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ROLE OF NUTRITION IN SPORTS

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Abstract

Nutrition plays an essential role on sports performance. Following an adequate nutrition pattern determines winning the gold medal or failing in the attempt. That is why it is commonly referred to as “invisible training.” However, regarding food and performance, it is not only referred to professional athletes. Nowadays, a large number of amateur athletes perform daily physical activity both recreationally and semiprofessionally. That population also seeks to achieve an improvement in their personal brands, which can be reached following proper nutritional guidelines. In athlete population, nutrient requirements are incremented compared with non-athlete population. Therefore, it is essential to carry out a nutritional approach adapted to the athlete and training sessions. In addition, other advantages of adequate food intake in sports are related to changes in body composition, reduction of injuries, and prolongation of professional career length. The objective of this chapter is to determine the nutritional requirements of athlete population that allow achieving their sporting goals. Nutritional strategies will be addressed in terms of macronutrients consumption, hydration, and timing depending on type and intensity of exercise.

Keywords

- nutrition
- sports performance(SP)
- intake
- nutrients
- hydration

Introduction

Nutrition is strongly linked to health, especially when sports are concerned, due to the increase in energy and nutrient demands. The nutritional practices of athletes are multifactorial and depend on the habits, culture, or nutritional knowledge of the athlete. So the work of a sports nutritionist is to advise the athlete and his environment to make the necessary changes in his intake and thereby improve sports performance (SP).

Nutrition is determinant in achieving an adequate SP, which is defined by three variables: training, rest, and feeding. However, the main objective of sports nutrition must be preserving the health of the athlete, which can be achieved with an adequate intake adapted to the type of training performed. Optimal nutrition provides the energy necessary to perform physical exercise while reducing injury rate, a factor that together makes the SP increase by itself.

Two of the aspects that can limit the SP are the state of hydration and the energy contribution. Hypohydration states produce alterations in homeostasis, decreased blood volume, increased heart rate, lower rate of sweating, increased organism temperature, and greater perception of effort which translates into SP deterioration. Likewise, low energy consumption accentuates fatigue, immunosuppression, and predisposition for injuries, which can interfere in the development of SP.

Unfortunately, sports nutrition is often referenced to sports supplements or “magical” strange diets. In fact 40–70% of athletes use sports supplements without even analyzing if their use is really necessary.

Body composition (BC)

The body composition (BC) of the athletes is related to the SP, as it can be modified throughout the season. There is no single BC for each group of athletes; however, it can serve as a guide for athletes and coaches.

The season of the athlete will be divided into different phases throughout the competitive period. Competitive season can be divided in preseason, competitive period, transition period, and in the worst case injury period. Due to different intensities, timing, and types of training, the BC is normally different in the competitive season. Therefore, it is vital to know the BC of the athletes in order to determine the adequacy of the current season stage.

Apart from a higher body mass index (BMI), there are several methods for the evaluation of BC. Dual-energy X-ray absorptiometry (DEXA) is considered the gold standard for the assessment of body fat, mainly due to its high reproducibility and accuracy. However, DEXA has high economic cost, is not portable, and also emits a small radiation, so its use is not very common.

Among the most used methods are bioelectrical impedance analysis (BIA) and anthropometry. Impedance is defined as the opposition shown by biological materials to the passage of an electric flow. Tissues with high impedance offer greater resistance (adipose tissue, bone, air in the lungs) and contain less amount of water. The greater the amount of water, the better this electrical flow, will pass through. Therefore, the hydration state of the individual is the determinant for the BC measurement by BIA. In addition, in order to standardize previous conditions and dismiss errors, certain protocols must be followed prior to the measurement of BC by BIA. That fact makes BIA a rather imprecise method.

Anthropometry allows the evaluation of different body dimensions and the overall composition of the body. It consists of the measurement of skinfolds, perimeters of the muscles, and bone diameters. This technique must be carried out by experts qualified by the International Society for the Advancement of Ki anthropometry (ISAK). It is the most widely used method in the sports field, from which the percentages of fat, muscle mass, and bone mass can be obtained by means of mathematic formulas. The most effective way to monitor an athlete using this technique is performing a sum of six body folds (triceps, subscapular, supraspinal, abdominal, thigh, and medial leg) that gives an absolute value. In summary mode, the values for said summation of folds are estimated in physically active people (75 mm men and 100 mm in women), footballers (<50 mm men and <65 mm women), and endurance athletes (<35 mm men and 50 mm women). The minimum values seen in the healthy sports population were 25 mm for men and 42 mm for women.

However, it must be taken into account that BC is not the only thing that will measure sports performance, but it is one more parameter of the measurements that must be made in the athlete.

Metabolic pathways and exercise

Prior to establishing requirements regarding quantity and timing of macronutrients, a brief approach about different metabolic pathways that provides energy during exercise is necessary. The energy systems are integrated by a set of metabolic pathways that come into operation during exercise, depending on the intensity and duration. In summary, they can be divided into non-oxidative pathways (phosphogenic and glycolytic pathways) and aerobic pathways (nutrient oxidation).

Both pathways aim to generate ATP that will be consumed during the exercise. The non-oxidative pathways occur in the cellular cytosol, do not require oxygen, and are activated during short-time periods (seconds). Phosphate route uses ATP and phosphocreatine, lasting between 1 and 10 s, and is a route that does not need oxygen and does not generate lactate. Glycolytic pathways metabolize glucose, muscle, and liver glycogen through glycolysis and occur in high-intensity exercises up to 3 min. These glycolytic pathways generate lactate and hydrogen bonds, generating acidity in the muscle cell—this acidity being one of its limitations.

The aerobic pathway occurs inside the mitochondria, so it requires the presence of oxygen to metabolize fuels. It is typical of resistance exercises with medium-low intensity and long duration. It includes the oxidation of CHOs, fats, and to a lesser extent proteins. This route generates much more ATP than the anaerobic path but more slowly, speed being the limitation of this path.

Energy needs

The key to success for any athlete will be to adapt energy intake to energy expenditure, which allows the correct functioning of the organism while improving BC. However, it can be complicated due to multiple changes in periodization of training and competitions.

The energy demands of athletes differ widely depending on the type of sport, duration, intensity, competitive level, and individual variability of each athlete. The more demanding the competitive levels of the athlete are, the greatest increase in the intensity of both training and competition occurs, which will result in a significant reduction energy reserves that must be replaced by an adequate diet .

The objectives of the athletes' diet are the following: provide the necessary energy for exercise, regulate body metabolism, and provide nutrients to maintain and repair tissues. Due to variation among athletes, different available food options, and individual food patterns, there is no single feeding pattern for athletes, so there are a large number of strategies and options to assess.

Caloric intakes below the basal metabolic rate (BMR) are not recommended because it can compromise organism functions. Depending on the type of training energy requirement, the following recommendations for athletes can be approached: moderate training $1.7 \times \text{BMR}$, intense training $2.1 \times \text{BMR}$, extreme training $3 \times \text{BMR}$, and with the maximum recommended limit being $4 \times \text{BMR}$.

Athletes should bear in mind that it is not enough to pay attention to food only on the day of competition, but daily. Appropriate nutritional guidelines will optimize SP, improve recovery, and reduce the risk of injury and illness. For example, in women daily intake below 30 kcal/kg body mass/day can induce damage to metabolic and hormonal functions that affect SP, growth, and health.

A varied diet is recommended, covering energetic requirements, and is based on foods as fruits, vegetables, legumes, cereals, dairy products, eggs, fish, and lean meat, in order to provide vitamins and minerals. A poor choice of foods cannot be compensated by the use of supplements.

Macronutrients

In order to establish recommendations for macronutrients, it is preferable taking into account the body weight (BW) of the athlete, instead of giving the typical percentages based on the total caloric intake of the diet. For this purpose the recommendations will be provided by grams of nutrient/kg of BW.

Main energy substrates used for physical exercise are carbohydrates (CHO) and lipids, while proteins as energy substrate are reserved for extreme conditions. The use of energy substrate varies depending on the intensity and duration of the exercise, level of training of the athlete, and the state of pre-workout CHO stores. The use of CHO as energy substrate is produced mainly during high-intensity and short-duration exercises. Meanwhile, less intense and long-term exercises use fats' main energy substrate. However the use of CHO will also have a great impact on exercises of less intensity and longer duration such as resistance test, showing that depletion of CHO together with dehydration is a major limitation of the SP.

One of the big differences between CHO and lipids is their storage in the body. While CHOs have a limited reserve which leads to around 1600–2000 kcal, fats suppose a practically unlimited energy reserve close to 70,000 kcal (depending on fat mass).

Carbohydrate

Currently, there are a large number of myths related to nutrition, which causes great confusion in general population. One of the most widespread errors is the demonization suffered by the CHO, which has generated some carbophobia in society, including the athlete population. This is a mistake, due to the importance of CHO as energy substrate for the brain and central nervous system. Moreover, they can also be used at different intensities both by anaerobic and aerobic pathways.

CHO are an energy fuel that provides 4 kcal/g of dry weight. They are stores in liver and muscle in the form of glycogen. Although, these deposits are limited to around 400-500 g, providing 1600- 2000 kcal, they can be depleted if the diet does not contain enough CHO. Glycogen stores in the organism are divided into 350–400 g in the muscle, 75–100 g in the liver, and around 5 g in the plasma. In addition to size differences, the liver is really a store of glycogen, responsible for maintaining blood glucose. Meanwhile, the muscle can be considered a “false” store since it only uses glucose for its own needs. In other words, the liver can contribute to the replacement of muscle glycogen in the event of depletion, something that does not happen in reverse, which can lead to hypoglycemia and considerably affect SP due to fatigue.

It is vitally important to maintain high levels of glycogen so as not to compromise the physical demands of physical activity, since low availability can be associated with loss of abilities and impaired decision-making and increases risk of injury and decreases SP. Therefore, it is essential to provide CHO before exercise, as well as during, in order to improve the SP and delay the onset of fatigue.

A good strategy in order to optimize increased glycogen reserves for a competition is the “CHO overload” in the hours or even days before. In athletes with good training status, it is not necessary to deplete these deposits previously, as was believed decades ago. In fact an intake of around 10 g CHO/kg/day during the previous 36–48 h would be enough. Athletes are advised to test how many CHOs are able to intake without gastric problems. On the other hand, it is also advisable not to try new things on competition days .

The type of exercise, length, and provisioning are determinant factors for the physical exercise. Depending on all the variables, the nutritional strategies will be adapted to the athlete as personalized as possible. To summarize, the recommendations of CHO during the exercise are:

- In an exercise of less than 30 min, CHO intake is not necessary.
- In exercise lasting 45–75 min, it seems that the intake of CHOs is not necessary and it would be enough to perform mouth rinses. However, ingesting this liquid can promote hydration.

- In exercises lasting 1–2 h, the intake of 30 g/h seems to be sufficient, increasing CHO intake up to 60 g/h in case of more delayed sports.
- In exercises lasting more than 2.5 h, the intake of CHO should be 90 g/h. High CHO amounts can cause digestive problems; therefore, a previous intestine training is determinant to tolerate such CHO intake.

The reposition of CHO is determinant in approaching the following training or competitive sessions. After the completion of physical activity, it is vitally important to replenish CHO stores after the training and competition sessions. These replacements of CHO levels can be approached by different methods, depending on the closeness and intensity of the next sporting event. It will be necessary to rehydrate and to ensure glycogen recovery as well as muscle tissue.

The appropriate intake of CHO before, during and, after exercise ensures a satisfactory energy intake to face both training and competitions. Most CHOs are found in cereals, fruits, legumes, and vegetables and can be found in smaller quantities in dairy products, unless they could have added sugars. Given the importance of CHO, it is considered essential that athletes ingest enough CHO complexes during the course of the day, leaving simple CHOs during and after exercise.

However, in some circumstances in which physiological adaptations to training are the target, different strategies can be handled to those previously mentioned. For example, training with low availability of glycogen induces mitochondrial biogenesis (increase in the number of mitochondria) and thereby enhances lipid oxidation. This strategy can make the athlete more profitable metabolically, allowing a saving of glycogen reserves during exercise and thereby delaying the onset of fatigue. Another purpose of this strategy can be to accustom the athlete to know the feeling of emptiness that can have at the end of a competition and know in advance how to deal with it.

Proteins

The proteins are composed of amino acid (AA) chains. There are 20 types of AA, divide into nonessential AAs (can be synthesized by the organism) and essential AAs (must be contributed by the diet).

Although proteins can contribute between 5 and 10% to the total energy used during physical activity, they are not considered as energy source. Proteins constitute the base of muscle tissue and of the immune system and are the major component of muscle enzymes and play a large role in SP.

Regarding sedentary population, the estimated consumption rate is 0.8 g/kg BW/day. In the athlete population, these requirements are increased to repair muscle damage caused by exercise, enhance metabolic adaptations to training, and avoid possible muscle catabolism. The focus of protein consumption is on estimating an adequate protein intake for each given moment.

Protein-rich diets are associated with increased risk of dehydration due to elimination of nitrogenous waste products, an increased cardiovascular disease risk due to the association of fat with protein products, or a shift of CHO. However, even at high doses, no negative effects on renal function have been reported in healthy subjects.

Regarding timing of protein intake along with exercise, it seems that the most optimal time is the period after exercise. Better doses ranged between 0.25 and 0.3 g/protein/kg BW (approximately 15–25 g protein). However, high protein intake is discouraged close to physical exercise, due to possible digestive problems as a result of its long time of gastric emptying. However, in very long duration exercise, there is not such limitation.

To choose protein sources, it is important that animal proteins may be of greater interest. In fact, animal proteins are considered as a complete protein due to the presence of all essential AAs.

The main protein sources are lean meat products, fish, eggs, dairy products, and legumes that provide vegetable protein and reduce animal consumption.

Lipids

Along with the CHO, lipids are major energy substrates during exercise. The difference is that fats are not as profitable per unit of time as CHO and high fat consumption is not associated with improvements in SP.

Lipid consumption is important for both energy intake and essential nutrients such as fat-soluble vitamins A, D, E, and K. Both quantity and quality of fats are determinant in the diet. The quality is often referred by its content on inflammatory fatty acids.

The recommendation regarding fat consumption in athletes is similar to that of the general population. It is advisable not to make restrictive consumption of fat, as it can lead to deficit of nutrients such as fat-soluble vitamins and omega-3 fatty acids.

Fatty acid requirements, according to the American College of Sports Medicine (ACSM), are 20–35% of the total kcal of the diet, where 7–10% should correspond to saturated fatty acids, 10% to polyunsaturated fatty acids, and 10–15% to monounsaturated fatty acids.

Adequate intake of omega-3 fatty acids should be ensured due to its anti-inflammatory effects, improvements in the organism's coagulation, or increase in omega-3/omega-6 ratio.

In particular, food as avocado or olive oil is recommended, due to their high content on monounsaturated fatty acids, which have less susceptible to oxidation.

It is recommended to reduce the consumption of fatty meats, substituting them for lean meats, fish, and legumes. It is also advisable to eliminate the consumption of processed products such as sausages.

Hydration

During exercise, increments of energy requirements are associated to larger production of metabolic heat. Human organism dissipates that extra heat mainly by the mechanism of evaporation, which ultimately induces dehydration.

One of the greatest limitations of SP is dehydration. It is estimated that each kg of BW lost during exercise corresponds to 1 L of sweat. The sensitivity to dehydration is personal, but generally no losses greater than 2% of the BW are recommended in order not to compromise the SP. In fact, 1% of BW lost leads to SP decrease by 10%. Some authors have raised the possibility of training dehydration, but there is some controversy about it .

The consumption of water is the only method to prevent dehydration and will be essential before, during, and after exercise. However, a large number of athletes usually begin the exercise in a state of hypo hydration. Therefore, it is necessary to instruct the athlete to acquire correct hydration habits according to the type of sports, so that the SP is affected as little as possible.

Losses of electrolytes, especially sodium, occur along with water losses. It has been seen that well-trained athletes “sweat more but sweat better,” that is, they sweat more water, but the loss of electrolytes is lower. Recent studies have compared both the rate of sweating and the concentration of sodium in tattooed people versus non-tattooed people, concluding that the most tattooed skin presented lower sweating rate and higher sodium concentration.

It seems interesting to perform a sweat test to athletes, in order to know their rate of sweating (liters/hour). To accomplish it, weighing the athlete before and after the exercise session is enough. This data reveals the amount of sweat that is lost at the time, so it can serve to adjust the athlete's water intake. In general, the rate of sweating is usually greater than that of gastric emptying. However athletes can be trained to increase gastric emptying during workouts and thereby reduce dehydration as possible. In conditions of higher temperature and humidity, this rate of sweating will rise higher. Another simpler way to determine the state of hydration in athletes is controlling the color of urine (darker colors are associated with enhanced dehydration states).

Regarding the drink to be used for sports, it is advisable to use replacement drinks instead of water, due to the CHO and sodium content. Both salts and CHO improve intestinal transport, which facilitates the arrival of fluid in the blood. Prepositional beverages should present an isotonic composition, with the following characteristics:

As commented before, it is advisable to use drink with different CHOs as glucose, sucrose, and maltodextrinas, in order to facilitate the absorption of liquid due to the use of different intestinal transporters. Moreover, the fructose content should not be very high; due to quantities between 20 and 30% can cause intestinal problems.

The hydration guidelines indicated for performing physical exercise are:

- Ingest between 400 and 600 ml of water along the 4 h before the start of the exercise.
- Just at the beginning of the activity, ingest 200–400 ml of water with CHO (5–8%).
- During the exercise, ingest 100–200 ml of water every 15–20 min.
- After physical activity consume 150% of the BW lost in the 6 h after.
- In low-intensity training and short-duration, the intake of water alone is sufficient
- The ideal temperature of drinks oscillates between 15 and 21°C
- The taste should be pleasant to the palate of the athlete.

In a situation where the environment is very hot and has high humidity, the recommendations of intake of liquid and sodium will be higher. A good strategy can be to make salted snacks in the hours before the exercise or add more salt content to the meals before and after the exercise. Such increase of sodium has a double purpose, on the one hand to increase the intake of liquid through thirst and on the other to favor the retention of that liquid in the organism.

Supplements

An ergonomic aid is a product that contains a nutrient or a group of nutrients that improve the SP without taking into account the harmful effects in athletes, while a supplement is a nutritional aid to complete the diet associated with the practice of physical exercise.

When an athlete seeks to improve in the SP, his ability to tolerate intense workouts and hard competitions is crucial to avoid falling into injury or chronic fatigue. To achieve this purpose, an adequate supply of nutrients is essential. However, many times this does not happen, and the use of dietary supplements is resorted to.

These supplements must be prescribed individually according to the needs of each person (sex, age, fitness, intensity and duration of the exercise, season, etc.), in order to maintain both the state of health and the improvement of the SP. Dietary supplements must offer maximum possible safety and have a degree of scientific evidence to support their effect.

Currently between 40 and 70% of athletes make use of supplements without previously analyzing if necessary. In addition, a large number of sports supplements have not shown empirical evidence to improve SP. Likewise; there is a certain legal vacuum with the labeling of these substances, where 80% of these products do not contain the quantities declared on the label. In addition, 10–15% of these contain prohibited substances, and this can generate a high risk of committing an offense involuntarily by the athlete.

According to the Australian Institute of Sport, supplements are classified into four groups, based on effectiveness and safety:

- Group A: based on the evidence. Recommended for athletes.
 - Useful and timely source of energy or nutrients in the diet of athlete
 - Scientifically proven their evidence for the improvement of the SP, when they are used with a protocol and specific situation

In this group we can find:

- Food for athletes (gels, bars, electrolytes, isotonic drinks, maltodextrins, whey protein)
- Medical supplements (vitamin D, probiotics, iron/calcium supplements)
- Substances to improve SP (creatine monohydrate, caffeine, beta-alanine, bicarbonate, beet juice)
- Group B: more research deserved and advised under research or monitoring protocol.
 - Some benefit in non-athlete population or have data that suggest possible benefit of SP.
 - Of particular interest to athletes and coaches.

In this group we can find (quercetin, HMB, glutamine, BCCA, CLA, carnitine).

- Group C: few tests of beneficial effect are not provided to athletes.
 - Not proven improvement RD despite its widespread use.
 - Very little or no benefit, and sometimes they even affect the RD in a negative way.

In this group supplements of group A and B may be included when used without an individualized protocol and without a basis in scientific evidence.

- Group D: should not be used by athletes.
 - Are prohibited or have risk of contamination with doping or positive substance by drug

In this group we can find glycerol, ephedrine, sibutramine, and tribulus terrestris.

Despite all this information, many athletes believe that supplements are the basis of the athlete's diet and believe that without that supplement, they will not reach their maximum level. This belief is one of the biggest mistakes in the world of sports nutrition, where the basic diet that is the true pillar on which sports nutrition is based is neglected.

Conclusions

The basis of sports nutrition is a varied diet and individually tailored to the requirements and appetency of each athlete. The athlete should be instructed about the importance of diet, called "invisible training," which is not only important on competition day. Prior to establishing nutritional guidelines, it is necessary to know and adapt the BC of the athlete in the different periods of the season and make revisions through the sum of six skinfolds.

It is necessary to know some physiology to know the different metabolic pathways that interact during the exercise. In this way depending on the type of sports performed, duration and intensity adapt dietary intake at expense. Macronutrient requirements will be established based on g/kg/BW. With respect to CHOs, recommendations vary between 3 and 12 g/kg/BW to avoid compromising the SP, and protein consumption can vary between 1.2 and 2.0 g/kg/BW, with the total daily intake being more important than the

number of intakes. Regarding to fatty acids, quality will prevail, improving the inflammatory profile with an increase in the consumption of omega-3 compared to omega-6.

Acronyms and abbreviations

SP sports performance

BC body composition

BMI body mass index

DEXA dual-energy X-ray absorptiometry

BIA bioelectrical impedance analysis

ISAK International Society for the Advancement of Kinanthropometry

CHOs carbohydrates

BMR basal metabolic rate

BW body weight

AA amino acid

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