Module 2. Nutrition and ergogenic aids

2.1 Introduction

2.1.1 The importance of nutrition in team sports

The importance placed on nutrition in sport has grown over the past few years, along with public interest in the topic. Today, it is understood that food contributes much more than just energy. Food also influences health, performance, rest, mood, injury prevention, and much more.

Nutrition is another aspect that needs to be managed within a sports team, depending on the importance it is given, which in turns depends on the coach. If the coach considers nutrition to be a key factor, this will be transmitted to the players and to the rest of the professionals. This, in turn, will translate into action in the form of monitoring hydration, weight, body composition, and providing nutritional education with optimal recovery as the objective.

In the long term, a team that monitors nutrition and treats it as a significant factor will impart discipline and a beneficial routine to its players, which will then automatically be assimilated by new players as they join the team.

The concepts of "dieting" and of "restriction" are now perceived as a useful and positive part of an athlete's training. The objective of nutrition when focused on training and competition is to ensure that the player individually knows how to eat, drink and rest at all times.

A few years ago, the "athlete's diet" focused on providing extra energy in the form of carbohydrates, that is, eating more pasta, rice, cereals, etc. Although today those foods are still important, individualization and periodization are the new performance objectives, since an improvement in performance is only achieved through adaptation. (Heaton, Davis, Rawson, Nuccio, Witard, Stein, 2017).

Periodization means to alter diets in accordance with the intensity of training sessions or matches, to achieve a greater degree of adaptation (Jeukendrup, 2017).

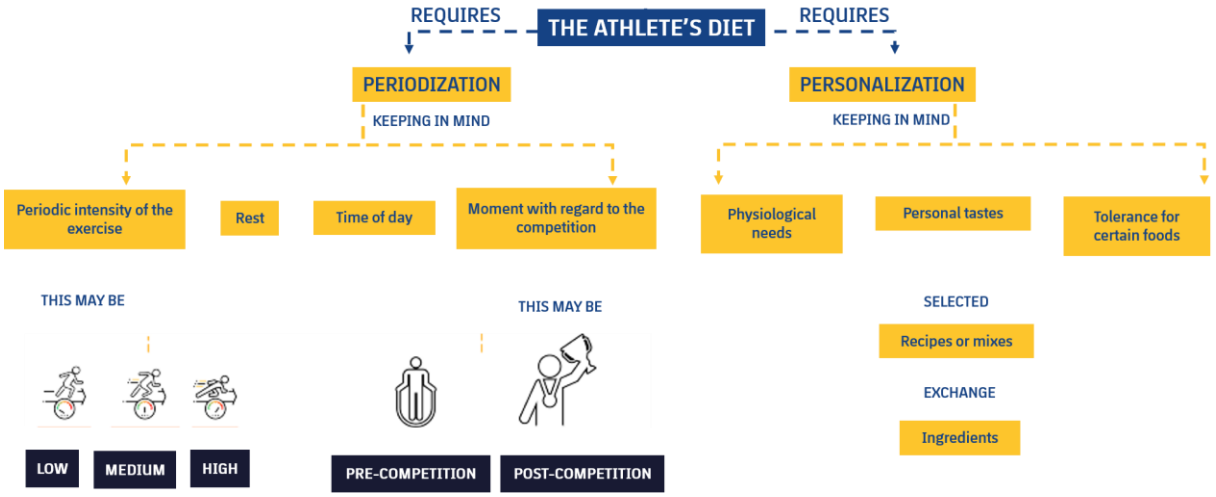
Not only is what athletes eat important, but when they eat it, so the concept of **timing** is of paramount importance. What athletes eat and drink before, during and after exertion should be planned out in accordance with the objectives for each of these moments.

Adaptation is a dynamic process that strikes a balance between the mental and physical demands of training sessions and matches. It should be counterbalanced by the capacity for recovery in accordance with guidelines for nutrition and rest, the capacity for coping with stress etc.

Personalization is grounded in understanding the individual needs of each player at a metabolic level, their body composition and also their supplementation, based on specific objectives that depend on each player's characteristics, their position on the team, etc.

In a not-too-distant future, nutrigenetics, metabolomics, metagenomics and other *"omics"* - encompassed by the term *sportomics* - will allow for à la carte knowledge and planning around a player's needs.

Figure 1: Periodization and personalization



Source: Modification of (Reference) (YEAR)www.ub.edu/grna

2.1.2 Nutrition objectives in team sports

All team sports have intermittent, high-intensity exertion in common, but there is a high degree of variability between the demands of different sports and even within the same sport, depending on the moment of the season and an athlete's position, playing style, etc.

Certain aspects of sports nutrition are common to all team sports:

1. Achieving the right body composition.
2. Adapting diet to training sessions and periodizing it in accordance with increasing or decreasing demand.
3. Planning nutritional and hydration strategies for competition.
4. Using the right ergogenic aids and supplements (Mujika & Burke, 2011).

Nutritional recommendations for team sports should include some group objectives which can then be adapted to the individual characteristics of each player in accordance with his individual traits, playing style, body composition objectives, etc.

General objectives:

1. To supply an amount of energy tailored to an athlete's needs and to adjust the amount of carbohydrate-rich foods on days with more or less activity, matches, etc.
2. To provide high-quality protein, portioned out over the course of the day, to facilitate muscular adaptation and recovery after exertion.
3. To choose healthy foods of high nutritional value that provide significant quantities of vitamins and minerals and help to control inflammation, maintain immunity, etc.
4. The importance of timing: knowing what to eat at each moment (before, during and after a training session or a match), in accordance with the different objectives of those moments.
5. Hydration and supplementation: will be examined in more depth in the next unit.

Other nutritional factors to consider

- Knowing how a player eats: who prepares their food, cultural aspects, religion, family environment, type of foods eaten outside the home (restaurants and favorite foods that determine diet quality).
- Knowing if a player is on a special diet or taking supplements of her own volition or is being advised by another professional.
- Developing and implementing a nutritional plan for travel and relocation.
- Nutritional education in the form of talks, providing informational material, etc.
- Assessing a player's profile and environment in order to learn about her attitude toward the proposed changes, as well as the extent of her adherence.

Within the group, some players may be more or less interested in nutrition, and these attitudes will spread to new additions to the team and also to youth teams, especially when there is a model or referent, a highly valued player who takes care of his diet and thus acts as a role model. This is a question of attitude and interest in nutrition as another tool to achieve their objectives.

A key strategy for changing a behavior is for players to know what they want to achieve and why they need to make the change, since they do not always consider diet to be a key factor in their performance. When there is a decline in performance, or even an injury, this may be the right moment to instill this interest in them.

A player should be his own nutritional expert and know what his optimal weight or body fat percentage is, be familiar with hydration strategies and foods for before and after a match, know the best supplements for maximizing performance and for feeling healthy in every way. Nutritionists, as well as the team sports physician, physical trainer, physiotherapist and the other professionals must provide the player with the information and tools to achieve this, but is important that the player be aware of his own decisions, given that several times a day, for his entire career, he must make a decision about what to eat and drink and how to rest.

The objective of these units is to summarize some of the key facets and nutritional strategies to bear in mind in the context of team sports, conveyed in a practical way that will be useful to professionals so that they, in turn, can pass them on to players.

2.1.3 Body composition

The relationship between proper body composition, health and athletic performance has been clearly demonstrated. In team sports, it important to maintain a specific somatotype or anthropometric profile for optimal development in each sport, and, to do this, evaluation and monitoring is essential. At the same time, it is important that the staff be familiar with both group and individual objectives and that they convey these to the players so as to provide a proper education in nutrition in order to optimize athletes' health and performance. We refer to optimal percentages and not fixed numbers.

There is an optimal somatotype and percentage of body fat for every sport, that depends on age and varies according to player type or the player's role within the team (Oliveira, Ferreira, Caetano, Granja, Pinto, Mendes, et al., 2017).

In team sports, it is typical for changes to be made over the course of the season and for body fat percentage, for example, to increase during a rest period. Typically, these values adjust themselves over the course of the pre-season in the same way that one or two daily training sessions tends to increase muscle.

For a variety of reasons, an excessive increase in weight and body fat may occur during the off season, when the athlete is not in competition shape, or is injured. It is important to have nutritional education strategies available for these situations that will teach players to make choices about what to eat at home, in restaurants, while on trips, etc.

Ideally, the player himself will be familiar with these changes and see the pre-season as the best time to improve, since it will be more difficult to do so when competition begins. During competition periods, an excess of training load and poor adaptation to this load can lead to muscle reduction, which is associated with other signs of overload and poor

recovery. Conversely, well-orientated strength workouts and the ingestion of a 25-30g bolus of protein during the post-exertion period promotes the gain of muscle mass and is sometimes used to optimize body composition during monitoring periods.

In order to monitor these changes, the simple routine of registering body weight is an easy and non-invasive way to evaluate a player's energy balance, although it does not detect when these changes are produced. This initial measurement can be added to later as part of a more detailed analysis.

The purpose of carrying out a long-term detailed analysis of body composition is to evaluate the combined effects of workloads, nutrition, a player's physical development and her proper adaptation to demand. It is important to bear in mind that a player's body composition is determined by genetics, although not exclusively. There are other influential factors, such as the type or intensity of training, nutrition, rest, and different hormonal factors, along with intestinal microbiota.

In the professional leagues of various team sports, body composition tends to be measured at the beginning of the pre-season and is monitored throughout the entire season, typically every one or two months. The frequency of and methods used to measure body composition depend on the resources available to the club and its preferences.

There are different methods for evaluating body composition. Based on our experience, we will mention the three main methods used by athletes that play team sports.

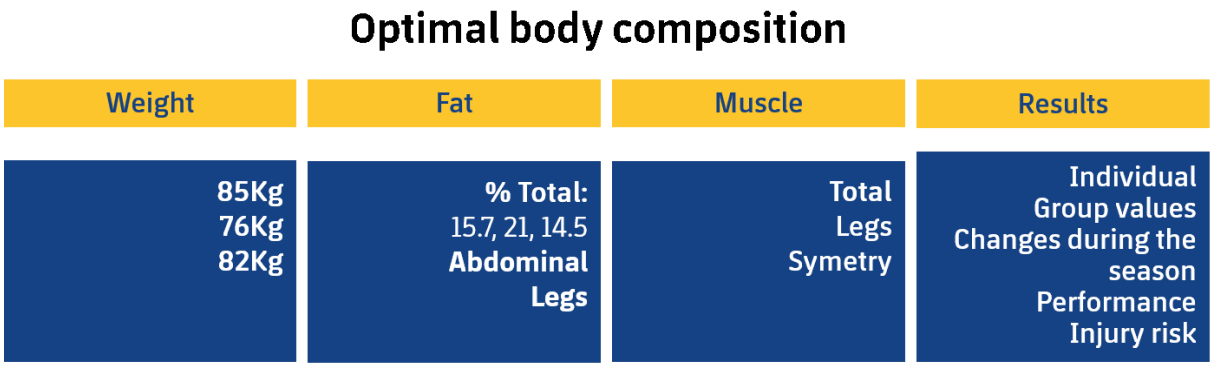
- **Anthropometry**: the measurement of skinfolds and the method most frequently used to evaluate body composition. Using calipers, this method measures skinfolds and fat at specific points of the body. This measurement is made at the 8 points of the body described by the International Society for the Advancement of Kinanthropometry: the biceps, triceps, iliac crest, supraspinatus skin folds, abdominal skinfolds, and calf. After these measurements are taken, the results are expressed as the sum of the thickness of the skinfolds at the points measured, or changes in specific skin folds are evaluated.
  The skinfolds that correlate most closely with body density and may reflect changes in the short- and medium-term are those located on the triceps and the abdomen, above the spine, and on the front of the thigh.
  The abdominal skinfold is linked to short-term changes associated with diet, while changes in the extremities may be related to increases or decreases in exertion intensity and muscle. Additionally, if the arm and leg circumferences are measured at their middle points, muscular circumference can be calculated or, adjusting for these same values, changes in these body parts can be monitored. This allows not only for changes in fat percentage to be evaluated, but also the percentage of

muscle mass over the course of the season. The shortcoming with this method is that it requires qualified personnel.

- **Bioelectrical impedance analysis (BIA):** this non-invasive technique determines body composition using a bioelectric method that measures resistance to the flow of a current. This resistance determines the amount of tissue that is a good conductor or poor conductor. Water and tissue with high water content, such as muscle, are good conductors, while fat behaves in the opposite way. This method gives us information about the total amount of water, fat, and the amount of lean body mass which in some individuals, can be clearly observed in each part of the body. Results obtained using this method have a direct relationship with results obtained using DEXA (see next point). The advantages of this method are that it gives the person administering the test the chance to direct it, the speed of the reading (from one to two minutes) and the speed with which results are obtained.

- **Dual-energy x-ray absorptiometry (DEXA):** an indirect technique that measures the varying attenuation of photons emitted as it relates to body composition and the thickness of the tissue that they pass through. DEXA studies three areas: fat mass, bone, and lean body mass. Body composition is measured with a sweep of the body and then by applying the attenuation coefficients.
  This technology has now become a very widely used method at the elite level of some team sports. It offers a relatively precise estimate of the proportion of lean body mass, bone density, and fat mass and an analysis of body parts such as the trunk, the limbs, etc.
  DEXA tends to be performed 3 or 4 times over the course of a season in order to evaluate changes. For example, during the pre-season, a month afterwards, and twice more, except, because of the small dose of radiation that it entails, in cases of special need, such as weight monitoring or in the case of injured players, when it may be performed more frequently.
  One of the problems with this method is that it is expensive and not available to many teams, and for that reason there are few reference values with which to make a comparison (Kelly, Wilson, Heymsfield, 2009).

Figure 2: Aspects of body composition that are relevant to team sports



Source: Lizarraga, 2018.

Generally, a common objective in team sports is to adjust fat percentages over the course of the season, while at the same time gaining muscle mass, looking for the most opportune moment in which to do this. The pre-season, as we have seen, is a propitious moment. Throughout the course of the season, there are influential factors (for example, whether or not players are starters, and the number of minutes played over the course of the season) which benefit those individuals who compete more than those who spend more time off the field.

Regular monitoring of body weight can be a way to evaluate the balance between what is eaten and what is expended. It is important to consider weight along with feedback in the form of tiredness, appetite, difficulty of getting to sleep etc., which may indicate poor adaptation.

Weight isn't everything. It is a useful indicator of a player's condition, but it should not be something that causes anxiety or stress or that might trigger a behavioral disorder.

In certain situations involving athletes, and female athletes in particular, it may be inadvisable to monitor weight. Special care must be taken with punishments or penalties for not losing weight, and an in-depth knowledge of every case is required.

It is helpful for team professionals (physician, physical trainer, etc.) to be motivated to ensure that players are in good physical condition, taking into account weight as a parameter to be monitored, but this must be done in a rationally, with clear objectives and a single message. Avoid derogatory comments at all times, they can be dangerous. Motivation for maintaining a proper weight and a good diet will be achieved by a player who considers such goals to be beneficial, positive, and desirable for the future of his career, as well as his post-career.

A group can be asked to maintain a specific percentage of body fat and each player can aspire to this, but it is important to individualize objectives and to be familiar with what

this implies for each athlete and how hard they will have to work to achieve the goal percentage. For example a team percentage of 12% body fat might be easy for some players to achieve without making a major effort, but for others, who start with higher values, reaching 13% or 14% might be a major achievement, which they must be congratulated for. An optimal individual value is something that each player must aspire to.

In order to be able to evaluate significant changes, a player's weight can be recorded regularly at the same time, which is usually when they arrive at training and when they are normohydrated. This gives us a control value that allows significant changes to be detected, with the flexibility of taking physiological oscillations into account, particularly for female athletes.

The strategy of weighing players before training and evaluating the amount of liquid they ingest and diuresis can be a useful tool for establishing hydration guidelines, as we will discuss. After a significant change in weight (gained as well as lost) it is important to assess potential causes and encourage the player to understand the causes.

Players who are going to be inactive for weeks (or months in the case of long-term injuries), require motivation in regards to changes in body composition and in making special adjustments to their diet. The objective is to control, insofar as it is possible, the increase in abdominal fat and the loss of muscle mass associated with immobilization and lack of exercise. In these cases, it is important to educate players so they can substitute the energy-rich foods they usually eat for other anti-inflammatory and protective foods with a lower calorie content. For example, reducing the intake of cereals or switching a pasta meal for a colorful vegetable salad with a small portion of pasta on the side, without forgetting that high-quality protein, which maintains muscle, should be included and portioned out at every meal.

The apportioning of daily protein, either in the form of a bolus or rations of 25-30g, 5-6 times a day will succeed in optimizing muscular response to exercise and the anabolic effect, or, in terms of gaining muscle mass, it is more noticeable if one of these protein intakes occurs after strength training.

The 25-30g mentioned above can easily be obtained through a 120-150g ration of meat or fish or through a protein shake, which may be more accessible immediately following exertion.

2.1.4 Energy expenditure

When athletes train or compete, energy expenditure increases significantly in absolute values, with significant variations between days of intense training or competition and

low-intensity days or days of rest. It is useful to know the estimated average of these requirements and to evaluate if they have been provided for or not, especially in situations in which tiredness, weight loss, immunological and hormonal changes etc. appear and can alert us to a shortfall in **energy availability**.

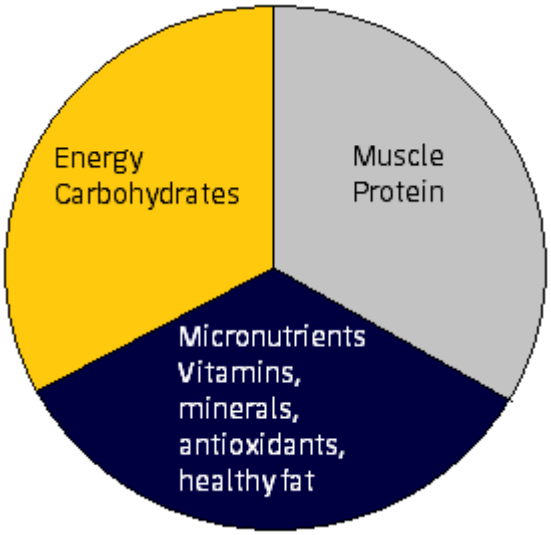
The literature indicates that when energy availability is low, that is, when daily energy intake is less than 30 Kcal/kg of lean body mass (free of fat), without taking physical activity into account, problems such as tiredness, fatigue, reduced athletic performance and immunodepression may appear.

It is important to be able to determine the population groups that are at risk because of a permanently insufficient energy intake. This can be the case for young athletes who are still growing, or in women's sports, in which it is more difficult to maintain weight and body composition. Sometimes female athletes follow strict or restricted diets that may lead to behavioral disorders related to food, hormonal changes, or even the complete triad, which includes the loss of bone mass.

2.1.5 Diet periodization adjusting energy and carbohydrates

Athletes use the plate model, which provides them with the three main food groups: energetic foods, protein-rich or body-building foods, and protective foods. Modifications are made to proportions in order to plan different plate models. These plans may include a model for days of low-intensity training or for players that monitor their weight. Another might be a plate for a day of typical training and another for a day of high-intensity training, which can be adapted for the day preceding a match, that is: day -1, match day, with all its particulars, and a recovery day (day +1).

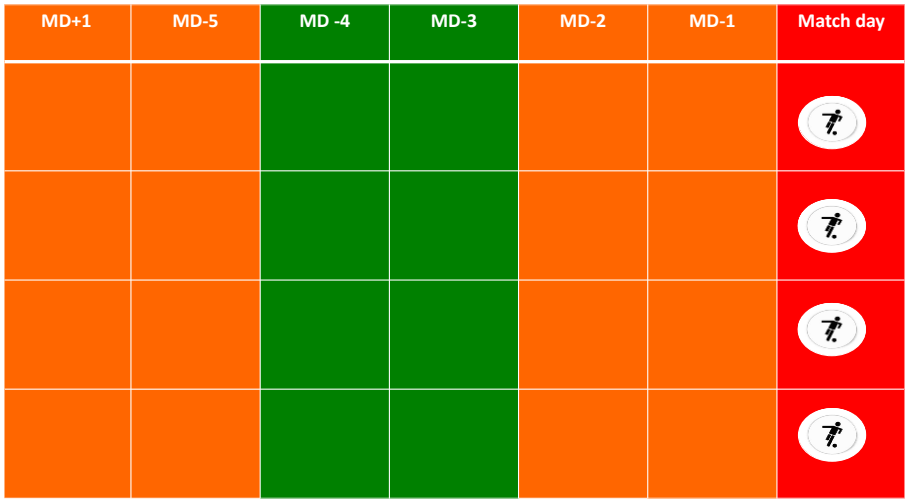
Figure 3: Example of plate model



Source: Prepared by the author.

On the basis of these values, diet periodization means that diet is adapted to days of rest, days of moderate intensity or of high intensity/match days, along with various other adjustments. In team sports such as soccer, these adjustments might presume, for example, an expenditure of 2,500 kcal/day on a day of rest; 3000 kcal on a low-intensity or recovery day and 3500 kcal on a match day, estimating the energy expenditure per match, in this case, a soccer match, to be 900-1000 kcal (Jeukendrup, 2017).

Figure 4: Diet periodization in a week with just one match



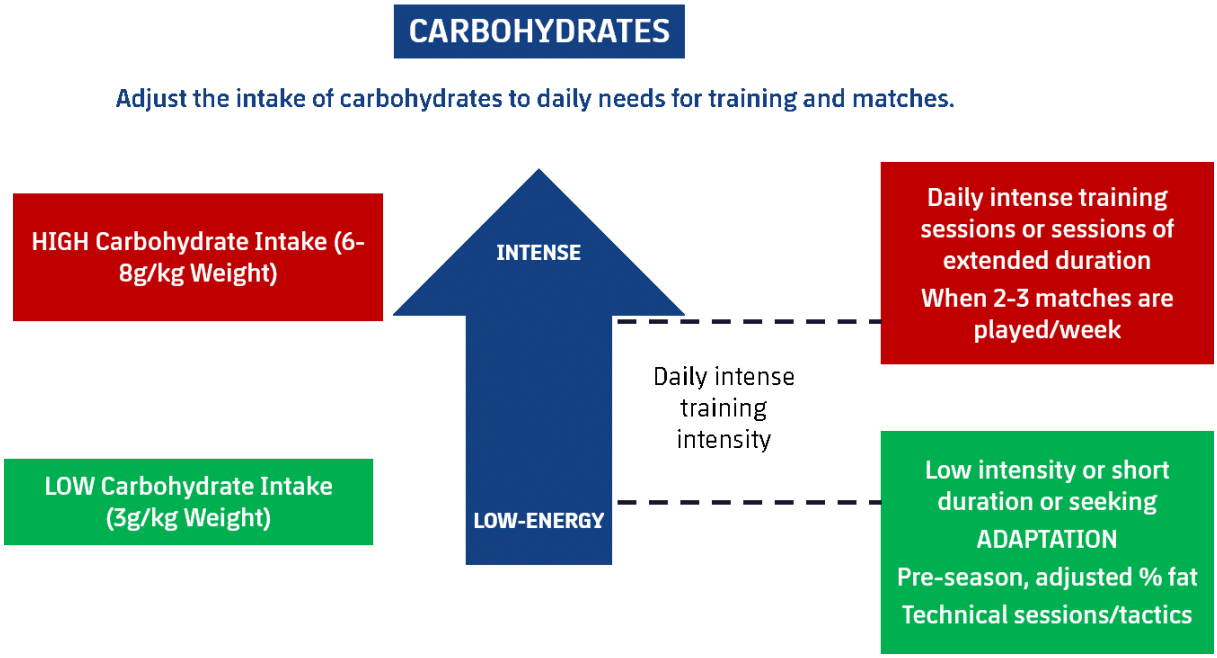
Source: Prepared by the author.

As shown in the figure through the use of different colors, we can periodize training loads and weekly nutrition for days with greater energy requirements (orange and red) and days of lesser intensity (green).

The objectives will vary in each case, but in general terms can be outlined as follows:

- Objectives for pre- and post-match days: -2 -1 Replenishing glycogen deposits in muscles.
- Match day objective: provision of extra energy, hydration, positive feelings, digestibility.
- 24-48 hours after the match: rehydration, optimal recovery of expended energy, muscle damage repair, inflammation control, etc. (Heaton, Davis, Rawson, Nuccio, Witard, Stein, et al., 2017).

Figure 5: Diet periodization or carbohydrate adjustment for sessions of increased intensity or match days



Source: Rollo & Lizarraga, 2017.

As we have mentioned previously, the energy expended on a day of rest can differ quantitatively from a match day or an intense day of training by 1000 kcal, but high-quality nutrition is still important, including in energy-controlled diets, and thus it is important to motivate the athlete to follow a diet that is:

1. Varied and colorful, protects against inflammation and rich in vegetables and healthy fats.
2. Has sufficiently high protein content and is portioned out over the course of the day.
3. Tailored to provide carbohydrates in accordance with the duration and intensity of exertion. These intakes may be in the form of small portions or snacks of fruit, cereals, rice, etc.

An athlete is unlikely to understand the percentage of calories in food or grams or kilograms of carbohydrates or protein weight, so the message about what to eat has to be delivered simply, with easy-to-identify size measurements - for example, big, medium or small, or even using photos as examples.

The concept of plate size and the portioning out of its contents, which are modified in accordance with an athlete's needs, such as increasing or decreasing the amount of pasta, rice, or potatoes or, conversely, salad, vegetables, etc. allows for meal options to be planned for different situations.

Although in individual sports the idea of periodization is well understood, and athletes train and eat differently depending on different factors, in the case of team sports, this is a more recent concept. In team sports, periodization is useful for making players aware that, in the same way that the load and intensity of their training is adjusted to achieve optimal adaptation, it is also necessary to adjust their diet and increase or decrease the quantity of certain key foods in order to maintain or recover energy reserves. For example, the amount of carbohydrates can vary in terms of absolute value from one day to another, and 2 rations of rice or pasta can be added to a standard diet, as can a bowl of chopped fruit, half a liter of a sports drink, or a recovery shake containing cereals that is ingested prior to falling asleep.

The periodization of carbohydrates means that on training days 4g/g of body weight is ingested, but on match days, this goes up to 7g/g of weight, so that a player weighing 80kg might eat up to an additional 250g of energy-rich foods, such as rice, pasta, fruit, cereals, or sports drinks, per day, a difference of 1000 kcal from one day to the next (Anderson, Orme, Naughton, Close, Milsom, Rydings, et al., 2017).

2.1.6 Schedule adjustment or timing

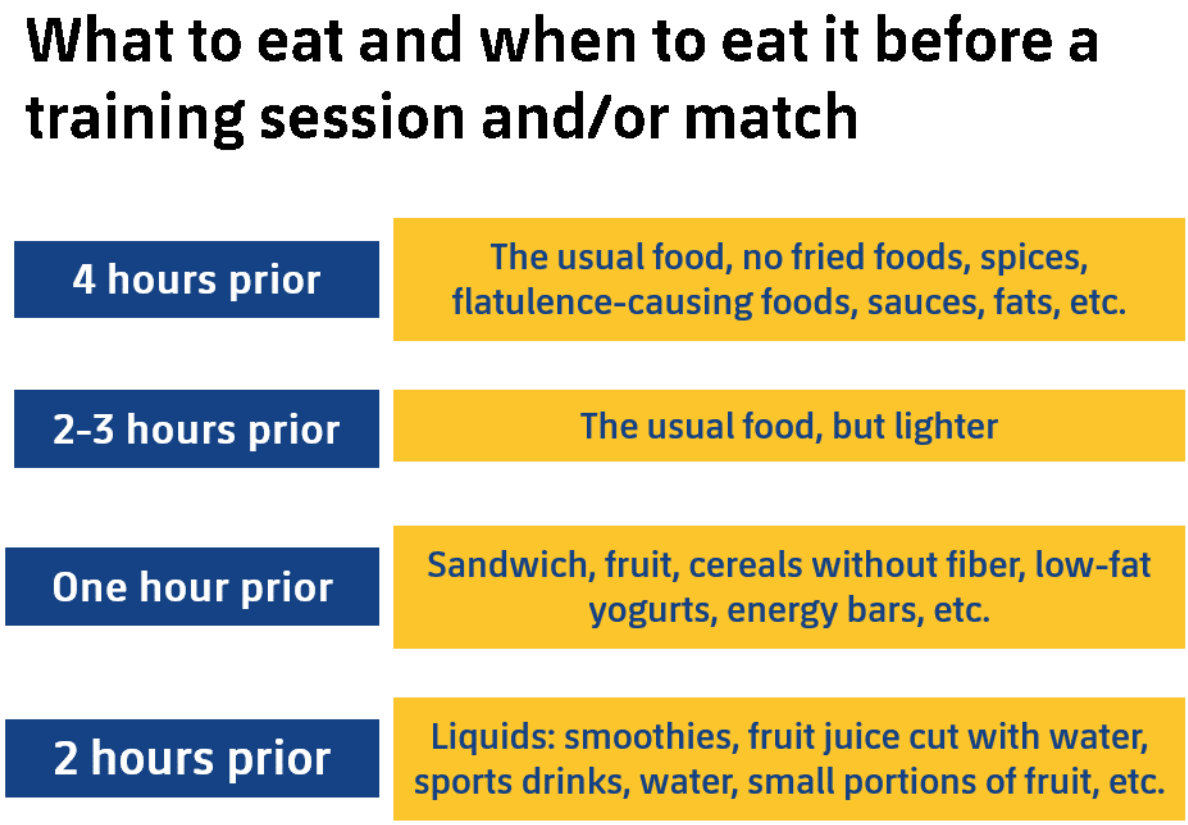
What time an athlete eats at is also very important. Athletes must be familiar with the concept of timing, or schedule adjustment, in order to understand when it is necessary for them to make an extra effort with their diet in order to optimize their recovery.

The purpose of timing meals in advance is to complete digestion before exertion and to prepare athletes, hydrate them, and provide glucose for their mental function just prior to starting a match. During exertion, athletes can ingest small quantities of fruit, gels, bars or drinks, in accordance with their tolerance, regulations, etc. Upon completing exertion, the objective is to adjust food and drink intake to achieve an optimal recovery.

There is a preparatory schedule available that takes previously recorded digestion periods into account and adjusts the quantity and type of food to the time available for

digestion. There is also an inverse schedule in which players begin their recovery with liquids and small meals so they can complete it in the hours that follow.

Figure 6: Overview of what to eat – and when to eat it – before a training session/match



Source: Prepared by the author based on Lizarraga, 2018.

The timing of adequate recovery is similar to an effect called muscular "open window", which refers to the fact that the two hours after exertion are considered vitally important for administering the drink, food and even supplements that we consider most appropriate for the athlete (Ranchordas, Dawson, Russell, 2017).

Figure 7: Overview of what to eat after a training session/match

What to eat after a training session or match

1 hour afterwards	Liquids: water, sports drinks, shakes, chocolate milk, fruit
2 hours post	Food for recovery: pasta, homemade pizza sandwiches, sushi, etc.
Before falling asleep	Chocolate recovery drink

Source: Prepared by the author based on Lizarraga, 2018.

The following variables often cause cumulative fatigue: dehydration, inadequate replenishing of muscle glycogen after exertion, metabolic acidosis and central fatigue caused by a fall in glycemia, among other causes (Mujika & Burke, 2011).

2.1.7 Nutritional strategies for recovery

It is important to know when to eat and what to eat. Today, food is more than just calories. For example, in addition to providing energy, it helps control hormonal responses and inflammation that occur in the hours following exertion. Recovery-promoting food that is eaten in the two hours after exertion is meant to limit cortisol levels and inflammation and promote the rapid replenishing of muscle glycogen, for which sufficient quantities of nutrients in the right proportions are needed.

A plate of carbonara, a low-fat pizza, sushi or a recovery shake can be good options for recovery and for achieving a 4:1 or 3:1 carbohydrate-to-protein ratio.

Optimal recovery is one of our main objectives when training sessions or matches overlap. This is difficult to achieve when there are less than three days between matches, which sometimes also involve travel, but the combination of **nutrition and rest** is the tool with which to do it (Dupont, Nedelec, McCall, McCormack, Berthoin, Wisløff, 2010).

Strategies such as protein shakes, or shakes combined with carbohydrates, ingested during the post-exertion period and before falling asleep can, together with a proper amount of sleep, minimize the effects of cumulative fatigue (Heaton, Davis, Rawson, Nuccio, Witard, Stein, et al., 2017).

2.2 Hydration and performance. Methods for evaluating dehydration and hydration strategies before, during and after training

Every day, during exertion, athletes lose lots of a water through sweat, urine, and breathing. However, they can take it in through foods and liquids in their diet. Dehydration by more than 2% of body mass can result in diminished performance. Each athlete has a different rate of dehydration, and so it is important to measure and monitor fluid balance.

To measure their rate of dehydration, the difference between a player's weight before and after exertion must be calculated, adding fluid intake and subtracting urine. The total is divided by minutes of exertion and multiplied by 60 to calculate their volume of sweat/hour.

This rate varies according to environmental conditions, the intensity of the training session or match, etc.

Formula:

$$\frac{\text{(Weight before exercise – weight after exercise) + (Volume of fluid ingested – volume urinated)}}{\text{Minutes of physical effort x 60 minutes}} = \text{Volume of sweat/hour}$$

It should also be kept in mind that minerals, such as sodium and chloride, are also lost through sweat, and that individual differences in this regard exist between players. So some players will need an extra intake of electrolytes after they finish activity in order to avoid cramps, etc.

Physical activity is often begun in a state of dehydration. This diminishes athletic performance and reasoning. That is why hydration before competition or training is as important as hydration during or afterwards. Players should know how to maintain their level of hydration and how to modify their fluid intake in accordance with the demands of exercise or environmental conditions.

The ingestion of fluid during training sessions and matches can help maintain plasma volume and prevent the adverse effects of dehydration on performance and health. When there is little time between matches, rapid and effective rehydration is crucial for

optimizing recovery. But it is also important to engage in daily strategies that improve hydration and build up a tolerance for liquids before and after exertion:

- **Prior to exercise:** 5-7 ml of fluid for every kg of body mass is recommended for the 2 hours before exercise is performed. The ingestion of liquids during meals, combined with small quantities of sodium, will help to stimulate thirst and retain water.
- **During exercise:** In order to avoid dehydration, it is important to follow suitable rehydration guidelines during training sessions and matches. To do this, athletes must be weighed regularly before and after training sessions and personalized guidelines must be designed that combine, for example, water with sports drinks. This will be particularly effective if exercise continues for more than 30 minutes in a warm environment. Unrestrained and excessive water consumption should be avoided during exertion over an extended period, as this can lead to hyponatremia (low concentrations of plasma sodium) caused by large volumes of sweat being replaced only with water. Hydration guidelines must be followed every day. Athletes should avoid consuming large quantities all at once to prevent the negative impact of excessive volume, such as the urge to urinate immediately, since this generates voluntary dehydration.
  When choosing sports drinks, it is important to see which drink is best adapted to the needs of the athlete. Nowadays, mineral salt content and carbohydrate content can be adjusted to 2, 5, or 12 percent, in accordance with athletes' needs. As we shall see, hydration through liquids also provides athletes with an opportunity to take in carbohydrates in accordance with their tolerance and needs. Drinks should be specifically tailored to the team sport to be played, and they should also be tested before being used during competition, to ensure that athletes do not suffer from intestinal problems. Sports drinks tend to contain sodium as well as water and carbohydrates in order to improve the absorption and retention of the water consumed.
- **After exertion**, it is important to rehydrate as soon as possible and to consume, in the two hours immediately following, at least 150% of what has been lost, through sports drinks, water, and food. In cases of severe dehydration, a combination of water, salt, and carbohydrates rehydrates more efficiently than water alone.

Ergogenic aids in team sports

Ergogenic aids include any substance that improves athletic performance, whether psychologically, materially, pharmacologically, or nutritionally. Nutritional aids includes both foods and functional foods, such as nutritional supplements whose purpose is to improve athletes' performance or to optimize their health. These supplements are often utilized by players during the season with the aim of improving performance and

optimizing recovery. One example of their extensive use is that 43% to 93% of soccer players use supplements, claims made in various studies. During the 2002 and 2006 FIFA World Cups, rates of supplement use of between 40% and 50% were recorded. In the face of these numbers, it is important to remember that it is rarely necessary to use supplements if athletes' diets are healthy, varied, and balanced. Even so, there are exceptions in which supplements can help with performance or recovery, but they must always be taken to complement a healthy diet, not as a substitute for it. In this context, a supplement is something that is designed to be edible and contains a dietetic component which is meant to provide additional nutritional value. The dietary ingredient can be a combination of the following substances:

- A vitamin.
- A mineral.
- A herb or other botanical components.
- Amino acids.
- Dietary ingredients are also utilized to increase an individual's total intake, through concentrates, metabolites, ingredients or extracts.

Sports nutrition products (such as drinks intended for athletes, protein drinks, or recovery drinks) are not considered supplements. Unfortunately, the athletic supplement industry is not well-regulated, and this implies a set of risks that must be avoided. Quality is an essential factor, and decisions about which supplements to use should be based on a rigorous cost/benefit analysis. Although there are thousands of supplements on the market, only a few are backed by scientific endorsement and evidence. These supplements or functional foods are classified according to their level of scientific evidence into the following groups:

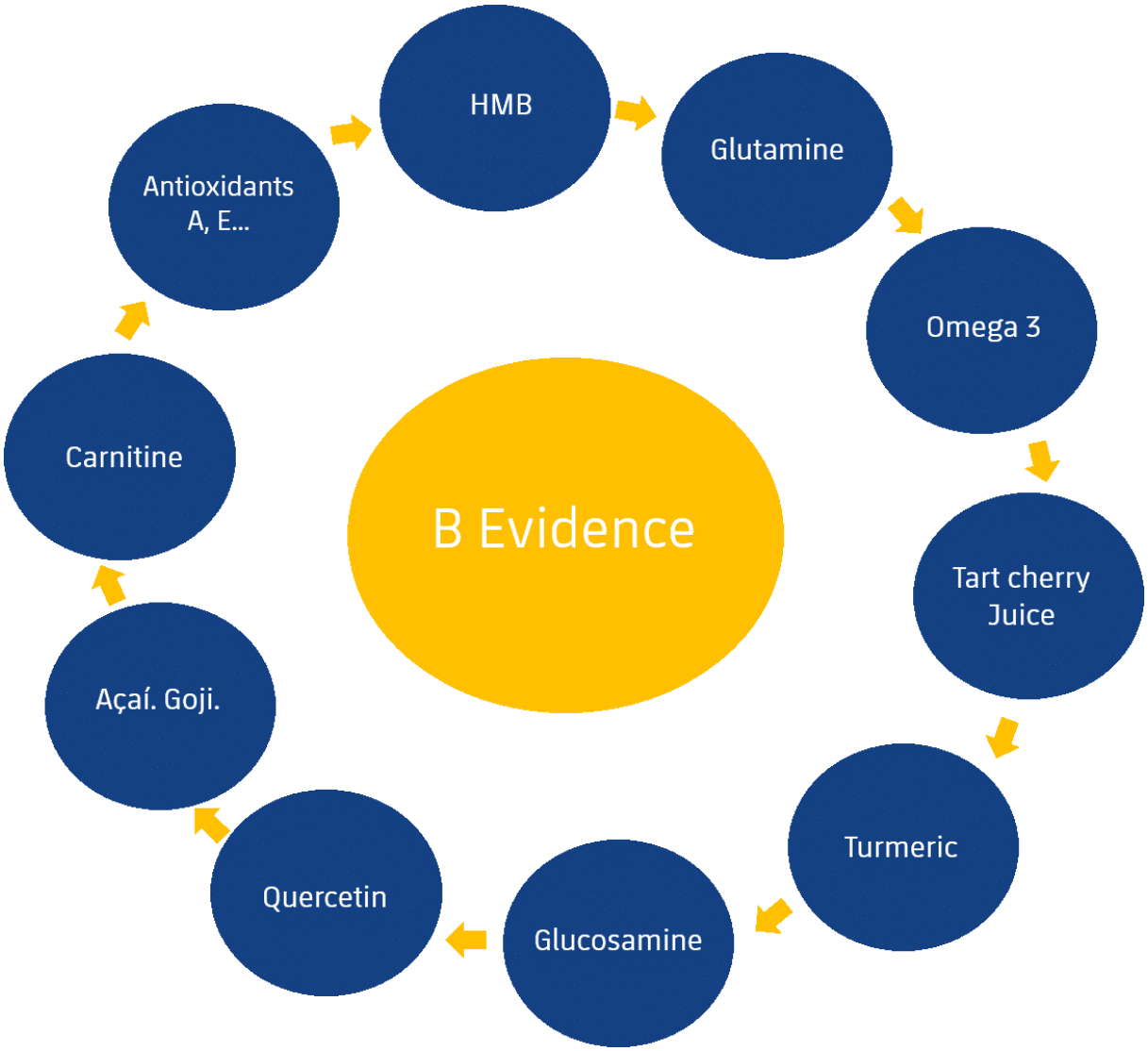
Grade A evidence.
Data from multiple randomized clinical studies or meta-analyses.

Figure 1: Supplementation with Grade A Evidence

Source: Prepared by the author.

Grade B Evidence.
Data from a single randomized clinical study or from large non-randomized studies.

Figure 2: Supplements with Grade B Evidence



Source: Prepared by the author.

Grade C Evidence.

Consensus of expert opinion and/or small studies.

It is important to keep in mind that, as professionals, we must preferentially recommend those supplements that are in groups A or B.

Grade D Evidence.

Banned or at a high risk of contamination by substances that might lead to a positive doping test. Should not to be used by athletes.

The recommending evidence must always be grades A or B in order to avoid false positives or inefficiency and to increase the demonstrated beneficial effects of supplements belonging to groups A and B.

2.2.1 The most commonly utilized nutritional supplements and functional foods

In this chapter we will take a detailed look at the most important supplements and corresponding scientific evidence. Next, some will be categorized according to their medical use (for the improvement of performance or of recovery):

Medical use, according to analytical results	Iron
	Multivitamin/Vitamin C
	Vitamin D
Improved performance	Caffeine
	Creatine
	B-Alanine
	Nitrates
Recovery	Tart cherry juice

This chapter will focus on those supplements that are used most frequently and have as their objective both the improvement of performance and the optimization of recovery. It is worth emphasizing that supplements should be used in specific situations in accordance with the protocols validated for their use. Supplements should be used after having been individualized, supervised and monitored by professionals working in the field. Although there is generalized evidence relating to these products, studies are needed to further refine individualized protocols, including for timing. Programs to ensure quality at every level are needed. These programs help to assure that supplements are safe and do not contain banned substances.

Supplement safety: quality assurance programs

There are significant risks associated with the use of unregulated dietetic supplements. These include:

- The absence of the active components named.
- The presence of harmful or toxic substances.
- The presence of drugs that should be prescribed and are potentially dangerous.

After the decision to use supplements has been made, it is very important to ensure that the supplement in question is among those supplements allowed by the World Anti-Doping Agency (WADA). In particular, we must also ensure that all supplements are free of banned substances. There are many examples of athletes who tested positive on an

anti-doping test as a result of their use of a nutritional supplement and experienced difficulties due to their use of these supplements. Thus, it is important to consider the risks and benefits before making a decision.

There are quality assurance programs that test products for banned substances. These programs analyze samples of supplements currently on the market and compare them using guides to substances banned by the WADA. However, these programs are still not reliable, since, in general, they do check whether the active components are present. Athletes, and those responsible for their supplementation, see these programs as a guarantee of the integrity of the products that they analyze. However, it is important to keep in mind that only a small number of supplements have been analyzed and that these analyses are limited in terms of minimum detectable amounts. Thus, although these programs make assurances that they are reliable, they do not offer an absolute guarantee of quality.

The supplements most commonly used by athletes are multivitamin complexes and mineral supplements, followed by other micronutrients, including vitamin C, vitamin D, magnesium and iron.

The supplements described in this chapter are those that are supported by a moderate-to-high amount of evidence and are important to various sports.

Performance-enhancing supplements

- **Caffeine**: Caffeine is a compound that is found in many drinks and food products (for example, in tea, coffee, cola, chocolate, etc.). It is possibly the most widely studied compound that is an ergogenic aid used to enhance performance. It has been consistently demonstrated that caffeine improves both cognitive performance as well as performance during various physical activities such as running, bicycling, swimming, and rowing (Burke 2008). Various studies have also concluded that it also improves the physical and technical aspects of athletic performance that are inherent to many athletic competitions.

  For example, caffeine can improve the ability to perform sprints and jumps, as well as improving performance in high-intensity intermittent sports (Grant et al., 2010). The ergogenic effects of caffeine are obtained with an intake of 2-6 mg/kg of body mass index (Burke 2013). Caffeine's peak plasmatic concentration tends to occur 45-60 minutes after its ingestion. It is recommended that it is consumed via drinks that contain caffeine, capsules, or gels (depending on the athlete's preferences) during warm-ups prior to the start of activity. Although the precise mechanisms

of caffeine's ergogenic contribution must still be verified, the majority of researches agree on caffeine's ability to affect the central nervous system. Caffeine moves through the blood-brain barrier easily and acts as an antagonist for adenosine, preventing its action. Caffeine can thereby increase concentrations of certain neurotransmitters such as dopamine, which elevates motivation levels and heightens physical ability. Recently, it has been shown that it can have an ergogenic effect in high-intensity intermittent sports through a mechanism related to muscle excitation. In fact, it has been demonstrated that caffeine supplementation causes an improvement in physical capability, since it reduces the accumulation of potassium in muscle during intense exercise (Mohr et al., 2011, 1372-1379).

Multiple studies have recreated competition scenarios and observed the effects of caffeine supplementation. Some of these have reported improved recovery and performance in comparison with players who were not supplemented with caffeine. In soccer, there are also studies that show a greater capacity for sprinting and jumping and improved perception on the part of players, since caffeine seems to reduce feelings of fatigue during training or matches. Unlike competition days, on which athletes consume caffeine products, on training days, they can obtain the same beneficial ergogenic effects if they consume caffeine by drinking tea or coffee at breakfast, prior to their training session.

Although there is ample evidence on caffeine supplementation in sports, it is recommended that athletes first trial supplementation during training. This is because caffeine may have adverse effects that limits its use in some sports or in sensitive individuals. These include: insomnia, headaches, intestinal irritation and bleeding and the stimulation of diuresis. Also, not all individuals obtain benefits after being supplemented with caffeine, and increasing the size of the dose (especially above 6 mg/kg BMI) can have negative consequences such as an increased heart rate, greater irritability, trembling, confusion, decreased concentration, shortness of breath, etc. Many of these side effects have a negative impact on athletic performance. Equally, consuming elevated doses of caffeine the night before a competition can also be problematic because sleep quality will be compromised (Morton, http://www.gssiweb.org/sports-science-exchange/article/sse-130-supplements-for-consideration-in-football, 2014).

Practical recommendations for caffeine supplementation

1. Carry out tests during training to ascertain the correct dose.

2. Set a goal of reaching 3mg/kg (within a range of 2-5mg/kg).
3. Take caffeine 45-50 minutes before a match.
4. If utilizing chewing gum for caffeine intake, take it just prior to or during warm-ups.
5. The form in which caffeine is taken will depend on athletes' tastes and preferences.

- **Creatine**: Like caffeine, creatine is one of the most frequently studied supplements, with a significant body of evidence available. Creatine is a guanidine compound that is synthesized in the liver and kidneys, derived from amino acids arginine and glycine. From a dietetic perspective, the richest sources of creatine are fish and red meat. For example, 1 kg of steak contains over 5 g of creatine (Maughan et al., 2011). The largest reserve of creatine in the body is in the musculoskeletal system, where between approximately 60%-70% of creatine is stored in a phosphorylated form known as phosphocreatine (PCr). Creatine supplementation has traditionally been associated with strength and power in athletes (such as, for example, the strength required by weightlifters or athletes who perform sprints) because of the role that PCr plays in the hydrolization and regeneration of ATP during the initial seconds of a high-intensity activity. In any case, in the context of high-intensity intermittent sports, creatine supplementation is especially important because PCr stores are markedly reduced during team sports such as soccer. As a consequence, creatine supplementation improves the repeated execution of sprints of both short and long duration and also improves the performance of intermittent exercises over an extended period of time. This improvement may be due to an increase in the reserves of phosphocreatine in recovery periods between sprints. Several sources (Casey, 1996) show an improvement in sprinting when creatine has been supplemented, as compared to athletes who have not been supplemented. Players can also take creatine with the objective of increasing muscle mass, strength, and power, as well as to improve their sprints.

  Harris and his colleagues provided the initial evidence that creatine supplementation (utilizing a supplementation protocol of 20g per day for 5 days) increased (by magnitudes of 20%) both total quantities of creatine as well as PCr stores in the musculoskeletal system (Harris et al., 1992). The guidelines for taking creatine have been standardized to a protocol for use (which usually implies 4 doses of 5 grams a day for 5-7 days) followed by a daily maintenance phase involving a dose of between 3 and 5 grams (Human et al., 1996). However, given that athlete adherence to this protocol may be limited, it should be kept in mind that the intake of

smaller doses over longer periods of time may, in the end, increase creatine in muscles, even to values similar to those observed after implementing more traditional supplementation protocols. After supplementation has been completed, muscle creatine stores tend to return to initial basal levels in 5 to 8 weeks. In order to maximize creatine stores, it is recommended that it also taken after physical activity in combination with carbohydrates or proteins, since an increase in insulin is also known to increase the production of creatine. At a practical level, this means ensuring that creatine is taken before and after periods of training together with other sports nutrition products that may contain carbohydrates and/or protein, or with a meal (breakfast, lunch, or dinner). Supplementation prior to exercise can also improve the resynthesis of muscle glycogen after exercise. Taking into account that it is difficult to replenish muscle glycogen deposits after physical exercise even with the proper contribution of carbohydrates, a strategy that includes creatine can be important during periods that feature numerous training sessions of matches, one after the other. (Morton, http://www.gssiweb.org/sports-science-exchange/article/sse-130-supplements-for-consideration-in-football, 2014).

It is important to take into account that not all athletes will have the same response to creatine supplementation, not only in terms of increased levels of muscle creatine but also in terms of improved athletic performance. In fact, the extent of the increases in muscle creatine (when a specific dose is administered) have an elevated rate of variation that depends on the initial quantity of muscle creatine present prior to supplementation. The latter is determined by dietary intake.

Improvements due to creatine in sports of intermittent duration are also greater in those athletes that have a higher starting level of creatine or PCr. A substantial supplementation of creatine can produce an increase in weight of between 1-1.15 kg. This effect occurs more frequently in men than in women (Mihic et al., 2000). This increase in weight is not associated with fat but may be due to increased concentrations of intracellular water. This is why not every player is interested in this type of supplementation: they may feel heavier and less fast. In particular, it will not be beneficial to athletes who require velocity and agility. This supplementation also has a negative effect on the liver and kidneys, although studies indicate that there is no relationship between creatine supplementation over long periods of time and liver or kidney damage in healthy individuals. In general, the current evidence suggests that creatine supplementation has positive effects in short-duration high-intensity

sports and in those with intermittent periods of activity. Creatine has crucial effects on the musculoskeletal system: it acts as an energetic sponge, as an energy carrier, and as a regulator for the ATP/ADP ratio.

After supplementation, it takes weeks for creatine levels to return to their original values, and, during this period, the benefits it provides can still be enjoyed. It is prudent to supplement during specific moments of the season (for example, in the pre-season, or when there are many matches scheduled one after the other, etc.) or in order to achieve objectives during training sessions (improving muscle mass, strength, etc.).

Recommended practices for creatine supplementation

1. Develop individual strategies.
2. Monitor changes in height and weight.
3. Supplementation can be of short duration (5 days x 20g/day) or be gradual in nature (3g daily for 30 days).

- **B-alanine**: In skeletal muscle cells, b-alanine combines with L-histidine to form b-alanine-L-histidine, better known as carnosine. Carnosine is associated with high-intensity exercises, since it can act as an intracellular sponge for hydrogen ions. In soccer, for example, repeated sprints can cause muscle pH to decline to levels that may impede the formation of ATP via glycolitic metabolism. For this reason, it is common for soccer players to consume b-alanine supplements daily in order to increase their stores of carnosine and improve their performance in high-intensity sports. In fact, it has been demonstrated that daily supplementation ofb-alanine raises concentrations of carnosine in the musculoskeletal system by approximately 50% in type 1 and type 2 muscle fibers (Harris & Sale 2012). Recent studies (Hobson et al., 2012) have also demonstrated that supplementation of b-alanine leads to ergogenic effects in sports with periods of high intensity that last between 1-6 minutes, such as track and field, rowing, swimming, etc.

  Unfortunately, there is a lack of precise research that evaluates the effects of b-alanine supplementation in high-intensity sports such as soccer. It is possible that, in the studies in which performance improves, this may be due to a longer period of supplementation and, thus, to an increase in b-alanine stores in muscles.

  Negative effects of supplementation with b-alanine include the reddening and tightening of the skin and paresthesia, which occur when a one-time

dose of over 10 mg per kilo of weight is administered. To diminish these negative effects, various formulations have been developed that allow for the intake of up to 800 mg at a time without bringing on these symptoms (Decombaz et al., 2012). Although the optimal protocol for use is still unknown, a relationship has been demonstrated between the total quantity of b-alanine consumed (in a range of 1.6 - 6.4 grams per day) and both relative and absolute increases of muscle carnosine. (Stellingwerff et al., 2012). To this end, it has been observed that four weeks of supplementation with 3.2 g of b-alanine per day leads to an increase in stores of muscle carnosine twice as large as with supplementation of 1.6 grams per day. It has also been observed that a supplementation of 3.2 g of b-alanine per day leads to more than double the muscle carnosine as compared with a supplementation of 1.6 grams per day. At the same time, it has been observed that a supplementation of 1.6 grams per day may lead to larger increases after four weeks of supplementation (Stellingwerff et al., 2012). Recently, it has been observed that after daily supplementation with 3.2 g of b-alanine for a period of six weeks, a daily dose of 1.2 grams per day is required to maintain an increased level of muscle carnosine that is 30% to 50% greater than the level that is typical without supplementation (Stegen et al., 2014). After supplementation, a return to initial levels occurs at 10-20 weeks (Baguet et al., 2009). On the basis of the above, it is recommended that, when necessary, levels of carnosine be rapidly increased. Supplementation with high doses (for example, 3.6 grams daily for three or four weeks) can be a good start, followed by a daily maintenance dose of over 1.2 g. Paresthesia symptoms can be minimized with formulas that are eliminated from the body more slowly and by spreading doses throughout the day. Finally, it has also been established that increases in carnosine achieved through supplementation of b-alanine are more pronounced in athletes that are in training than in individuals who are not in training (Morton, http://www.gssiweb.org/sports-science-exchange/article/sse-130-supplements-for-consideration-in-football, 2014).

Recommended practices for beta-alanine supplementation

1. Use slow-release b-alanine formulas to avoid side effects
2. Take between 3-6g daily for three to four weeks and, afterwards, take 1.2 g of b-alanine as a maintenance dose.

- **Nitrates:** Dietary supplementation with inorganic nitrates is being increasingly studied due to the effects that nitric oxide has on various physiological functions. In fact, it has been documented that nitric oxide

plays a role in regulating blood flow and replenishing muscle glucose, and also has an effect on the contraction of skeletal muscle (Jones 2014; Jones 2016). The traditional pathway of nitric oxide production involves the oxidation of L-arginine by nitric oxide synthase. In any case, it is known that inorganic nitrates that are ingested can also be metabolized into nitrates and then into nitric oxide, complementing those nitrates that are produced by the oxidation of L-arginine (Hord et al., 2011). The identification of this biochemical pathway has led to numerous studies on the ingestion of inorganic nitrates and physical performance. Nitrates are mainly found in leafy green vegetables such as spinach, chard, lettuce and beets, although their nitrate content can vary widely depending on the soil or the time of year. As a reference for the ingestion of a stable quantity of nitrate, many researchers use a standard dose of beet juice (keeping in mind that half a liter is equivalent to approximately 5 mmol of nitrate) in order to increase the availability of nitrate and nitrite. Utilized either regularly (half a liter of beet juice daily for 3-15 days) or on specific occasions (2.5 h prior to training), beet juice has been demonstrated to lower blood pressure, reduce oxygen consumption, and to heighten capacity during high-intensity exercises of short duration, such as in cycling and competitive running events (Bailey et al., 2009). It has also been observed that race times for distances of between 4 and 16.1 km (between 5 and 30 minutes of exercise, approximately) are also reduced. These positive effects are not observed in elite endurance athletes, which may be due to a combination of physiological differences between elite athletes and those with lesser ability, which make elite athletes less sensitive to increases in nitric oxide (Jones 2014, S35-45).

The mechanism that provides the basis for reduced oxygen requirements and improvements in performance is thought to be related to improvements in muscular efficiency and energy metabolism (Jones 2014, S35-45).

The optimal doses for facilitating nitrates' ergogenic effects are not yet clear, for example, it is not known if one-time, concentrated doses or regular doses are more beneficial. Protocols for use are therefore required. In any case, when the protocol for occasional use is followed, no variation in physical endurance has been observed for nitrates doses between 8.4 and 16.8 mmol consumed 2.5 hours prior to physical exercise, although both of these quantities are more effective than a dose of 4.2 mmol (Wylie et al., 2013). It was also observed that the reduction in oxygen consumption became more noticeable as the dose increased (Wylie et al., 2013). This information suggests that the inability to detect the

physiological effects of nitrates in episodic supplementation scenarios may be overcome by using greater doses prior to physical activity or through the use of longer duration protocols (Morton, http://www.gssiweb.org/sports-science-exchange/article/sse-130-supplements-for-consideration-in-football, 2014).

Although initial studies were carried out on continual, high-intensity physical activity, recent studies have examined the benefits of beet juice in high-intensity intermittent sports. Through the use of higher intensity supplementation protocols (approximately 30 mmol over a period of 36 hours), improvements have been seen in intermittent sports that feature repeated sprints during competition (Wylie et al., 2013).

From a practical perspective, it is more likely that it would be easier for athletes to supplement themselves with larger quantities of nitrates over the course of 36 hours than with more moderate quantities over the course of 3-6 days.

It is very important that athletes experiment with nitrates supplementation before competing (perhaps it is more important that they do so with this type of supplementation than with those mentioned earlier). In order to enhance the beneficial effects of supplementation with beet juice, it is recommended that athletes do not use antibacterial mouthwash or chew gum, as these products inhibit the conversion of nitrate into nitrite.

Practical recommendations for supplementation with beet juice

1. In the two days prior to a match, take a tablet of beet juice concentrate in the morning and another at night.
2. Take two sips of beet juice 1 to 4 hours before the beginning of physical activity.
3. Avoid mouthwash and gum.
4. Always experiment with this supplementation during training, prior to competing.

2.2.2 Supplements for performance enhancement

- **Tart cherry juice:** Both tart and sweet cherry juice contain high levels of antioxidants, including melatonin, carotenoids, hydroxycinnamates, and several flavonoids such as anthocyanins and quercetin (McCune et al., 2011). Although the mechanisms involved are not known, there are reports that both sweet cherries and the Montmorency variety reduce

inflammation (Kelley et al., 2006), oxidative stress and muscle pain, and improve muscle recovery.

In sports such as soccer, muscle stress is high, which results in muscle damage. This damage is followed by a second phase of inflammation, which is part of the recovery process. During this phase, the muscle is inflamed and its function diminished. It is believed that cherry juice acts mainly during this second phase, reducing inflammation and damage and maintaining muscle function. In general, current evidence indicates that there are ergogenic benefits to consuming cherry juice both before and after playing sports.

Practical recommendations for supplementation with cherry juice

During a very intense season with 2-3 matches a week, take a concentrate equivalent to 100 tart cherries in liquid or capsule form per day.

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