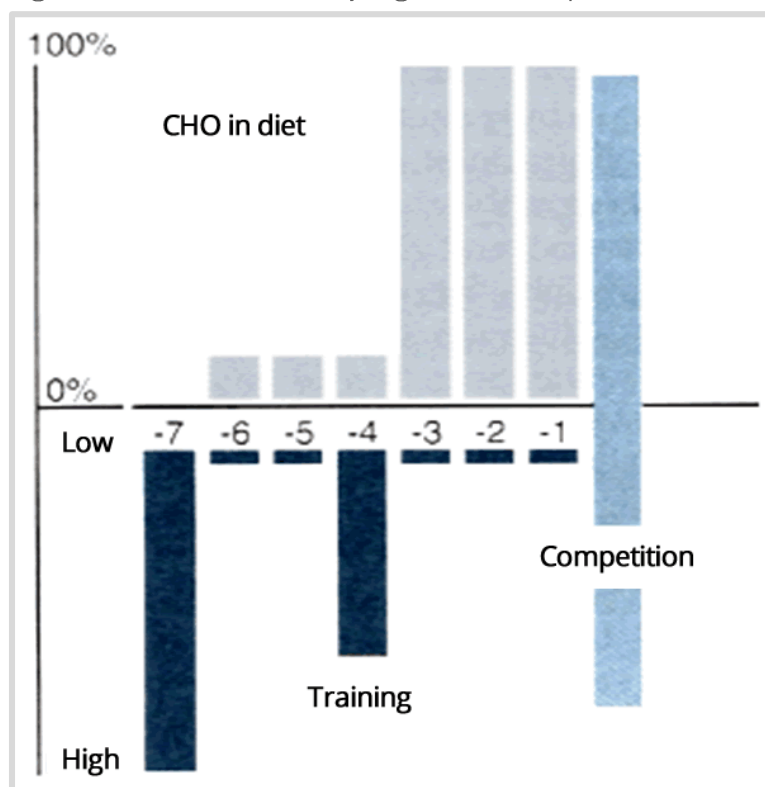
Scandinavian researchers in the sixties discovered that muscle deposits could be increased well above normal levels by manipulating the diet and training during the days before competition. They developed a methodology known as **glycogen overload or glycogen supercompensation**. This protocol takes about a week and begins with intense exercise that depletes the body's glycogen stores (Figure 1). A diet low in CHO is then followed for three days. Another exhausting bout of exercise is done on the fourth day before the competition, after which the type of diet is changed to one with a high content of CHO for three days.

¹ The literature expresses muscle glycogen concentration in different ways. The most common forms are mmol of units of glucose/kg w.w. (wet weight) or mmol of units of glucose/kg d.w. (dry weight). To convert the values expressed in w.w. to d.w. glycogen concentration must be multiplied by 4.28 (Jeukendrup & Gleeson, 2004).

This protocol is known as the **classic protocol**, and the original studies reported that it induced muscle glycogen concentrations of ~210 mmol/kg w.w. (95.45 mmol/lb), although it could also present a number of drawbacks (Jeukendrup & Gleeson, 2004):

- Development of hypoglycemia while on a low CHO diet.
- Practical issues to undergoing such extreme diets.
- Gastrointestinal issues, mainly during low CHO diet (diarrhea usually being the most common).
- Scarce recovery during a low CHO phase.
- Athletes do not feel very comfortable spending many days without training.
- Increased risk of injury.
- Mood changes during low CHO diet.

Figure 1. Classic Muscle Glycogen Overcompensation Protocol



Source: Adapted from Jeukendrup & Gleeson, 2004.

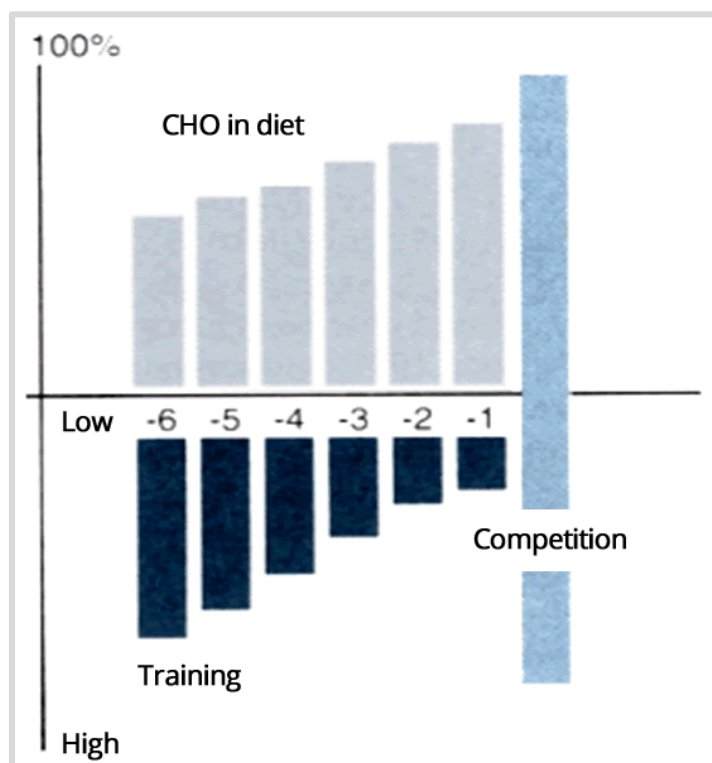
Because of the problems of the classic protocol, and based on data showing that trained athletes do not need the depletion phase to produce overcompensation in muscle glycogen, a **modified protocol** was proposed in the early 80s (Sherman, Costill, Fink, & Miller, 1981). This

strategy, which was much less radical and easier to implement than the classic protocol, produced a muscle glycogen concentration of 203 mmol/kg (92,27 mmol/lb.) w.w.

Either way, the overall strategy proposed by the modified version of the overload protocol is that in the days before competition, training effort (tapering or tuning phase) should be noticeably decreased and at the same time, the content of CHO in the diet should be significantly increased, especially in the last 3 days before the competition (Figure 2). This revised protocol has the advantage of being more practical to prepare for a competition, because it avoids the fatigue associated with low levels of muscle glycogen recorded in the depletion phase, besides being a simpler training and feeding strategy to carry out.

While the glycogen overload protocols mentioned are effective in increasing muscle glycogen stores to very high levels, they all share a limitation, which is that they all take several days to do. This is important for athletes who do not want to interrupt or alter their training program for so long before the competition. That is why there is a need to develop shorter glycogen overload protocols.

Figure 2. Overall Strategy of the Modified Glycogen Overcompensation Protocol



Source: Adapted from Jeukendrup & Gleeson, 2004.

In this regard, one of the shortest protocols reported in the literature is the one proposed by Fairchild et al. (2002). Based on reports of higher glycogen resynthesis rates after short duration and near maximum intensity exercise, compared to those recorded for prolonged moderate intensity exercise, they proposed a protocol that requires only 1 day. In this study 7 men trained in endurance did a 3-minute exercise on a cycle ergometer (150 seconds at 130% of peak $\dot{V}O_2$, followed by a 30-second maximum sprint), after which they consumed a diet high in CHO (10.3 g/kg (4.68 g/lb) of body weight) for 24 hours; for this case, the intake of food with poor energy content (e.g., vegetables) as well as foods high in proteins and fats were minimized to facilitate the consumption of CHO source foods, mainly those with a high glycemic index (GI). This strategy proved to be very effective, as it increased muscle glycogen levels, from initial values of 109.1 ± 8.2 mmol/kg w.w. (45.59 ± 3.73 mmol/lb), up to 198.2 ± 13.1 mmol/kg w.w. (90.09 ± 5.95 mmol/lb) registered 24 hours later.

In conclusion, through different glycogen overload protocols (we have only mentioned some of the most popular strategies, but there are variants thereof) it is feasible to bring muscle glycogen deposits to levels that range from 150-200 mmol/kg w.w. (68,18-90,91 mmol/lb), which would be an advantage when competing in long endurance exercises.

CHO Overload and Performance in Endurance Exercises

It is important to note that the benefit of doing a glycogen overload would only be observed in exercises in which it would be possible to see whether their performance suffered a glycogen depletion, meaning, those lasting 90 minutes or longer. This nutrition strategy has been linked to improvements in endurance times of up to 20%, and 2-3% reductions in times required to develop a certain effort (e.g., time trial race) (Hawley, Schabort, Noakes, & Dennis, 1997). This means that such interventions could be of great help in many endurance races, such as marathons, triathlons, or prolonged cycling tests.

However, for exercise lasting between 45 and 90 minutes, glucogenic overloads do not generally produce significant improvement in performance (Burke, 2006).

Finally, it is important to note that this technique, which at first seems simple, is difficult to implement, and it is useful for the athlete to be supervised by a nutritionist, in addition to trying to do it during training or less important competitions before applying it in important competitions.

Diets for Other Sports

Those athletes who do not compete in endurance competitions, meaning those who take part in competitions lasting less than 90 minutes, may not get any benefit from this strategy before a competition as overcompensated muscle glycogen stores offer no advantage from the energy point of view to competitions lasting 60 to 90 minutes.

In the case of soccer and intermittent dynamics sports, FCB recommends the daily carbohydrates intake to be proportional to the estimated energy spent in a training session or a match. The relative contribution of carbohydrates and fats during exercise depends on numerous factors, including carbohydrates stored during pre-exercise (muscle and liver glycogen), intensity and duration of exercise and the player's training status (Jeukendrup 2003). Unfortunately, and as mentioned above, total carbohydrates stored in the body are limited and are often substantially lower than the energy required in the training sessions and competitions athletes undergo. It should also be taken into account that the reduction of carbohydrates stored by the body is the cause of fatigue or performance deficiency during exercise, particularly during long, submaximal or intermittent high-intensity sessions (90 min or more). This fatigue can be seen in both the muscular system (peripheral fatigue) and the central nervous system (central fatigue) (Noakes 2000; Nybo 2003). Therefore, consuming carbohydrates is among athletes' strategies in the pre-, intra- and recovery period exercises.

Current guidelines recommend that for low-intensity training, players should consume 3 to 5 g of carbohydrates/kg BW/day (1.36 to 2.27 g/lb). When the intensity or duration of training increases, meaning when players complete moderate workouts lasting about 1 hour a day, carbohydrate intake should be from 5 to 7 g/kg BW/day (2.27 - 3.18 g/lb BW/day) (Burke et al., 2011). Intake requirements over this amount are less common in team sports athletes; however, during the preseason, when the athlete's fitness is very important, the daily amount of carbohydrates should range between 6-10 g/kg BW/day (2.73 - 4.55 g/lb BW/day) to support 1 to 3 hours of training (Burke et al., 2011). Either way, these should be subject to each athlete's changes in body composition, usually observed during the preseason. The provision of carbohydrates for different situations is illustrated in Table 2.

Table 2. Daily Carbohydrates Necessary for the Provision of Energy and Recovery

	Situation	Carbohydrate Targets g/kg/BW/day (g/lb/BW/day)	Type and Time of Intake
Low	Low intensity, recovery or activities of specific skills.	3-5 (1.36-2.27)	The time of intake should promote rapid replenishment of glycogen, or provide carbohydrate intake around training sessions of the day. As long as carbohydrate needs are provided, the consumption pattern can be carried out depending on convenience and individual choice.
Moderate	Moderate exercise program 1 hour a day	5-7 (2.27-3.18)	
High	Endurance program or moderate to high intensity exercise 1-3 h per day	6-10 (2.73-4.55)	Athletes may choose compact carbohydrate-rich sources that are low in fiber and easy to consume to ensure that the objective of the energy required is met. Athletes should practice to find a carbohydrate plan that suits their individual goals, including hydration needs and intestine repose.
Very high	Extreme commitment to moderate to high intensity exercise > 3 h per day	8-12 (3.64-5.45)	

Source: Adapted from Burke et al., 2011.

Note: These recommendations should be redefined with individual considerations of the total energy required, and specific training needs, and feedback on training / competition.

Carbohydrates stored in muscles and the liver should be well administered prior to exercise. This is particularly important when athletes want to perform at their best. Key factors in glycogen storage are dietary carbohydrate intake, and in the case of muscle stores, tapered exercise or rest. In the absence of muscle damage, muscle glycogen deposits can be

restored in ~24 hours of rest, if accompanied by an adequate intake of CHO (7-10 g/kg/day) (3.18 - 4.55 g/lb BW/day) (Burke et al., 1995), although amounts up to 10g/kg/day (4.55 g/lb/day) may be a bit excessive for sports like soccer, but not for rugby for example. Either way, the most practical thing would be to schedule a rest day before the competition or light training, while following a diet rich in CHO (Burke, 2006).

There are several research reports that have reported performance benefits when carbohydrates are consumed before and during high-intensity exercise of ~1 hour (Anantaraman et al., 1995; Below et al., 1995; Jeukendrup et al., 1997; Carter et al., 2003; Carter et al., 2005; Rollo & Williams 2009). In fact, in this type of exercise, the athlete's body has the ability to store an amount of carbohydrates that should be sufficient to withstand the match without an extra contribution. Therefore, the reason why the extra carbohydrates would provide an advantage is not clear. It is possible that carbohydrate intake improves the function of the brain and central nervous system, reducing the perception of effort during the exercise. In line with this, infusion of glucose has been shown not to affect performance (Carter et al., 2004), but a mouth rinse with a carbohydrate solution (without swallowing the solution) has been reported to improve both running (Rollo et al., 2010) and cycling performance (Carter et al., 2004). The potential activation of brain areas involved with exercise regulation and reward by means of the stimulation of receptors in the mouth has been cited as the potential mechanism; highlighting the metabolic and central benefits of carbohydrates.

Carbohydrate intake during and after exercise also seems to help the immune response to exercise (Gleeson 2000; Gleeson 2006; Nieman & Bishop 2006; Nieman 2007). Cellular immune parameters are often reduced or compromised after prolonged training. It is reasonable to assume that improving the immune status through carbohydrate intake can result in fewer sick days experienced by the athlete.

Eating Hours before Competition

It is clear from the information in the previous section that an increase in the intake of CHO in combination with a reduction in the intensity and/or volume of training days before the competition can significantly increase intramuscular glycogen stores. However, when nutritional preparation prior to competition has not been optimal, if there has been a moderate fasting period (8-12 hours), or if access to CHO during competition is diminished or is impossible, then CHO intake hours before competition can have a beneficial effect on performance.

It is extremely important for players to apply pre-exercise nutrition strategies during the months before the competition, to thereby be able to detect possible tolerances and minimize adverse effects.

In general, research on pre-competition CHO intake have focused on two time periods: three to four hours pre-competition, or 30'-60' (minutes) before the start of the exercise. In both cases, the goal is to increase the availability of glucose to the musculoskeletal system, while trying to minimize gastrointestinal distress and the potential adverse metabolic effects that hyperinsulinemia may produce in susceptible individuals.

Carbohydrate Intake 3 to 4 Hours before Exercise

Consuming foods and fluids rich in carbohydrates before exercise is very important in situations where carbohydrate stores in the body have not been all restored and/or when the sports event is of a longer duration and a greater intensity and may deplete the stores.

In this case, the importance of glycogen in soccer has led to the widely recurring strategy of a **pre-match meal**. Eating a meal rich in CHO (approximately 140-330 g of CHO) makes it possible to increase muscle glycogen stores (and apparently liver stores as well) and improves performance (Hargreaves, 2001).

During a match, the benefits gained from endogenous glycogen reserves with the contribution of carbohydrates are relative to the original amount and to the muscle's training status. In addition, because the liver glycogen stores can be significantly reduced after a night of fasting, ingestion of CHO may increase these reserves and contribute, together with the continuous absorption of CHO ingested from the digestive tract, to maintaining blood glucose during exercise. Interestingly, after fasting overnight, ingesting a meal containing 2.5 g of carbohydrate per kg (1.14 g/lb) of the player's body mass has been reported to increase muscle glycogen by 11-15% and liver glycogen by 33%, 3 h after ingestion (Taylor et al., 1996; Wu & Williams 2006).

Consumption of CHO in the hours before exercise often results in a transient decrease in blood glucose at the beginning of exercise, an increase in CHO oxidation and a decrease in the mobilization of free fatty acids (FFA) (Hargreaves, 2001). Although these metabolic disturbances may persist for several hours after consumption of CHO, they do not seem to have a negative effect on performance during the exercise, provided a greater availability of CHO compensates for the increased CHO utilization.

Sherman et al. (1989) carried out a study that exemplifies the advantages of consuming CHO before an endurance exercise. The effect of ingesting

a liquid supplement that provided 312 g of CHO vs. placebo 4 hours before intermittent effort on a cycloergometer was assessed on 10 subjects (total duration: 95 min) followed, after a 5 minute break, by a time trial where subjects were required to complete a pre-set amount of work as quickly as possible. The placebo did not provide CHO, while the 312 g of CHO in the supplement represented an amount equivalent to 4.5 g of CHO/kg (2.05 g of CHO/lb). After consuming the drink with CHO, an increase in insulin levels was observed at the beginning and during exercise, as well as a decrease in blood glucose in the first 15 minutes of exercise (which then increased and remained constant). However, subjects were able to reduce time trial test duration by 8.3 min., representing a performance improvement of 15% ($p < 0.05$).

In a practical sense, if access to CHO during exercise is limited or impossible, consuming 200-300 g CHO three to four hours before exercise can be an effective strategy to try and improve endurance performance.

Carbohydrate Intake 30' to 60' (minutes) before Exercise

CHO intake within the hour before exercise results in a marked increase in plasma glucose and insulin. Therefore, immediately prior to warm-up or the match (depending on individual preference) players may ingest carbohydrates (25-30g) to decrease the release of glucose from the liver (Howlett et al., 1998). The role of liver glycogen is to regulate blood glucose concentrations (euglycaemia: 4-5.5 mmol·l⁻¹).

When the athlete starts exercising, there is a rapid fall in blood glucose, although the CHO ingested through the intestine continue to be absorbed. This is due to a combined stimulatory effect caused by hyperinsulinemia and contractile activity on glucose uptake by the musculoskeletal system and by the inhibition of the increase that would generally be induced by muscle activity in hepatic glucose production (Hargreaves, 2001). Interestingly, blood glucose has been reported to be elevated during repeated sprint activity and is rarely observed to decrease to concentrations that may impact on performance (Krustrup et al., 2006). These data would suggest that the rate of glucose release from the liver is sufficient to compensate for the use of blood glucose throughout 90 min of soccer activity in well fed players.

It is important to note that during a prolonged match, meaning if it goes to overtime and penalties, blood glucose concentrations will fall and if not replenished may result in hypoglycemia (Foskett et al., 2008). Symptoms of hypoglycemia include suboptimal functioning of the central nervous system, which could have implications on physical and technical

performance (Vergauwen et al., 1998; Nybo 2003; McRae & Galloway 2012).

An increase in consumption and oxidation of plasma glucose by the musculoskeletal system seems to be the phenomenon that explains the higher CHO oxidation generally observed when CHO is ingested before exercise (Costill et al., 1977; Horowitz, Mora-Rodriguez, Byerley, & Coyle, 1997).

Pre-exercise CHO intake causes an attenuation in increasing plasma free fatty acids (FFA) typically observed with exercise, following the attenuation of lipolysis caused by an increase in insulin (Horowitz et al., 1997). This lower fat oxidation when ingesting a meal rich in CHO before exercise is due to reduced availability of plasma FFA, but also due to an inhibition of the oxidation of intramuscular triglycerides (IMTG) (Coyle, 1998; Coyle, Jeukendrup, Wagenmakers, & Saris, 1997).

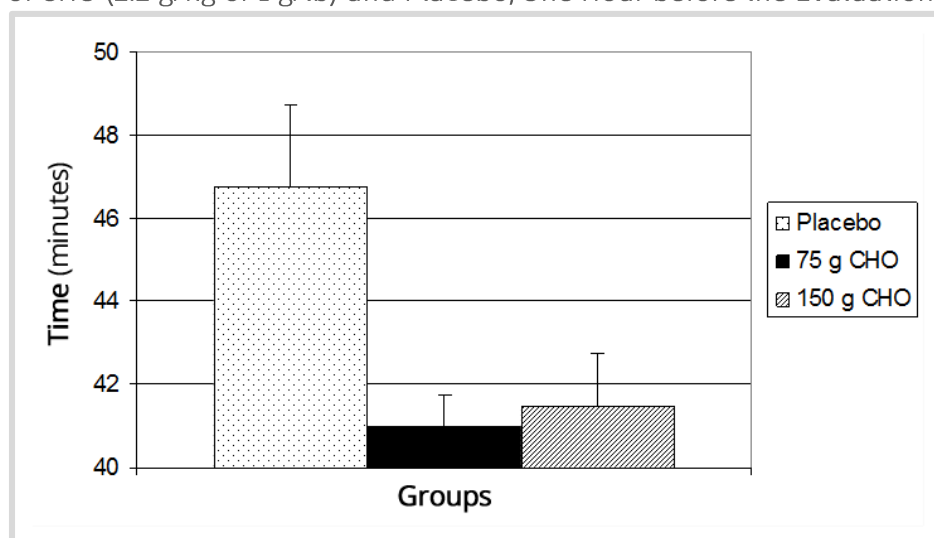
Because all the metabolic effects of pre-exercise CHO intake are the result of hyperglycemia and the resulting hyperinsulinemia, numerous alternatives have been investigated to minimize changes in blood glucose and insulin before exercise. Some of them are: a) intake of fructose or CHO other than glucose with a different GI value; b) changing the amount of CHO and time consumption; c) adding fat to the pre-exercise meal; d) adding a warm-up before exercise. In general, although these interventions modify the metabolic response to exercise, attenuating the pre-exercise insulinemic and glycemic response does not seem to cause a significant advantage over the physical performance (Hargreaves, 2001). In addition, when CHO are ingested during prolonged exercise, the GI of the pre-exercise meal has no significant effect on metabolic responses and performance (Burke, Claassen, Hawley, & Noakes, 1998).

Metabolic alterations associated with CHO intake in the hour preceding the exercise could affect physical performance. It has been suggested that the increase in muscle glycogenolysis seen in some studies (Costill et al., 1977) could result in an earlier onset of fatigue during exercise. However, since the publication of these studies, other studies have either found no changes (Febbraio, Keenan, Angus, Campbell, & Garnham, 2000; Sparks, Selig, & Febbraio, 1998), or have reported improved physical performance (Kirwan, O'Gorman, & Evans, 1998; Sherman et al., 1991).

As an example, we will briefly discuss the results of the study conducted by Sherman et al. (1991). This study compared the effect of consuming 2 CHO liquid supplements 1 hour before a cycloergometer exercise. There were nine participants who consumed a beverage that provided 75 g of CHO (1.1 g CHO/kg or 0.5 g CHO/lb), another which provided 150 g of CHO

(2.2 g CHO/kg or 1 g CHO/lb) or a non-caloric placebo. The subjects cycled at 70% $\dot{V}O_{2\max}$ for 90 min., and then they conducted a time trial (similar to that implemented in the study conducted by Sherman et al. (1989)). Figure 3 shows the result of the time trial. It is important to note that all subjects completed the performance test in less time after consuming the CHO. The average performance during the time trial improved by 12.5% when the beverage with 75 g of CHO (1.1 g/kg or 0.5 g/lb) was consumed. It is also worth acknowledging that performance did not improve or worsen when twice the amount of CHO (2.2 g/kg or 0.5 g/lb) was consumed. This means that, despite having significantly elevated plasma concentrations of insulin, and an initial drop in blood sugar at the beginning of the exercise, CHO intake 60 min. before exercise improved performance.

Figure 3. Performance in a Time Trial Test on a Cyclergometer after Consuming Two Drinks which Provided 75 g (1.1 g/kg or 0.5 g/lb) or 150 g of CHO (2.2 g/kg or 1 g/lb) and Placebo, One Hour before the Evaluation.



Source: Adapted from Sherman, Peden, & Wright, 1991.

Therefore, even though CHO intake within the hour before exercise has remarkable metabolic effects, which could have negative consequences in susceptible people, it seems that there is very little scientific evidence to recommend not consuming CHO within the hour preceding the exercise (Coyle, 1997; Hargreaves, 2001). Furthermore, it should be noted that CHO intake during exercise reduces the potential negative effects that accompany intake in the hour pre-exercise.

It is important to note that a pre-competition feeding strategy must be developed individually for each athlete, and should be tested during training or less important competitions in order to compare different intake protocols and see which one achieves the best results. Each athlete must judge the benefits and practical issues associated with pre-effort

diet in his particular situation. In general, a pre-competition diet should balance a number of factors including also issues such as individual preferences, availability of food and beverages, and gastrointestinal comfort.

At FCB, the type, timing, and number of pre-exercise meals should be chosen according to the athlete's individual circumstance, experience and preference. Foods low in fat, low in fiber and low-moderate-protein are preferred for pre-exercise meals as they are less likely to cause gastrointestinal problems (Jeukendrup & Killer 2010).

Acute carbohydrate intake strategies for competition of varying timing are referenced in Table 3.

Table 3. Acute Carbohydrate Intake Strategies. These guidelines are designed to promote high availability of carbohydrates to promote optimal performance in key training sessions and in competition.

	Situation	Carbohydrate Targets g/kg BM/day (g/lb)	Type and Timing of Intake
General Preparation	Preparation for events up to 90 min in duration	7-12 (3.18-5.45)	Athletes may choose compact carbohydrate-rich sources that are low in fiber and easily consumed to ensure that fuel targets are met, and to achieve goals for intestine repose or faster races. There may be benefits in consuming small regular snacks
Carbohydrate Loading	Preparation for events greater than 90 min continuous/ intermittent exercise	36-48 h of 10-12 (4.55-5.45)	It can be achieved by increasing meal portion sizes of carbohydrate and snacking on carbohydrate rich foods between meals.
Pre-Exercise Meal	Before exercise > 60 min	1-4 g (0.45-1.82) 1-4 h before exercise	The timing, amount, and type of carbohydrate foods and beverages should be chosen to suit the practical needs of the event and individual preferences/ experiences. Avoid foods high in fat/protein/fiber to reduce the risk of gastrointestinal disturbances during the exercise. Low GI choices may provide a more sustained source of fuel for situations where carbohydrates cannot be consumed during exercise.

During Short Duration Exercise	< 45 min	No mouth rinse required	Athletes may benefit from rinsing their mouths with carbohydrate solution
During Continuous High-Intensity Exercise	45-60 min	Small quantity needed / mouth rinse	
During Endurance Exercise Including "Intermittent" Sports	1.0-2.5 h	30-60 g/h	Opportunities to consume foods and drinks vary according to the rules and nature of each sport. A range of drinks and sports products can provide carbohydrates that are easy to consume. Availability of dietary choices and specialized sports products ranging in form from fluid to solid may be useful. The athlete should practice carbohydrate intake during training before adopting this practice in competition. This will help determine individual goals and preference considering hydration needs and gut comfort.
During Ultra-Endurance Exercise	> 2.5-3 h	Up to 90 g/h	Higher intakes of carbohydrates are associated with better performance. Products that provide multiple transportable carbohydrates (glucose and fructose mixtures) will achieve high rates of oxidation of carbohydrates consumed during exercise.

Quick Recovery	< 8 h recovery between two demanding sessions or playing two competitive matches per week.	1.0-1.2 g in the 4 h post exercise, then resume daily carbohydrate needs	The athlete should practice to try and find a carbohydrate plan that suits his individual goals including hydration needs and gut comfort.
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Source: Adapted from Burke et al., 2011.

Pre-Competition Hydration

Dehydration is probably one of the most common nutritional problems in sports. In most situations it is possible that the ability to consume fluids during exercise is not enough to match the losses caused by sweating. Therefore, it is essential for athletes to begin competition and training well hydrated. This is even more important when subjects might not have been able to regain their balance of body fluids after previous efforts.

A general recommendation that could be useful for most athletes is to consume a volume equivalent to 5 ml of fluid per kg (2.27 ml of fluid per lb) of body weight before the beginning of the exercise. A slightly more detailed plan could be consuming 300-600 ml with the pre-competition meal and then 300-450 ml 15-20 min. before the event starts (Burke, 2006). Another recommendation for pre-hydration is to consume ~5-7 ml/kg (2.27-3.18 ml/lb) at least 4 hours before the beginning of the exercise. If the subject does not urinate or his urine is dark, he should increase fluid intake (~ 3-5 ml/kg or 1.36-2.27 ml/lb) about 2 hours before the start of competition (Sawka et al., 2007). Starting pre-hydration several hours before allows the athlete enough time to urinate in case he needs to get rid of any excess fluid.

Although water may be a suitable option for pre-hydration, the use of sports drinks (i.e., CHO and electrolyte solutions) could be a good idea, especially before longer events, since it provides both fluids and CHO.

3.2.2 Strength, Speed and/or Power Sports

Strength and power are important factors in the performance of numerous sports. This is perhaps most evident in sports where athletes must demonstrate high levels of these abilities in a single effort (e.g., Olympic-style weightlifting or javelin throw), but the ability to produce strength, especially power, also plays a key role in the performance of many other sports.

Due to the large number and variety of sports we could cover when addressing those that depend to some extent on strength and power, this material will not go over each in detail, but will outline the general nutritional aspects applied to strength training.

To maximize training results, the athlete should follow a diet plan that makes it possible to support a demanding training plan, which generates a hormonal environment conducive to anabolic reactions and reduces catabolism, and provides all necessary nutrients in due course to achieve the adaptations sought.

The main nutritional factors of interest in this diet plan are the achievement of a positive energy balance, adequate protein intake and optimum nutrient supply (in terms of type, quantity and timing) in relation to strength training. The last point mentioned can be summarized under the concept of timing, meaning the timely and coordinated contribution of key nutrients, depending on the stimulus (training session) to optimize adaptations, and thus achieve a more efficient workout that ultimately allows for improved performance.

Energy Intake

The first thing to note is that to modify body weight, we must alter energy balance², either producing a negative energy balance if our goal is to lose weight, or a positive energy balance if we seek to gain weight. While this might lead us to believe that manipulating energy balance is simple, the truth is that several factors can affect the ability of a subject to do this. These factors may be innate in the modification of the components of the energy balance equation, but they are also influenced by other factors that are unique to each individual, and need to be taken into account. These factors may be related to genetics, lifestyle, social class and behavioral aspects, evolutionary phase, as well as eating habits and physical activity (Manore & Thompson, 2007).

² Review related subjects using the material from Unite 2 of the course

Thus, it would seem like a simple task for athletes to gain weight: increasing energy intake slightly should suffice. However it is not so, and many athletes have issues reaching a positive energy balance. In addition, weight gain is sought at the expense of lean tissue and not simple weight gain, which may result from an increase in fatty tissue, therefore the quality of that extra energy to achieve a positive energy balance is an important aspect.

The weight gain program for an athlete should begin with the development of a strength plan with adequate characteristics to increase muscle mass, together with an energy-dense diet, providing a positive energy balance. It should take rest and recovery into account, as these are essential for the synthesis of new tissues. A logical and realistic weight gain goal should be implemented; a weight gain of between 0.25 and 0.5 kg/week (0.55 and 1.1 lb/week) is usually appropriate (although this will depend on each subject's characteristics, particularly their genetics and strength training history). If the increase is excessive or happens too fast, fat mass is likely to be increasing as well.

A positive energy balance will promote an increase in body weight, usually at the expense of an increase in both lean mass and fat mass. However, each subject's response varies greatly as to the amount and distribution of weight gained (Bouchard et al., 1990).

The magnitude of increasing energy needs and the degree of positive energy balance that is necessary to maximize muscle mass increase and minimize fat mass increase have not been studied in depth among athletes. In part, this is due to the complexity and the intricate relationships between energy and protein metabolism.

The literature is not very extensive when reviewing the recommendations made by different authors on this point, but most recommend modest increases in energy intake to maximize gains in lean tissue and minimize gains in fat mass. The recommendation is to estimate the daily energy expenditure of the subject and give this a small "plus" of energy, to facilitate the achievement of a positive energy balance. Some authors suggest slight increases such as 200 kcal/day, or 3 kcal/kg (1.36 kcal/lb) (Butterfield, 1991). Others propose an increase of between 300-500 kcal/day over the estimated energy expenditure, maintaining an even distribution among the macronutrients in the diet (Manore & Thompson, 2007).

As for body weight loss, due to how complex this situation is, it is usually best for athletes to carry out this plan off season.

Carbohydrate Intake

Many strength and power sports athletes do not believe CHO consumption is important in their diets. In fact, the needs of CHO in this sports population have been researched far less than other sports. However, CHO intake may play an important role in optimizing the adaptations induced by a strength training plan. There are two different ways this could happen. First, an adequate supply of CHO for strength and power athletes would allow them to train harder, meaning that it would have a **direct ergogenic effect**, thus optimizing training adaptations. Second, CHO intake may promote a **favorable cellular hormonal environment** for a positive net energy balance (that is, protein synthesis > protein breakdown) of muscle proteins, or to improve other aspects of recovery and adaptation to training.

There are no longitudinal studies in the literature that have assessed the total daily intake of CHO in the results associated with strength training. However, some studies have assessed the effect of acute CHO supplementation before and/or during a strength session on different aspects of performance in these sessions. The results are somewhat conflicting, because although some studies reported favorable effects with CHO consumption, others did not report the same findings. These differences may be explained by several factors, but it is generally believed that the main reason has to do with the amount of glycogen used during the session. Therefore, it is more likely that the intake of CHO has an ergogenic effect when it comes to long sessions (~ 60 min. or more), involving a high workload, that is, similar to the work done in hypertrophy phases when carrying out periodized strength training (Haff, Lehmkuhl, McCoy, & Stone, 2003).

In conclusion, although the available data seem to show a positive effect of CHO consumption on different aspects of metabolic responses to strength training, these are insufficient to propose specific recommendations. However, it seems reasonable to recommend strategic CHO intake to athletes in relation to the training sessions. CHO consumption before and during the sessions will allow them to maintain a more adequate availability of glucose during prolonged exercise. CHO consumption after the session, although it seems to have less effect on the net balance of muscle proteins (i.e., synthesis less protein degradation), will have a favorable effect on glycogen resynthesis, which will be positive to doing the next training session.

While it is true that the diet of strength and power athletes does not require significant amounts of CHO compared to other sports specialties (e.g., endurance), this is no reason to recommend a deliberate restriction

of CHO, or use diets very low in CHO, as many fad diets do (e.g., Atkins). Therefore, it should provide a normal amount of CHO (meaning, 5 to 6g/kg/day (2.27 to 2.73 g/lb/day)), although this should be adjusted according to the standards of the training plan.

Protein Requirements

Because the body is not able to synthesize all the AA necessary for protein synthesis (meaning essential AA), and that reusing AA from the catabolism of body protein is not 100% efficient, it is necessary to provide a certain amount of protein daily by means of a diet (Phillips, 2002).

Controversy surrounding protein requirements of physically active people and those who train strength in particular seem to focus on the concept of "adequate" (i.e., the amount of proteins needed to cope with stress imposed by exercise). In this regard, it was noted that an increase in protein synthesis occurs when the ingested amount is sufficient (1.4 g/kg/day or 0.64 g/lb/day) to meet the demands of training versus poor diet (0.85 g/kg/day or 0.39 g/lb/day). However, when an excessive amount of proteins is provided, it will not have an "extra anabolic effect" but will induce an increase in the oxidation of AA (1.4 vs. 2.4 g/kg/day diet) (0.64 vs 1.09 g/lb/day). (Tarnopolsky et al., 1992).

Another important aspect is that the amount of protein required in the diet, both to maintain and to increase deposits of body protein, is closely and inextricably related to the amount of energy provided by our diet (Butterfield, 1991; Phillips, 2002; Tarnopolsky, 2006). If we consume enough energy, our protein requirements will be lower than if we have a low calorie diet.

Either way, it seems that athletes require slightly higher amounts of protein than sedentary subjects (especially when this has been estimated from studies using the nitrogen balance). Generally speaking, a protein intake ranging between 1.2 and 2 g/kg body weight/day (0.55 and 0.91 g/lb BW/day) is suggested. A more detailed recommendation including different situations can be seen in Table 4. However, it should be noted that these values are only a guide, and to establish the optimal protein requirement, other factors should be taken into account: not only the sport done but the particular situations of each athlete, such as the goals set (e.g., weight loss) or the particular characteristics of the training program.

It is important to highlight that although the usually recommended maximum value (2 g/kg/day or 0.91 g/lb/day) more than doubles the value for sedentary people (0.8 g/kg/day or 0.36 g/lb/day), this amount of protein is relatively easy to cover with a natural and varied diet, the

consumption of protein supplements not being essential, especially when athletes consume enough energy in their diet and include sources of high biological value protein (Tarnopolsky, 2006, Tipton & Witard, 2007).

Table 4. Estimated Protein Requirements for Different Sports and Sedentary People

Group	Requirement Protein in g/kg/day (g/lb/day)
Sedentary Men and Women	0.8 to 1 (0.36 to 0.45)
Recreational Endurance Athletes	0.8 to 1 (0.36 to 0.45)
Endurance Athletes (Moderate Training)	1.2 (0.55)
Endurance Athletes (Elite)	1.6 (0.73)
Strength-Power Sports	1.4 to 1.7 (0.64 to 0.77)
Strength Sports: Beginning of Training Program	1.5 to 1.7 (0.68 to 0.77)
Strength Sports: Maintenance	1 to 1.2 (0.45 to 0.55)
Teenage Athletes	1.5 to 2 (0.68 to 0.91)
Female Athletes	~ 15% less than men

Source: Adapted from Tarnopolsky, 2006.

Note: (a) Training equivalent to 4-5 times a week for 30', at least 55% VO₂max.; (b): training approximately 4-5 times a week, between 45' and 60'; (c) training that requires endurance training, aerobic workouts and power (e.g., rugby or American football).

Effect of Nutrient Type and Timing of Intake on the Metabolism of Muscle Proteins

Until not long ago, the discussion on protein requirements of athletes seemed to revolve solely around the total daily amount of protein needed. However, in recent years there has been abundant evidence that protein needs must not only reach a daily total value but there are other factors that may be as important or even more important, such as the type of protein or AA to be consumed, the timing of consumption, and whether consuming it with another nutrient (e.g., CHO) simultaneously has an added benefit. Therefore, beyond establishing a given protein requirement, which is almost impossible for some authors (given the complexity of the topic) (Tipton & Wolfe, 2004), other important factors that should be considered by the athlete are what to eat and when to eat it.

Endurance exercise causes an increase in the rate of **muscle protein synthesis (MPS)** in the post-exercise recovery period, but in conjunction with this increase, it also causes an increase in the rate of degradation.

Therefore, the net protein balance remains negative until AA is provided to the muscle (Tipton, Ferrando, Phillips, Doyle, & Wolfe, 1999). It also seems that the composition of AA supplied in recovery can influence the response of the net balance of muscle proteins, because protein synthesis is stimulated just by providing essential AA (EAA), which suggests that the contribution of non-essential AA is not necessary (Borsheim, Tipton, Wolf, & Wolfe, 2002; Tipton et al., 1999).

Another important aspect to consider is the dose of AA provided. The minimum effective dose of AA necessary to increase MPS above baseline or post-workout strength values when fasting is ~3-6 g of EAA (Borsheim et al., 2002; Cuthbertson et al., 2005; Miller, Tipton, Chinkes, Wolf, & Wolfe, 2003), while the dose that would stimulate the MPS to the highest level, both at rest (Cuthbertson et al., 2005) and after strength training (Moore et al., 2009), is around 8-10 g of AAE.

Recent studies have questioned the role of CHO intake and concomitant hyperinsulinemia in achieving an optimal response in muscle protein exchange. For example, the study by Koopman et al. (2007) assessed the effects of different amounts of CHO consumed together with a sufficient amount of protein on MPS after endurance exercise. Ten young men took part in three experiments. Each had a strength session (~1 h duration) followed by an assessment of the 6-hour recovery period, during which they consumed one of the following 3 drinks every 30 minutes: a.) PRO, contained only proteins (0.3 g/kg/hour) (0.14 g/lb/day); b) PRO + LCHO, proteins with a low dose of CHO (0.3 g PRO/kg/hour + 0.15 g CHO/kg/hour) (0.14 g PRO/lb/hour + 0.07 g CHO/lb/hour); c) PRO + HCHO, proteins with a high dose of CHO (0.3 g PRO/kg/hr + 0.6 g CHO/kg/hour) (0.28 g PRO/lb/hr + 0.28 g CHO/lb/hour). No differences were recorded in the fractional synthesis rate (FSR) of muscle protein among the different drinks. In short, it appears that when the dose of protein consumed is adequate, consumption of CHO during the recovery phase of the strength exercise is unnecessary to maximize MPS (Koopman et al., 2007; Phillips, 2011, Phillips, 2014).

Generally proteins, depending on the digestion rate, can be differentiated into "fast" proteins (e.g, whey or soybean protein) or "slow" (e.g., casein) according to the speed at which AA are absorbed and appear in circulation (Burd, Tang, Moore, & Phillips, 2009; Phillips, 2011).

Another important factor that can modulate the anabolic effect of different protein intake, in addition to its rate of digestion, is the AA content of the specific protein. This means that different proteins considered nutritionally complete (i.e., "high quality") can give rise to a different amplitude and duration in elevation in plasma of essential AA, and leucine

in particular, which will end up affecting the degree to which protein synthesis is stimulated, especially at the muscular level (Phillips, 2009; Phillips, 2011).

Tang, Moore, Kujbida, Tarnopolsky, & Phillips (2009) conducted a study in which they compared the response of MPS to intake of 3 high quality protein, but different rates of digestion, both at rest and after strength training. There were 18 young male participants, separated into 3 groups. Each group consumed an equivalent amount (~ 21 g) of a type of protein (whey, casein or soy), after the strength session. While at rest, whey and soy consumption produced significantly greater FSR than casein consumption. After the strength exercise, the FSR was significantly higher than that recorded at rest in the 3 groups, and although again the values obtained with whey and soy were significantly higher than those of casein, it was also observed that the response from whey consumption was significantly higher than for soybean.

We must also ask whether there is a dose-response relationship between the amount of protein consumed and MPS stimulation after endurance exercise. Not many studies have been published on this. Recently Moore et al. (2009) conducted a study that examined the response of the MPS at different doses of egg protein (0, 5, 10, 20 and 40 g) after endurance exercise. The main finding was that increasing the dose of MPS stimulates protein intake in a dose-response relationship up to 20 g of protein consumed (equivalent to ~8.5 g of EAA); after which greater MPS is not observed, but increased oxidation of AA is observed when the optimal dose is expressed in terms of body weight, equivalent to 0.25 g/kg (0.11 g/lb) (Phillips, 2014).

Some research has addressed this issue in the context of whole foods, although they are less abundant. There have been some studies that indicate other positive effects of milk consumption in the recovery phase after strength exercise. For example, Wilkinson et al. (2007) examined the effect of isonitrogenous and isocaloric amounts of beverages based on milk and soy proteins (745 kJ; 18.2 g protein, 23 g CHO, 1.5 g fat) on net balance and FSR of muscle proteins after strength exercise. The different rates of protein digestion, probably along with different composition of AA, provided different responses, despite both being complete high quality protein. The main finding was that while both drinks resulted in a positive net balance of protein and an increase in the FSR of muscle protein after the strength exercise, the effect observed with the consumption of the drink based on milk was higher.

While there is strong evidence supporting the beneficial effect of consuming different combinations of nutrients post strength training,

there is still some controversy on when would be the most appropriate time to do so. Beyond certain discrepancies among the different studies, the information available suggests that the increased availability of AA in the period after the strength exercise (either before, during, or after) is beneficial to ensure adaptations to strength training. In this respect, some authors propose that the "**anabolic window**" during which AA or proteins should be consumed to achieve the greatest increases in muscle mass is probably a period of 30-45 min. before and/or within 2 hours post-exercise (Phillips, Tang & Moore, 2009).

3.2.3 Intermittent Sports

Intermittent exercise is characterized by being composed of high-intensity efforts alternating with periods of lower intensity efforts or even rest. This distinctive feature of these types of exercises involves a series of very different physiological demands that characterize the efforts of prolonged endurance we discussed in the previous section.

This type of activity typically covers a great range of sports (most team sports and many individual sports), and although they usually have some common characteristics, they are usually grouped into three main groups to facilitate analysis:

- 1) Field Team Sports (e.g., soccer, rugby, field hockey, etc.).
- 2) Court Team Sports (e.g., basketball, volleyball, etc.).
- 3) Racket Sports.

In this section of the material, we will focus on the first group, since they are the most studied in the area of SN applied to intermittent efforts.

General Characteristics of Team Sports

Most field team sports can be considered, depending on how long they last, long effort or even endurance sports, because they usually last between 60 and 90 min. However, it would be wrong to consider them to have the same characteristics as a continuous and prolonged effort, as discussed in the previous section, just because in some cases they have similar durations. Some of the distinguishing features of these activities are summarized below:

- Stages of high intensity throughout the game are alternated with lower intensity activities (walking, jogging), or sometimes even pauses.

- The game incorporates dynamic interruptions. These can be formal ("time outs") or informal pauses (due to substitutions, injuries, violation of regulations, etc.).
- The game dynamics of different positions within a team, or even playing styles among teams, can vary greatly. This means that in the same sport there may be different demands (both physical and physiological) on players who have different needs from the nutritional point of view.
- One of the main features of these sports is that the work regime during competition is unpredictable. A priori, not much of what will happen during the match can be predicted, so it is difficult to make an accurate assessment of what the nutritional challenges that players will face in each competition will be.
- While some estimates of the pattern of activities carried out by players (e.g., total distance traveled, time or distance covered at different speeds, etc.) have been calculated in some sports, these calculations generally underestimate energy expenditure during the game because accelerations, decelerations, changes of direction, ball handling, etc., increase energy costs.
- There are different models of competition. There may be several alternatives, but the most common are: a) a regular league or season; b) "play-offs" where pre-phases are played before the final phase; c) a tournament (several matches in a short period of time). Each requires different strategies when planning training and recovery periods. The amount of skills needed from the athletes also tends to vary and even different competitions often overlap. All this poses a real challenge to planning nutrition strategies (both for training and competition) to be used by athletes to achieve their nutritional goals.
- Finally, another distinctive feature in these sports is that performance is usually determined by a complex combination of physical/physiological determinants as well as coordinative skills.

Common Nutritional Issues for Team Sports

Nutritional requirements imposed by field team sports are complex and varied. In some cases, giving an account of them is challenging for athletes. These needs may change even throughout the season, depending on the phase of the season. While it is clear that there are differences in the nutritional needs among different sports, sometimes there are differences even within the same team.

Below is a summary of some common points that should be taken into account by the field team athletes, separating them according to competition or training:

Training:

- Cover high energy requirements, especially during demanding training periods (preseason, "double shifts", etc.) during strength training phases for the development of muscle mass, or during periods of growth and adolescence.
- Achieve high intakes of CHO to allow optimal repletion of body glycogen stores.
- Consume an adequate amount of protein that will help to undergo demanding training, recovery processes, and adaptation to training.
- Pay attention to CHO and fluids intake during prolonged training sessions.
- Carry out nutrition education programs that improve knowledge of athletes on key issues related to nutrition.

Competition:

- Eat a pre-competition meal.
- Manage fluid and CHO intake during the match.
- Replenish fuel stores and rehydrate properly between competitions, especially during tournaments.
- Plan optimal nutrition when athletes must travel to compete.
- Reduce consumption or consume as little alcohol as possible, especially after competition, not to hinder the recovery process.

Below, we briefly describe two basic aspects of team sport diets: CHO and fluid intake to maintain optimal hydration status.

Carbohydrate Intake in Team Sports

The limited availability of data makes it difficult to develop precise guidelines regarding CHO intake for these events. Either way, it seems logical to think that in those sports where there are more demanding play patterns, or even within the same sport or team, players who typically have higher demands during training or matches should pay more attention to adequate CHO intake.

A study conducted with soccer players reported that a high CHO diet (~ 8 g/kg/day) (~ 3.64 g/lb/day) increased muscle glycogen stores even more and allowed players to complete a greater amount of work (~ 33%) at high

intensity during a simulated, 90 min. 4 vs. 4 match, compared with consumption of a low CHO diet (Balsom, Wood, Olsson, & Ekblom, 1999).

Although more studies are necessary to provide clearer recommendations to team sports players, it seems reasonable to set a goal of 5 to 7 g CHO/kg/day (2.27 to 3.18 g CHO/lb/day) for those sports that do not have very demanding game dynamics, for training or competition situations that are not very demanding, or for players with low energy requirements. For players with more significant demands who want to maximize their muscle glycogen stores between sessions or matches, it would be necessary to increase consumption to 7-10 g CHO/kg/ day (3.18 to 4.55 g CHO/lb/day).

Fluid Balance and Performance in Team Sports

The effect of dehydration on performance in continuous and sustained exercise has been extensively studied. In these types of efforts, dehydration has been linked to a decrease in capacity and endurance performance, as well as to lower thermoregulatory capacity, especially in hot environments. It has also been shown to reduce gastric emptying and to increase the risk of gastrointestinal disturbances; these two factors are extremely important since they make fluid and CHO replenishment even more difficult.

However, for intermittent efforts, such as those that characterize team sports, the impact of hypohydration has been much less studied. Despite this, both resilience and performance are expected to be adversely affected by states of hypohydration. Due to the fact that team sports are not only characterized by efforts of an intermittent nature, but also by relying on coordinative abilities and mental functions (related to reading the game and decision-making), it is even likely that hypohydration has a greater effect on these types of sports, than those that are characterized more by a locomotive type of performance (such as running or cycling). It has been observed that hypohydration levels as low as 2% loss of body weight can adversely affect mental functioning.

Due to all of the above, below we summarize a series of recommendations to maintain the balance of body fluids and minimize the effect of hypohydration (Burke, 1997):

- 1) In moderate environmental conditions, meaning where there is great thermal stress, try to keep a deficit below 1 to 1.5% of body weight prior to training. Under hot conditions, it would be more practical to be a bit more flexible with this goal, and try to maintain a deficit of less than 2%.

- 2) In warm environments (e.g., when temperatures exceed 25°C/77°F and 60% RH), check how excessive heat can build up. In some cases it is possible to modify some of them to reduce heat stress (especially in training). For example, the time of day, length of session, working time without pausing to ingest fluids, and the clothes used, among other things, could be taken into account.
- 3) Players can learn their typical sweat losses, and those under different environmental conditions, by simply weighing themselves before and after a workout or game. This would not only monitor the success of fluid replacement strategies, but it would also identify players who are likely to suffer large losses of sweat.
- 4) Ideally, players would begin the session or match in euhydration. If they are not completely in this state, consuming 500 ml 2 hours before the game can be useful.
- 5) Opportunities to consume beverages should be identified and optimized. This is easier to handle during training than during matches. Either way, during competition, halftime, formal time outs (due to injury, substitutions, or when a goal is scored), may be some useful moments for fluid replacement.
- 6) A hydration plan should compensate at least 80% of sweat loss, although sometimes this may not be practical or possible (especially when it comes to players who have high sweat rates).
- 7) Access to drinks during matches should be planned in advance. This is a key factor, because even though the player knows he needs to drink, if it is not easy to do, then that knowledge is not very useful. Among the points to consider, the following should be taken into account:
 - That there should be an adequate supply of drinks to allow players to meet their fluid needs before, during and after the training or match;
 - Using individual bottles is often useful to keep track of each player;
 - Organizing the coaching staff to bring drinks to the players when the game situation allows it;
 - Encourage players to consume fluids when they have the chance.

- 8) Another important point to consider is palatability and temperature of the drinks, as these are key factors to stimulate consumption.
- 9) Sports drinks provide a "double advantage" over water: a) they help replenish not only fluid but also electrolytes; b) they also provide CHO.
- 10) Given that there will be some degree of hypohydration (especially during matches), post-effort rehydration is a critical part of the recovery plan. 150% of weight lost should be replenished since part of the fluid that is consumed is lost through urine. Beverages containing CHO and electrolytes should be prioritized as much as possible.
- 11) Finally, highlight a key principle of the applicable sports nutrition to any nutritional manipulation, including those related to fluid replacement: the "hydration plan" should be practiced for matches and tested during training to look for issues that may arise and each individual player's response, and make adjustments as deemed necessary.

3.2.4. Sports by Weight Class

A distinctive feature of these sports is that having to "**weigh-in**" for a class is part of their culture. Weighing-in refers to the processes used by athletes to lose weight in order to qualify in a class below the subject's natural weight (Wright & Garthe, 2014).

While there have been some changes in weighing rules in some sports and various sports-related medical organizations have warned of the potential risks that these practices involve, there are still athletes who use risky practices to weigh-in.

It is very common for individuals competing in these sports to have to two **weight cycles**, meaning stages that alternate weight loss and gain, which can be repeated between 1 and 15 times in a competitive season. During these cycles, athletes try to weigh-in striving to maintain their lean body mass, physical performance and health, and after weighing, they regain their previous weight and performance capabilities through the consumption of a large amount of food and beverages (Wright & Garthe, 2014).

Strategies for weight loss include restricting the consumption of food and/or drink and/or an increase in exercise. Among the most commonly

used techniques to restrict food intake are: fasting, skipping meals, and inducing vomiting. Dehydration techniques often include using saunas, hot tubs, heated workout rooms, plastic or rubber clothes to stimulate sweating, laxatives and/or diuretics (Wright & Garthe, 2014). Overall, in order to weigh-in, athletes often use a combination of different techniques.

There are several potential concerns related to the nutrition, performance, and health of athletes when they try to weigh-in for competition. The extent and severity of each will depend on how extreme the strategy used is, the frequency of application, how long the low weight is supported for, and the athlete's individual response.

Regarding the nutritional aspect, each athlete's nutritional needs should be individualized and these should be adapted to the moment of the season and the weight loss goals sought. In general, athletes who take part in these sports are advised to maintain a weight that is no greater than 3% above the desired competition weight (Wright & Garthe, 2014). If the goal is to make changes to body composition, the off-season period would be the ideal time to do it.

Apply a gradual weight loss technique (≤ 1 kg/week or 2.2 lb/week) is recommended during pre-competition, mainly to promote the loss of fat mass and maintain lean mass, and thereby minimize the potential negative effect that rapid weight loss would cause on performance (Wright & Garthe, 2014).

According to each athlete's need, the plan should be for the last 1-2 kg (2.2-4.4 lb) to be lost the last day prior to weighing, through **rapid weight loss (RWL)** techniques, and thus minimize the loss of lean body mass and muscle strength.

When weighing-in prior to weighing, athletes are recommended to limit rapid weight loss to less than 3-4% of body weight. This would help to minimize the decline in performance as well as the symptoms associated with rapid weight loss strategies (e.g., dizziness, nausea, headaches, etc.). Rapid weight loss strategies (decrease > 1 kg/day or 2.2 lb/day) are often implemented from 7 days to 1 day before weighing (Wright & Garthe, 2014).

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