

1.2 Nutrients

Currently, there are many scientific journals where each month new findings are presented related to exercise sciences. It would seem that progress has been made in relation to training methods and the physiological characterization of different sports such as mountain biking or soccer. While journals and papers generally point to a specific topic, when optimizing the performance of athletes of different levels and objectives, it seems ineffective to study or analyze problems separately.

Even if a training method is properly designed and performed to the letter, the induced adaptations will not be the same if the subject starts his workout in a state of dehydration, low levels of muscle glycogen, improper hydration or if he does not carry out the appropriate recovery strategies after the challenge imposed by training on the physiological systems of the body. That is, beyond the fact that the training method is appropriate and carried out correctly, all these variables have an impact on the induced adaptations.

This means that sports nutrition and specifically hydration, nutrition and supplementation should be integrated into the training program. They should be taken into account as one more aspect, with the same importance as a pause, or the number of repetitions of a series, or the time accumulated in a training area of a microcycle.

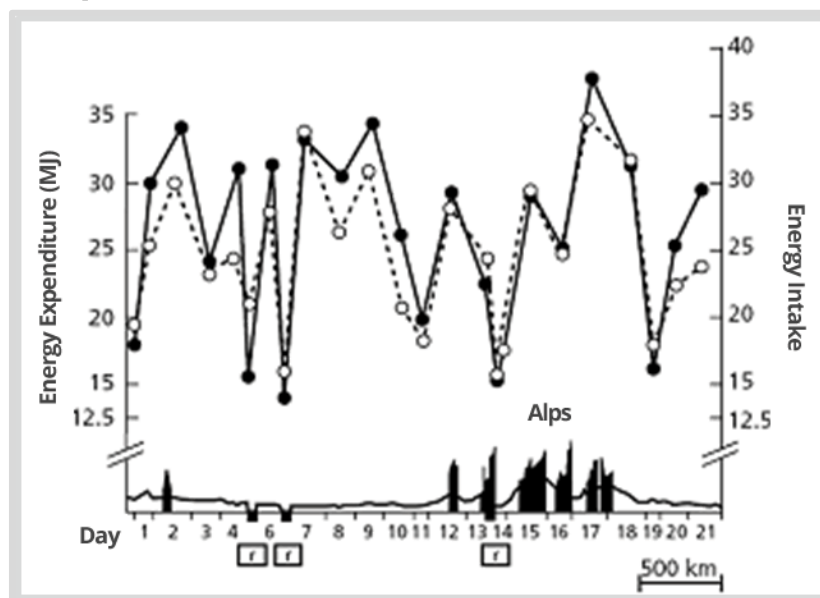
Macronutrients

The first component to optimize training and performance through nutrition is to ensure that the athlete consumes enough calories to match energy expenditure. People who participate in general physical fitness programs (e.g., 30-40 min of exercise per day, 3 times a week) can generally achieve their nutritional needs by following a normal diet (e.g., 1800-2400 kcal/day⁻¹ or about 25-35 kcal/kg⁻¹/day⁻¹ for subjects weighing 50-80 kg), because their caloric demands are not very large (e.g., 200-400 kcal/session⁻¹) (Kreider et al., 2000).

On the other hand, athletes involved in moderate levels of elevated training intensity (e.g., two to three hours per day of intense exercise performed five to six times per week) or training of high intensity and volume (e.g., 3-6 hours per day of intense training in one to two sessions over five to six days per week) can spend 600-1200 kcal or more per hour during exercise. Thus caloric needs can reach 50-80 kcal/kg⁻¹/day⁻¹ (2500-8000 kcal/day⁻¹ for athletes weighing 50-100 kg (110-220 lb)).

For elite athletes, energy expenditure during training or competition can be very high (Kreider et al., 2000). During the cycling race known as the Tour de France, it has been estimated that energy costs can reach 12000 kcal/day⁻¹ or 150-200 kcal/kg⁻¹/day⁻¹ for athletes weighing 60-80 kg (132-176 lb). Figure 3 shows the intake and caloric expenditure during various stages of the above mentioned competition. It can be seen how intake does not equate to caloric spending in a particular cyclist, which could involve a reduction in body mass, and a potential effect on the immune system. According to the International Society of Sports Nutrition (Kreider et al., 2000), maintaining an energy deficient diet during training can lead to a significant loss of body mass (including lean body mass), disease, onset of physical and psychological symptoms of overtraining and reductions in performance; so it is highly recommended to monitor the mass and body composition of athletes on a daily basis.

Figure 3: Daily Energy Expenditure (●) and Intake (○) Measured in a Cyclist During the Tour de France



Source: Jeukendrup, 2000, p. 563.

The profile of the race, as well as the length of the stages are shown at the bottom of the figure and r indicates the days of rest.

The nutritional analysis of the diets of athletes has revealed that many may be susceptible to maintaining negative energy intakes during training. Susceptible populations include runners, cyclists, swimmers, triathletes, gymnasts, skiers, dancers, wrestlers, boxers and athletes trying to lose weight very quickly (Kreider et al., 2000). It has also been shown that athletes have a high incidence of eating disorders. Therefore, it is important for sports nutrition specialists working with athletes, to make sure they are well fed and consume enough calories to offset the large energy demands of training in order to maintain body mass.

In this regard, it is noteworthy that intense training can often suppress appetite or alter the hunger pattern of athletes, therefore many athletes do not feel the desire to eat. Moreover, in general, athletes eat a few hours before to avoid the feeling of a full stomach or intestinal discomfort. Travel to training camps or competitions may also contribute to disruption of athletes' normal eating habits. Thus, the timing of nutrients must be carefully planned, like any other training variable, so that athletes have availability of energy-dense and nutritious food throughout the day.

For these reasons, it is recommended that athletes consume 4-6 meals per day and snacks between meals in order to meet the energy demands. The use of nutrient dense energy bars and supplements with carbohydrates and proteins provide a convenient way for athletes to supplement their diet in order to maintain energy intake during training (Kreider et al., 2000).

1.2.1 Carbohydrates

People who carry out a general physical fitness regime can, characteristically, achieve their macronutrient needs eating a normal diet (e.g., 45-55% carbohydrates [$3.5 \text{ g/kg}^{-1}\text{day}^{-1}$] 10-15% protein [$0.8\text{-}1.0 \text{ g/kg}^{-1}\text{day}^{-1}$] and 25-35% fat [$0.5\text{-}1.5 \text{ g/kg}^{-1}\text{day}^{-1}$]) (Kreider et al., 2000). However, it should be noted that athletes whose training programs involve moderate to high volumes and intensities may require a higher consumption of both carbohydrates and protein. Athletes involved in training programs with moderate levels of intensity (2-3 hours per day, 5-6 days per week), characteristically need to consume 55-65% carbohydrate (e.g., $5\text{-}8 \text{ g/kg}^{-1}\text{day}^{-1}$ or $250\text{-}1000 \text{ g/day}^{-1}$ for athletes weighing 50-150 kg) in order to maintain their reserves of muscle and liver glycogen (Kreider et al., 2000).

FCB athletes doing hard exercise have daily carbohydrate requirements based primarily on the needs of muscle power that can be quantified according to the size of the athlete and the duration / intensity of their exercise program. This makes sense, and it is a good practice, to be consistent in describing the daily carbohydrate intake in terms of grams per kg of body weight of the athlete. This allows the athlete and medical professional to quickly calculate the carbohydrates needed in every situation - e.g., 7 g/kg MC for an athlete of 70 kg (154 lb), equivalent to 490 g.

It has been suggested (Kreider et al., 2000) that athletes who are involved in training of high volume and intensity (e.g., three to six hours per day of intense training in one to two sessions for five to six days week) may need to consume 8-10 g of carbohydrates per day (e.g., 400-1500 g of carbohydrates per day for subjects weighing 50-150 kg (110-330 lb)). The glycemic load (defined as the product of the glycemic index by the mass of carbohydrates of a given portion of food in question, divided by 100) of foods must be controlled depending on the timing of CHO. Immediately after exercise, when insulin response favors recovery of glycogen stores, foods should be ingested with high glycemic loads, while at times away from training, glycemic load may be lower to avoid a sharp insulin response and the concomitant effect of lipid biosynthesis and inhibition of its catabolism.

It is important to note that it can be difficult to consume such a large amount of carbohydrates (400-1500 g) when an athlete performs a program of high intensity or volume, so many sports nutritionists recommend that athletes consume juices or drinks concentrated in carbohydrates or nutritional supplements rich in carbohydrate in order to meet these demands.

Simple vs. Complex Carbohydrates

Traditionally, foods containing significant amounts of CHO have been categorized according to the predominant structural classification of CHO. This has led to a simplistic division of foods containing CHO in: **simple CHO** (mono-, di- and oligosaccharides) and **complex CHO** (polysaccharides). It is important to note that this classification implies many misconceptions that have brought confusion to the science and practice of nutrition. Describing bread or lasagna as carbohydrates, underestimates the complex nature of food and the variety of chemicals that each possesses. The description of foods as rich in CHO, or containing CHO, better recognizes the heterogeneity of each food and the presence of other nutrients.

It is also worth noting, that there is little correlation between the structural type of CHO in food and its true effect on blood glucose and insulin levels. Many foods rich in CHO that contain mostly sugars (e.g., fruits and sweetened dairy products) produce a flattened glucose curve when ingested, while other foods that are rich in complex carbohydrates (bread or potatoes), produce an elevated blood glucose response similar to that of glucose intake by itself (Burke, 2000).

Table 3: Examples of Overlap between the Nutritional and Structural Classification of Foods Rich in CHO

	Nutritious	Less nutritious
Foods Rich in Simple CHO	Fruits, fruit juices, canned fruits, dried fruits, flavored milk, yogurt and other sweetened dairy products (especially low fat), liquid meal supplements, some energy bars.	Sugar (sucrose), honey, jam, syrups, soft drinks, flavored mineral water, sports drinks, carbohydrate loading supplements, sweets, chocolates, jelly, mousses and fat rich desserts, ice cream.
Foods Rich in Complex CHO	Bread, bagel, breakfast cereals, pasta and noodles, rice and other cereals, starchy vegetables (potatoes, corn), legumes and pizzas.	Pastries, crispy/baked potato chips, croissants.
Foods rich in CHO with a mixture of simple and complex CHO	Low fat cakes and desserts, breakfast cereals with fruits and sweetened, baked beans, some fruits and vegetables (banana, pumpkin), some energy bars.	Cakes rich in fats, pastries, cookies, desserts, granola bars or muesli, some energy bars.

Source: Burke, 2000, p. 76.

Nutritious foods are defined as those that provide significant amounts of protein and macronutrients, and contribute less than 30% of their energy in the form of fats (saturated). Less nutritious refers to foods that provide negligible amounts of other nutrients, or have a fat content (saturated) representing more than 30% of their energy.

1.2.2 Proteins and Lipids

Proteins

Protein requirements for different populations has set off debates. Initially, it is not advised for athletes to consume more protein than that recommended by the RDA (Recommended Dietary Allowances) that is 0.8 to 1 g/kg⁻¹/day⁻¹ for children, adolescents and adults (Kreider et al., 2000).

However, research over the past decade has indicated that athletes involved in intense training programs need to eat about 1.5-2 times the RDA of protein in their diet (1.5 to 2 g/kg⁻¹/day⁻¹) in order to maintain protein balance (Kreider et al., 2000). There is evidence that if an insufficient amount of protein is ingested, the negative nitrogen balance can increase protein catabolism and delay recovery. In the long term, this can lead to loss of lean body mass and intolerance to training (Kreider et al., 2000).

The active subjects involved in programs to improve physical fitness can generally reach their protein requirements with 0.8-1.0 g/kg⁻¹/day⁻¹. Moreover, athletes involved in moderate amounts of intense training should consume 1-1.5 g/kg⁻¹/day⁻¹ (50-225 g/day⁻¹ for athletes weighing 50-150 kg), while athletes involved in high intensity training, should consume 1.5-2 g/kg⁻¹/day⁻¹ (75-300 g/day⁻¹ for an athlete weighing 50-150 kg (110-330 lb)). When we, however, have athletes with greater body mass, it can be difficult to meet the aforementioned proteins requirements. Keep in mind, also, that some foods rich in protein, such as beef or chicken, contain a fraction of lipids (saturated fatty acids) that also increase the energy provided by fat in the diet. However, in this regard, it is interesting to note the results of some studies (Tabatha et al., 2006) conducted in humans at rest, that measured the whole body using a model of multicomponents, reached the conclusion that concurrent ingestion fat and sucrose with milk proteins can modify the amino acid uptake in peripheral tissues.

Elliot A. Tabatha and his colleagues (2006) conducted an study to determine the response of net muscle protein balance after strength training through amino acid intake from real food (in this case, milk) instead of a supplement. In the study, 24 young, healthy subjects trained on strength were assigned to one of three groups, which were given three milk drinks, after they performed 10 sets of 8 repetitions of knee extension exercises. The three groups were: fat-free milk (FM), n = 8; whole milk (WM), n = 8; and fat free isocaloric milk (IM). The composition of the milk ingested by each group is presented in Table 4.

Table 4: Nutrient Content of Milk Consumed per Group after Endurance Training

	Energy (KJ)	CHO (g)	Fat (g)	PRO (g)	PHE (mg)	THR (mg)
FM	377	12.3	0.6	8.8	420	390
WM	627	11.4	8.2	8.0	390	360
IM	626	20.4	1.0	14.5	696	647

Source: Tabatha et al., 2006, p. 669.

References: FM, 237 g of fat-free milk; WM, 237 g of whole milk; IM, 393 g of fat-free milk; CHO, carbohydrates; PRO, proteins; PHE, phenylalanine; THR, threonine.

It was found that the average ratio of phenylalanine captured or ingested for the WM group was 90% and 70% higher than for FM and IM groups, respectively. However, these differences were not significant. The same ratio for threonine was 312% higher for the WM group compared to FM ($p < 0.05$), and 91% higher than the IM group, although in this case the difference was also not significant. The authors hypothesized that these data suggest that some property of the WM improved the quantity of threonine and possibly phenylalanine, used for muscle protein synthesis. If so, it is unclear what property of the WM was responsible for the increased utilization. If we analyze Table 4, we can see that at least one of these properties could be the combination of protein and fat.

Importantly, not all proteins are equal. They differ based on the source of the proteins ingested, the amino acid profile and methods for processing or isolating the protein (Kreider et al., 2000). These differences influence the availability of amino acids and peptides has been reported to have biological activity (e.g., α -lactalbumin, β -lactoglobulin, glycomacropeptide, immunoglobulins, lactoperoxidase, lactoferrin, etc.). Therefore, care should be taken that athletes and active individuals not only ingest enough protein, but also that these are high quality (Table 5).

Table 5: Rankings of Protein Quality

Types of proteins	Protein Efficiency Ratio	Biological Value	Net Protein Utilization	Protein digestibility value corrected for amino acids
Beef	2.9	80	73	0.92
Beans / Black Beans	0		0	0.75
Casein	2.5	77	76	1.00
Egg	3.9	100	94	1.00
Milk	2.5	91	82	1.00
Peanuts / Peanut Butter	1.8			0.52
Soy Protein	2.2	74	61	1.00
Wheat Gluten	0.8	64	67	0.25
Whey Protein	3.2	104	92	1.00

Source: Adapted from Hoffman, 2004, p. 120.

Information regarding the different indexes to assess the quality of proteins, pertaining to each one, is included below.

Protein Efficiency Ratio

The **protein efficiency ratio (PER)** determines the effectiveness of a protein by measuring animal growth. It is considered that any value exceeding 2.7 is an excellent source of protein.

Biological Value

The biological value measures the quality of proteins by calculating the nitrogen used in the formation of tissue, divided by the nitrogen which has been incorporated in the foods. This product is multiplied by 100 and expressed as a percentage of nitrogen used. The biological value provides a measure of how efficiently the body uses proteins consumed in the diet.

Net Protein Utilization

Net protein utilization is similar to biological value, only involving a direct measure of absorbed nitrogen retention. Net protein utilization and biological value both measure the same parameter of nitrogen retention, however, the difference lies in that the biological value is calculated from the absorbed nitrogen, while net protein utilization is calculated from nitrogen ingested.

Amino Acid Score Corrected for Digestibility

In 1989, the Food and Agriculture Organization and the World Health Organization (FAO and WHO), in a position statement, stated that the quality of a protein could be determined by expressing the content of the first limiting essential amino acid of the test protein as a percentage of the same amino acid content relative to a reference standard for essential amino acids (FAO and WHO, 1990). The reference values used were based on the requirements of essential amino acids in Preschoolers. The recommendation of the FAO and WHO statement was to take this reference value and correct it according to the fecal true digestibility test. The value obtained is the amino acids score corrected by digestibility (PDCAAS). This method has been adopted as the preferred method for measuring the value of protein in human nutrition (Hoffman, 2004).

Regarding protein intake, in a position statement published a few years ago, the following points were highlighted:

- A great number of studies support the idea that individuals involved in training on a regular basis require more protein in their diet than sedentary individuals.
- Protein intakes of 1.4-2.0 g/kg⁻¹/day⁻¹ for active individuals is not only safe, but can improve training adaptations induced by exercise.
- When it forms a part of a nutrient-dense, balanced diet, protein intake at this level is not harmful to kidney function or bone metabolism in healthy and active persons.
- While it is possible for physically active individuals to get their protein requirements from a regular and varied diet, supplementation with proteins in different forms is a practical way for athletes to ensure adequate, quality protein intake.
- The different types and qualities of proteins can affect the bio-adaptability of the amino acids after protein supplementation. The superiority of one type of protein over another, in terms of optimizing recovery or training adaptations, has yet to be convincingly demonstrated.

- Protein intake at the right time is an important component of an overall training program, essential to a successful recovery, key to maintenance of the immune system and significant for growth and maintenance of lean body mass.
- Under certain circumstances, supplementation with specific amino acids, such as branched chain amino acids (BCAA) can improve exercise performance and recovery afterwards.

(Campbell et al., 2007, p. 1).

Lipids

Maintenance of the energy balance, the recovery of intramuscular triacylglycerol reserves and an adequate intake of essential fatty acids all have great importance among athletes and justify a higher intake of lipids (Kreider et al., 2000). Interestingly, diets with a higher fat content seem to maintain better concentrations of circulating testosterone than low-fat diets (Kreider et al., 2000). In general, it is recommended that athletes consume a moderate amount of fat (about 30% of their daily caloric intake).

For athletes looking to reduce body fat, it has been recommended to ingest 0.5 to 1 g/kg⁻¹/day⁻¹ of fats. The rationale for this is that some weight loss studies indicate that people who had more success in losing weight and maintaining that weight loss were those who ate less than 40 g of fat per day in their diet (Kreider et al., 2000).

Regarding the different types of lipids, the intake of saturated fats should be decreased (fatty acids of 14 and 16 carbons) which have the potential to increase the concentration of plasma cholesterol (Boyd & Cordain, 1997); and an increase made in the intake of polyunsaturated fats, which are essential for the organism. Regarding the latter, it is important to consider the relationship between ω -3 and ω -6 fatty acids, since in today's human diet, the ω -3 and ω -6 relationship appears to have decreased significantly, which could have adverse consequences for the functioning of the organism (Boyd & Cordain, 1997).

In relation to this issue and the foods that were eaten by our hunter-gatherer ancestors, which may have determined the adaptations that occurred in the human genome of modern humans, we recommend reviewing the work of Boyd & Cordain (1997).

1.2.3 Micronutrients

Vitamins

Vitamins are organic compounds, whose function is to regulate metabolic processes, energy production systems, neurological processes and prevent destruction of the cells (Kreider et al., 2000).

A main classification divides them into water-soluble and fat-soluble. The latter include vitamins A, D, E and K, while among the former are vitamin C and B complex. There is documented evidence that certain vitamins can provide health benefits (vitamin E, niacin, folic acid, vitamin C, etc.), although there are few reports indicating that these have an ergogenic value (Kreider et al., 2000).

However, it is interesting to note that some vitamins, such as vitamin C and E, could help better tolerate training, reducing the oxidative stress induced by it and maintaining the integrity of the immune system (in the case of vitamin C). The remaining group of vitamins seems to have little ergogenic value in athletes who eat a normal diet with a sufficient supply of nutrients.

On the other hand, it should be noted that the American Medical Association has recently evaluated the available medical literature and has recommended that Americans consume a daily low dose of a multivitamin in order to promote general health. Table 6 shows the recommended daily allowance (RDA), the alleged ergogenic value and a summary of the findings of the literature on fat and water soluble vitamins.

Table 6: Proposed Nutritional Ergogenic Aids: Vitamins

Nutrient	RDA	proposed ergogenic value	Summary of research findings
Vitamin A	Men: 900 µg/day Women: 700 µg/day	Constituent of rhodopsin (pigment of vision). It is involved in night vision. A supplement may improve vision in sport.	No studies have shown that vitamin A supplementation improves exercise performance.
Vitamin D	5 µg/day (Age <51 years)	It promotes bone growth and mineralization. Improves calcium absorption. Calcium supplementation can help prevent bone loss in people with osteoporosis.	Calcium supplementation can help prevent bone loss in athletes susceptible to osteoporosis. However, vitamin D supplementation does not improve exercise performance.
Vitamin E	15 mg/day	As an antioxidant, it has been shown to help prevent the formation of free radicals during intense exercise and prevents the destruction of red blood cells, improving and maintaining oxygen transport to the muscles during exercise. Some evidence suggests that it can reduce the risk of cardiovascular disease or reduce the incidence of recurrent heart attack.	Numerous studies show that supplementation with vitamin E can decrease oxidative stress induced by exercise. However, most studies have shown no effects on performance in regions that are at sea level. At high altitudes, vitamin E can improve exercise performance. Further research is needed to determine whether long-term supplementation can help athletes better tolerate training.
Vitamin K	Men: 120 µg/day Women: 90 µg/day	Important for blood clotting. There is also some evidence that it may affect bone metabolism in postmenopausal women.	It has been reported that supplementation with vitamin K (10 mg/day) in elite women athletes increases the capacity of calcium binding in the osteocalcin and promotes an increase of 15-20% in bone formation markers and a decreased of 20-25% in bone resorption markers, suggesting that a better balance between formation and resorption is produced.

Thiamine (B1)	Men: 1.2 mg/day Women: 1.1 mg/day	It is a coenzyme (thiamine pyrophosphate) in removing CO ₂ from the decarboxylation reactions of pyruvate to acetyl-CoA and in the tricarboxylic acid cycle. Theoretically, supplementation improves the anaerobic threshold and transportation of CO ₂ . Deficiencies can decrease the efficiency of energy systems.	The availability of thiamine in the diet does not appear to affect the ability to exercise when athletes perform a normal intake.
Riboflavin (B2)	Men: 1.3 mg/day Women: 1.7 mg/day	Constituent of the coenzymes nucleotides of flavin involved in energy metabolism. It is thought to, theoretically, improve energy availability during oxidative metabolism.	The availability of thiamine in the diet does not appear to affect the ability to exercise when athletes perform a normal intake.
Niacin (B3)	Men: 16 mg/day Women: 14 mg/day	Constituent of the coenzymes involved in energy metabolism. It is proposed theoretically that they can mitigate the increase in fatty acids during exercise, reduce cholesterol, improve thermoregulation and improve energy availability during oxidative metabolism.	Studies indicate that supplementation with niacin (100-500 mg/day) can help lower blood lipid levels and increase homocysteine levels in patients with hypercholesterolemia. However, it has been reported that supplementation with niacin (280 mg) decreases exercise capacity, by decreasing fatty acid mobilization.
Pyridoxine (B6)	1.3 mg/day (Age <51 years)	It has been indicated as a supplement that increases muscle mass, strength and anaerobic power in the lactic acid and oxygen systems. It can also have a calming effect that has been linked to	In well fed athletes, pyridoxine failed to improve aerobic capacity or the accumulation of lactic acid. However, when combined with vitamins B1 and B12, it can increase serotonin levels and improve fine motor skills, which may be necessary in

		improved strength.	sports such as pistol shooting and archery.
Cyanocobalamin (B12)	2.4 µg/day	A coenzyme involved in the production of DNA and serotonin. DNA is important for the synthesis of proteins and red blood cells. Theoretically, it increases muscle mass, the oxygen carrying capacity of blood and decrease anxiety.	In well-trained athletes, no ergogenic effect has been reported. However, when combined with vitamins B1 and B12, cyanocobalamin has been shown to improve performance in pistol shooting. This may be due to increased levels of serotonin, a neurotransmitter in the brain that can reduce anxiety.
Folic Acid (Folate)	400 µg/day	Functions as a coenzyme in the formation of red blood cells and DNA. An increase in red blood cells could improve the transport of oxygen to the muscles during exercise. It is thought to be important in helping prevent birth defects and may help lower homocysteine levels.	Studies suggest that increasing dietary availability of folic acid during pregnancy can reduce the incidence of birth defects. Moreover, it can lower homocysteine levels (a risk factor for heart attack). In well fed, folate-deficient athletes, folic acid did not improve exercise performance.
Pantothenic Acid	5 mg/day	It acts as a coenzyme for acetyl-Coenzyme A (acetyl-CoA). This can benefit the aerobic or oxygen-dependent energy systems.	Studies have not reported improvements in aerobic performance with acetyl-CoA supplementation. However, one study reported a decrease in the accumulation of lactic acid, without an increase in performance.
Beta-carotene	None	They serve as antioxidants. Theoretically, they help minimize lipid peroxidation and muscle damage induced by exercise.	Research indicates that supplementation with beta-carotene, with or without other antioxidants, may help reduce exercise-induced peroxidation. Over time, this can help athletes tolerate training. However, it is not clear whether antioxidant supplementation affects exercise performance.
		It is used in a number of different metabolic processes in the body. It is involved in	In well fed athletes, supplementation with vitamin C does not seem to improve physical performance.

Vitamin C	Men: 90 mg/day Women: 75 mg/day	the synthesis of epinephrine, iron absorption, and is an antioxidant. Theoretically, it could benefit performance during exercise, by improving metabolism during exercise. There is also evidence that vitamin C can improve immune system functioning.	However, there is evidence that vitamin C supplementation (e.g. 500 mg/day) after intense exercise can reduce the incidence of upper respiratory tract infections.
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Source: Adapted from Kreider et al., 2010, p. 12

Minerals

Minerals are essential inorganic elements for a number of metabolic processes. They serve as tissue structure, constitute important components of enzymes and hormones and serve as metabolic regulators and nerve control. It has been demonstrated that some minerals are deficient in some athletes or become deficient in response to training or prolonged exercise. In athletes who have a deficit in general, it has been shown that supplementation improves exercise capacity. Therefore, some minerals seem to have an ergogenic or health value for athletes under certain situations.

Calcium supplementation in athletes susceptible to premature osteoporosis can help maintain lean body mass and may help control body composition. In the case of iron, it has been shown that supplementation in athletes with a deficit of this mineral, or anemia, improves performance. Moreover, there is evidence (Kreider et al., 2000) indicating that a sodium phosphate load can increase maximum oxygen consumption, the lactate threshold and improve endurance training capacity by 8 to 10%. Table 7 shows the recommended daily intake (RDA), the proposed ergogenic value and reports in the literature regarding the potential ergogenic effect of different minerals.

Table 7: Proposed Nutritional Ergogenic Aids: Minerals

Nutrient	RDA	proposed ergogenic value	Summary of research findings
Boron	None	Boron has been sold to athletes as a dietary supplement that can promote muscle growth during endurance training. The rationale was based primarily on an initial report that indicated that supplementation with boron (3 mg/day) significantly increased β -estradiol levels and testosterone in postmenopausal women who consumed a diet low in boron.	Studies that have researched the effects of 7 weeks of supplementation with boron (2.5 mg/day) during endurance training on testosterone levels, body composition and strength, have not reported an ergogenic value. At the moment, there is no evidence that supplementation with boron promotes muscle growth during endurance training.
Calcium	1000 mg/day (age: 19 to 50 years old)	It is involved in the formation of teeth, blood clotting and nerve transmission. It stimulates fat metabolism. The diet should contain sufficient amounts especially in growing children and adolescents, female athletes and postmenopausal women. Vitamin D is needed to help absorption.	Calcium supplementation could be beneficial in populations susceptible to osteoporosis. It has also been shown that calcium supplementation promotes fat metabolism and helps to control body composition. Calcium supplementation does not provide an ergogenic effect on exercise performance.
Chrome	Men: 35 mg/day Women: 25 μ g/day (age: 19 to 50 years)	Chromium, commonly sold as chromium picolinate, has been marketed with statements indicating that the supplement increases muscle mass and decreases body fat levels.	Animal research suggests that chromium supplementation increases lean body mass and reduces body fat. Early research with humans reported similar results, however, more recent, well-controlled studies reported that chromium supplementation (200-800 mg/day) does not increase lean body mass or reduce body fat.
Iron	Men: 8 mg/day Women: 8 mg/day (age: 19 to 50)	Iron supplements are used to increase aerobic performance in sports that employ the oxygen system. Iron is a component of hemoglobin in red blood cells, which is an oxygen transporter.	Most research on iron indicate that it does not seem to increase aerobic performance unless the athlete has a condition of iron depletion or anemia.

	years)		
Magnesium	Men: 420 mg/day Women: 320 mg/day	Activates enzymes involved in protein synthesis. It is involved in the reactions of ATP. Serum levels decrease with exercise. Some suggest that magnesium supplementation may improve energy metabolism or the availability of ATP.	Most well-controlled research indicates that supplementation with magnesium (500 mg/day) does not affect exercise performance in athletes unless there is a deficiency.
Phosphorus (Phosphate Salts)	700 mg/day	Phosphate has been studied for its ability to improve the three energy systems, mainly the oxygen system or aerobic capacity.	Well-controlled research studies conducted recently reported that supplementation with sodium phosphate (4 g/day for 3 days) improved the oxygen system in endurance exercises. There seems to be little ergogenic value to other forms of phosphate (such as calcium phosphate or magnesium phosphate). More research is needed to determine the mechanism by which improvement occurs.
Potassium	2000 mg/day	Electrolyte that helps regulate fluid balance, nerve transmission and the acid-base balance. Some suggest that an excessive increase or decrease of potassium may predispose athletes to cramps.	Although potassium loss through perspiration during intense exercise has been anecdotally associated with muscle cramps, the etiology of cramps is unknown. It is unclear whether potassium supplementation in athletes decreases the incidence of cramps. No ergogenic effects have been reported.
Selenium	55 µg/day	It is sold as a supplement for performance in aerobic exercise. Working closely with vitamin E and glutathione peroxidase (an antioxidant), selenium can destroy the destructive production of free radicals of lipids during aerobic exercise.	Although selenium can reduce peroxidation of lipids during aerobic exercise, no improvements in aerobic capacity have been demonstrated.
Sodium			A large amount of sodium is lost through sweat during the first days of intense training in the heat, Also, ultraendurance exercise can lower

	500 mg/day		levels of sodium, leading to hyponatremia. It has been shown that the increased availability of salt during intense training in the heat helps maintain fluid balance and prevent hyponatremia.
Vanadyl Sulfate (Vanadium)	None	Vanadium may be involved in reactions in the body that produce effects similar to those of insulin on protein and glucose metabolism. Due to the anabolic nature of insulin, this has drawn attention to vanadium as a supplement to increase muscle mass and increase strength and power.	Limited research has shown that type 2 diabetics can improve their glucose control, however, there is no evidence that vanadyl sulfate has any effect on muscle mass, strength or power.
Zinc	Men: 11 mg/day Women: 8 mg/day	Constituent of enzymes involved in digestion. Associated with immunity. In theory, it can reduce the incidence of upper respiratory tract infections in athletes involved in intense training.	Studies indicate that zinc supplementation (25 mg/day) during training, minimizes exercise-induced changes in immune function.

Source: Adapted from Kreider et al., 2010, p. 14

1.2.4 Phytochemicals and Water

Phytochemicals

Phytochemicals or phytonutrients are certain organic components of plants that are thought to promote human health but they are not nutrients (Jeukendrup & Gleeson, 2010). They differ from vitamins because they are not considered essential nutrients, but they can be beneficial to health. Through different mechanisms, they exert an antioxidant function, improve immune response and cell-to-cell communication; they alter estrogen metabolism, metabolize carotenes into vitamin A, generate the death of cancer cells, and repair damaged DNA.

Among phytochemicals are the widely known carotenoids, found in broccoli, green leafy vegetables and yellow vegetables, as well as polyphenols, which are found in red fruits and red wine.

Current recommendations suggest one should ingest about five servings of fruits and vegetables to ensure a supply of phytochemicals and their beneficial health effects.

Water

Living organisms, and therefore the human body, have a high water content. From a chemical point of view, the human body could be divided into minerals, carbohydrates, protein, fat and water, where the latter represent 40% of the total mass (Wilmore, 1996).

The largest volume of water in the body is found inside the cells, in what is called intracellular compartment. In these can be found approximately 70% of total body water (Robergs, 2006). On the other hand, blood contains approximately 6% of total body water (vascular compartment) and between the cells (interstitial compartment), on finds 24% of total body water.

In humans performing exercise and dehydrating, the greatest loss of body water occurs in the intracellular component, so if 3 liters of sweat is lost during exercise, 50% of the loss will come from the intracellular compartment (Robergs, 2006).

It is worth noting that while sweat loss for a human at rest during a day may represent as low a volume as 200 ml, as we shall show later, a human performing exercise can lose 3, 4, 5 liters or more, during exercise. This loss of body mass is explained almost entirely by body water lost as sweat.

Pre-Exercise Hydration

Given that under certain climatic conditions (hot and humid), physiological (athletes with high rates of sweating) and sports specific (long events, such as, e.g., Over 90 min.) dehydration can achieve high rates (> 2%), as a result of the above-mentioned aspects (with the aggravating condition that in some sports the availability of liquids may be restricted), pre-hydration becomes very important. There are interesting results from Ahumada, Barale and Zóccola (2010) regarding the level of dehydration that athletes of average performance levels can reach during workouts in different weather conditions. It is clear that this scenario can be very adverse to the athlete, who will suffer a marked loss of performance and can endanger their health. Thus it is key at the beginning of the sports practice to be in an euhydrated condition, as well as possibly starting the exercise in a condition of hyperhydration.

The hyperhydrating agent which showed very encouraging results is glycerol. For a comprehensive review on the metabolism, applications, medical uses and action mechanisms of this substance we invite you to review the work of Robergs and Griffin (1998). Unfortunately, this year, this substance was included in the prohibited list by the World Anti-Doping Agency (WADA), since glycerol would have applications as a masking agent by increasing plasma osmolality, expand plasma volume and diluting the concentration of any banned substances that may be used. Apparently, they are studying other substances capable of inducing an effect of hyperhydration. As will be discussed in a later section, beverages containing high concentration of sodium, 50-70 mM (which is similar to sweat) have the potential to induce hyperhydration. However, a high concentration of sodium in a drink affects its palatability.

Regarding hyperhydration, in practical terms it might be interesting to use a series of equations developed by Eric Goulet (2009) to calculate the volume of fluids to hydrate the athlete.

The first equation is meant to determine the level of dehydration reached during a given exercise:

Percentage of dehydration (%) = [(sweat rate (L/h) - fluid intake (L/h))* exercise duration (h)] / body mass (kg).

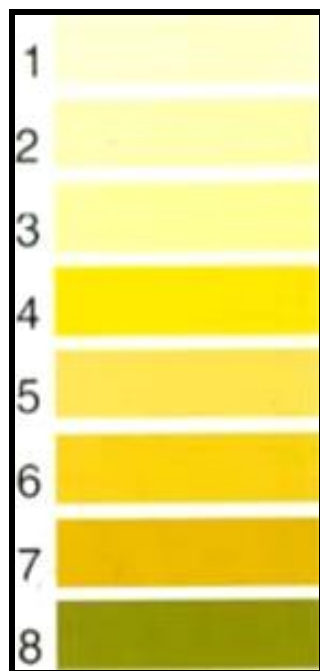
The second equation is meant to assess the volume of fluids that should be ingested during hyperhydration to reach a desired level of dehydration during exercise, for example, 2% of body mass.

Fluid volume (L) = [(the result of the equation 1/100)* body weight (kg)] - [body weight (kg)* (% desired dehydration/ 100)].

Thus, the result indicates the volume of fluids that should be consumed for hyperhydration. Goulet (2009) stated that hyperhydration would be justified only when the result of equation 1 was $\rightarrow 2\%$. This equation was intended to be applied to a glycerol hyperhydration protocol. While a sports drink will not be as effective as glycerol for this purpose, even if isotonic, this is a practical option for determining the volume of fluid specifically required by an athlete in a certain condition, since the sweat rate will depend on the subject, but also on climatic conditions.

A useful tool for assessing the level of hydration and ensuring that athletes begin their exercise in a euhydrated state is the urine color scale (Figure 4) developed by Lawrence Armstrong, et al. (1994). If the color of urine is between 1 and 3 this indicates that the athlete is euhydrated.

Figure 4: Urine Color Scale



Source: Adapted from Armstrong et al, 1994, p. 274.

Intra-Exercise Hydration

In this section, in addition to fluid intake, data will also be presented on the contribution of carbohydrates, as this aspect was not discussed in the previous section devoted to the study of these macronutrients.

While there are solid foundations that support carbohydrate intake during exercise to improve performance and reduce fatigue, it is worth noting the results of a review of the literature by Coombes and Hamilton (2000).

After reviewing a number of studies, the authors found that the benefits of sports drinks are more easily observed in individuals suffering depletion of glycogen reserves. These studies were with subjects who were in this condition, but clearly this is not the situation in which athletes are before a competition.

The work of Coombes and Hamilton, who support the idea that carbohydrate delivery delays fatigue and improves performance, is based on the work of Coyle (1983; 1986), and Coggan and Coyle (1987; 1988; 1989). In all these studies, the subjects performed a fast 12 to 16 hours before exercise. It should also be noted, that the carbohydrate drinks consumed during exercise had a carbohydrate concentration of 50%, which resulted in a dose of carbohydrates from 2 to 12 g/h⁻¹/kg⁻¹. We believe that this level of concentration is difficult to tolerate during intense exercise. To achieve a similar carbohydrate contribution from sports drinks at 8%, a consumption of at least 1750 mL.h⁻¹ would be required. This amount of fluid intake is impractical and makes it difficult to relate the performance findings using drinks with elevated carbohydrate content with the commercially available sports drinks (Coombes and Hamilton, 2000). Of the 69 studies cited in the review, only 16 used commercially available drinks.

Given this, overall the evidence suggests that ingestion of CHO during endurance training is a well-established strategy to maintain glucose levels, save glycogen and potentially promote higher levels of performance (Kerksick et al., 2009).

It is well accepted that the peak oxidation rates of a single type of CHO (glucose) is approximately 1 g/min⁻¹ that is 60 g/h⁻¹. In some way, this explains the 6% concentration in some world-renowned sports drinks, such as Gatorade. Thus, this CHO contribution should ideally be reached per hour, which with a commercially available drink would also ensure a contribution of about 1 L/h⁻¹ of fluids. It is important to note that this rate of fluid intake may be much lower than the sweat rate of some athletes (Ahumada, Barale & Zóccola, 2010), which, depending on the duration of effort (see the equations presented above), may involve a significant level of dehydration (> 2%).

It also seems that the higher the rate of gastric emptying would be approximately 1200 mL/h⁻¹ or 20 mL/min⁻¹ (Ryan et al., 1998), implying that when the sweat rate of a given subject exceeds this value, a given level of dehydration will be assured including a concomitant loss of performance.

Regarding the rate of carbohydrates oxidation, the combination of two types of carbohydrates (glucose and fructose) can increase by 40% the peak levels of carbohydrate oxidation, reaching 1.5 g/min⁻¹ (Kersick et

al., 2009). Thus, a drink that provides these two carbohydrates in a concentration of about 90 g in 1200 mL of fluid, would maximize the rate of carbohydrates oxidation, preserving the hepatic glycogen and attenuating the lowering of blood glucose. This could have a crucial practical application for very long duration tests such as an Ironman, ultramarathon, or similar tests.

It is important to mention that dehydration may increase the risk of heat stroke, reducing blood flow to the skin and reducing the rate of sweating (Ryan et al., 1998). In this regard, an increase of 0.1-0.4° C core temperature has been reported for every 1% loss of body mass (Ryan et al., 1998). However, it is also important to note that there might be a threshold of dehydration from which this increase occurs and may correspond to a 2-3% loss of body mass (Cheuvront & Haymes, 2001). In addition, there is evidence that a 4% level of dehydration, with an elevated core temperature (~ 39 °C/ 102 °F), affects gastric emptying (Ryan et al., 1998). Thus, this indicates that excessive loss of body water not only increases the storage of body heat during exercise, but it can affect the individual's ability to restore his fluid, carbohydrates and salts needs (Ryan et al., 1998).

It is important to mention that the pattern of fluid intake can markedly affect the rate of gastric emptying. Apparently, repeated ingestion of small volumes of fluid can maintain a high rate of gastric emptying compared to one single voluminous intake. Therefore, this can increase the rate of fluid and carbohydrates transported into the intestine (Ryan et al., 1998). Note also that there is evidence that repetitive fluid intake, perhaps through the stimulation of the oropharyngeal reflex, can attenuate the reductions in blood flow to the skin and sweat rate associated with thermal dehydration.

Beyond the issues raised above, we now know that in actual competitions, and specifically in endurance sports, such as the marathon, triathlon or mountain biking, when athletes drink ad libitum (and we know that the best athletes do), they reach high levels of dehydration (3, 4, 5% and even higher levels of dehydration). Despite this, they are able to achieve very high levels of performance without significant muscle damage, keeping their pace and finishing with safe core temperatures (<40 ° C). Conditions for outdoor sports are very different from those found in laboratories where many baseline studies of the scientific literature have been performed. Analyzing this topic in detail is beyond the scope of this course.

Post-Exercise Hydration

The two main factors influencing the rehydration process are the volume and composition of the fluids consumed.

The volume consumed will be influenced by many factors, including palatability and its effect on the thirst mechanism (Shirreffs, 2000).

Water intake alone in the post-exercise period results in a rapid fall in plasma sodium concentration and a drop in plasma osmolality. These changes have the effect of reducing the stimulation to drink (thirst) and increase urine output, and both factors will harm the rehydration process (Atkinson, Davidson, Jeukendrup & Passfield, 2003). Complete rehydration after exercise can only be achieved if both the sodium and water lost in sweat are restored. To reach a state of euhydration, sodium intake should be higher than its loss. Ingestion of a beverage containing sodium will not only promote rapid fluid absorption in the small intestine, but also allows the plasma sodium concentration to remain elevated during the rehydration period and helps maintain thirst, while it delays stimulating the production of urine. It is thought that the inclusion of potassium in beverages consumed after exercise improves the restoration of intracellular water and thus promotes rehydration, but currently there is little experimental evidence to support this (Atkinson et al., 2003).

Regarding the sodium concentration, it has been proposed that drinks used for post-exercise rehydration should have a concentration similar to that of sweat (Shirreffs, 2000), but considering that the electrolyte content in sweat shows a considerable variation between subjects and over time, it would be impossible to prescribe a single formula for each subject or for each situation. A study by Shirreffs (2000) to investigate the relationship between sodium losses of the whole body and the effectiveness for rehydrating of beverages with different sodium concentrations seems to confirm that optimal rehydration is achieved with a drink with a sodium concentration similar to sweat. However, it is important to mention that in practical terms a sports drink with these characteristics will likely not have good palatability, as its sodium concentration should be more than twice (depending on the subject and condition) that of any sports drink commercially available. Thus, ingestion of solid foods like soups and pizzas whose sodium concentration is usually high, may be an appropriate option. In fact, this is documented in the literature, where the ingestion of food plus water is compared to a sports drink (where the water volume equaled that of the sports drink). In these studies, the urine produced was lower in the case of food and water intake. Apparently, the increased efficiency of food and water to restore the body's water balance was due to the higher content of sodium and potassium.

Shirreffs et al. (2000) also investigated the influence of the volume of beverage on the effectiveness of rehydration after an exercise induced dehydration of 2%. The beverage volumes were equal to 50, 100, 150 and 200% of the sweat losses during exercise. To investigate a possible

interaction between the volume of beverage and its sodium content, a beverage with a low concentration of sodium (23 mM) was compared with a beverage with a high concentration of electrolytes (61 mM). With both beverages, urine production was related to the volume of the beverage consumed. Regardless of the composition of the beverage, subjects did not restore their level of hydration when they consumed a volume equivalent to (100%), or only half of the sweat lost during exercise. When a volume of beverage equal to 150% of sweat loss was consumed, subjects were slightly hypohydrated 6 hours after consuming the test beverage when it had a low sodium concentration, a similar condition to when they ingested the same beverage in a volume double that of the sweat loss. In the case of a beverage with a high concentration of sodium, a sufficient quantity of fluid was retained to achieve a state of hyperhydration 6 hours after the ingestion of 150 or 200% of the sweat loss, in the test beverage. As a practical application, one could argue that with a sports drink with a minimum concentration of 23 mM, provided that 150% of fluid lost during exercise is ingested, one can reach a level close to normal hydration in a period of 6 hours.

It is very important to note also that the rate at which the lost fluid is ingested can influence the rate of urine production, and thus the effectiveness of rehydration. Prolonging the rehydration period may be more effective in reaching a level of euhydration earlier. Thus, ingestion of 150% of the lost fluids could be extended for 120-150 minutes.

In general sports drinks have sodium concentrations of 10 to 25 mM, which is a contribution of between 250 and 500 mg of sodium per liter of solution. Human sweat can have a sodium concentration doubling these values, although it has been reported that this is very variable. Thus, 10 liters of sweat could involve the loss of 29 g of sodium chloride (Atkinson et al., 2003) which illustrates the importance of intake of solids in the post-exercise period.

Regarding the role of sodium in the process of post-exercise hydration, a recently published review (Shirreffs, 2011) asserts that after exercise, replacement of sodium and restoring its balance is a prerequisite for effective restoration and maintenance of euhydration, since no other electrolyte plays a significant role in this process. This review also notes that the investigations in recent years have highlighted the importance of not making a very rapid rehydration after exercise, so as to avoid diuresis and achieve and maintain euhydration. The delay of the onset of fluid flow rehydration may be achieved by altering the pattern of fluid intake or delaying gastric emptying of the beverage from the stomach into the intestine, by means of, for example, increasing the carbohydrate content of the beverage. Thus, this is the time in which it is appropriate to use a hypertonic drink, with carbohydrates, proteins and sodium.

Finally, we note that an altered fluid and temperature balance can affect not only performance but also health (Shirreffs, 2000). As a result, except in situations in which there has not been a decrease in body water, the main purpose of the post-exercise recovery should be to restore the deficit of fluids. Then, priority should be given to the contribution of carbohydrates to fill glycogen stores and protein intake to offset the protein catabolism and promote recovery.

Nutrient *Timing*

Regarding nutrition, not only is macronutrient composition and quantity important, but also the time in which they are ingested, which is what we mean by *timing*. Nutrition at the right time is key to optimizing performance and improving health.

Pre-Exercise

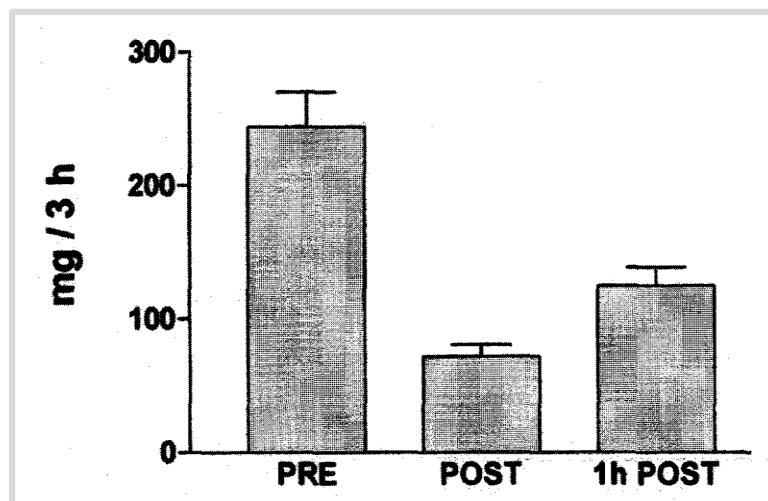
Depending on the volume, intensity, level of training and objectives, a high CHO diet is recommended in order to maintain glycogen levels (Kerksick et al., 2009), while increasing the fraction of CHO to about 70% in the five to seven days before the competition, is a way of maximizing muscle and liver glycogen stores, which will maintain blood glucose levels during exercise (Kerksick et al., 2009). Thus, it was recently determined that an intake of 7-10 g/kg⁻¹/day⁻¹ of carbohydrates should be sufficient to completely replenish carbohydrate stores and allow for optimum performance (Atkinson et al., 2003). It is interesting to note also that you can achieve maximum glycogen levels after only 1 to 3 days of consuming a diet rich in CHO if the volume of exercise performed is minimized (Kerksick et al., 2009). In general, research involving the ingestion of CHO within an hour before exercise have shown equivocal results regarding changes in performance. In this respect, it is interesting to note that carbohydrate intake and their elevated levels stimulate the mobilization and oxidation of these, and inhibit lipid metabolism, although it would seem that most oxidation is offset by its increased availability.

In relation to proteins and amino acids, there is a lot of literature full of data, much of that obtained by the team of Kevin D. Tipton, at the University of Texas. This research found that when a group of subjects ingested a solution consisting of 6 g of essential amino acids and 35 g of carbohydrate, either immediately before or after a resistance exercise, the response of the muscle protein net balance was considerably higher when the drink was ingested immediately before than when it was ingested immediately or an hour after exercise (Tipton & Wolfe, 2001) (figure 5). Phenylalanine uptake is studied, since this amino acid cannot be oxidized in the muscle, and its net uptake involves its utilization for a process of protein synthesis. According to what is posited by Tipton and

Wolfe (2001), the largest anabolic response observed when nutrients are consumed pre-exercise, probably reflects increased amino acid transport into the muscle, thus allowing a greater proportion of amino acids to be captured by the muscles.

The general guidelines recommend an intake of 1-2 g of CHO/kg⁻¹ and 0.15-0.25 g of proteins/kg⁻¹ 3 to 4 hours before competition or exercise (Kerksick et al., 2009).

Figure 5: Phenylalanine Uptake by Muscle



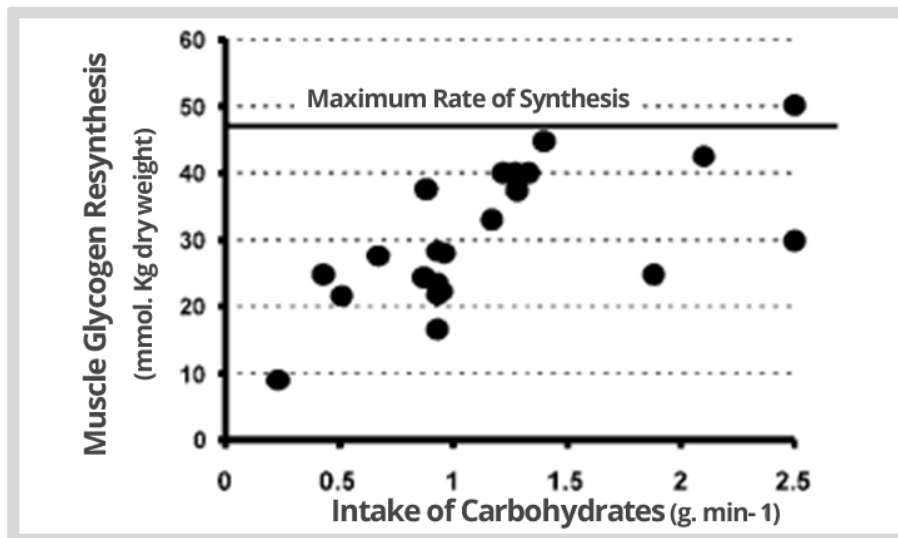
Source: Tipton and Wolfe, 2001, p. 122.

References: phenylalanine uptake by the muscle for 3 hours when a solution with carbohydrates and amino acids was ingested immediately before (PRE), immediately after (POST) and one hour after exercise (1h POST). All values are statistically different from each other ($p < 0.05$).

Post-Exercise

Athletes who ingested 1.5g of CHO per kg body weight within 30 min after exercise, experienced a higher rate of glycogen resynthesis when supplementation was delayed by two hours. This is due largely to the increased sensitivity of muscle to insulin (Kerksick et al., 2009). As seen in Figure 6, this mass of CHO per kg appears to be the limit to CHO intake to achieve maximum resynthesis speed (Atkinson et al., 2003).

Figure 6: Maximum Rates of Glycogen Synthesis after Ingestion of Different Amounts of Carbohydrate in the Hours Post-Exercise



Source: Atkinson, 2003, p. 780.

Liquid and solid forms of CHO promote similar levels of glycogen resynthesis (Kerksick et al., 2009). Delaying the intake of CHO by just 2 hours may decrease the rate of glycogen resynthesis by 50%. Ingesting 1.0 g of CHO/kg⁻¹ during the first 30 min and every 2 hours during the first 4 to 6 hours, with the aim of restoring glycogen stores, has been suggested (Kerksick et al., 2009). Similarly, the highest rates of muscle glycogen synthesis have been reported in studies in which carbohydrates were provided at regular intervals (every 15 to 30 min) (Atkinson et al., 2003). This is probably due to the maintenance of high levels of blood glucose and insulin. So, eating small meals often seem to have an extra benefit over eating more food, fewer times. In addition, eating less food probably reduces the risk of gastrointestinal upset.

As previously stated, there is evidence that the intake of solid food reduces urine production, which ultimately means greater fluid retention and thus body water (Atkinson et al., 2003). This would allow achieving euhydration in less time. Solid foods such as pizzas, pasta, etc., generally have a higher concentration of sodium than fluids. Interestingly, sports drinks generally have concentrations of 10 to 25 mM sodium, which is a contribution of between 250 and 500 mg of sodium per liter of solution. Human sweat may have double that concentration, although it has been reported that this is very variable. Thus, 10 liters of sweat could involve the loss of 29 g of sodium chloride (Atkinson et al., 2003). This illustrates the importance of ingesting solids in the post-exercise period.

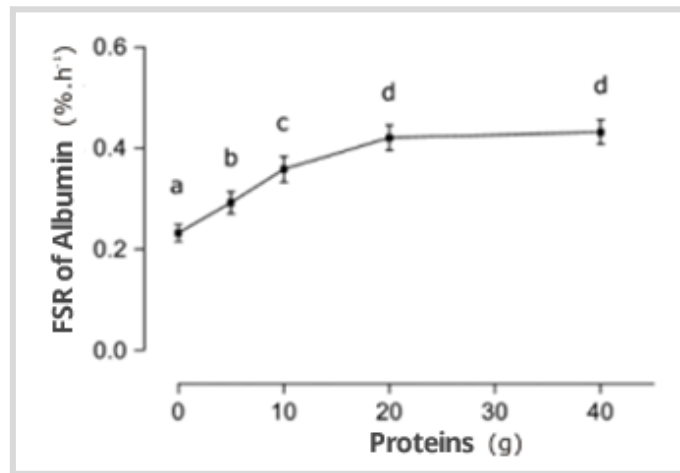
Regarding the intake of foods that provide all the macronutrients, it is interesting to note the results of a study by John Ivy and colleagues (Kerksick et al., 2009). The researchers instructed a group of cyclists to

complete 2.5 hrs. of cycling and then ingest a supplement with either CHO + PRO + fat (80 g CHO, 28 g of PRO, and 6 g of fat), few CHO (80 g of CHO and 6 g fat) or many CHO (108 g of CHO and 6 g fat), immediately after exercise and 2 hours after. The authors concluded that supplementation with CHO + PRO + fat was more effective to restore muscle glycogen, because it causes a more pronounced insulin response (Kersick et al., 2009).

In relation to the intake of proteins and amino acids, it is important to note that the availability of essential amino acids after exercise, especially branched chain amino acids (valine, leucine and isoleucine) influence recovery, optimizing the synthesis of PRO as well as of glycogen after exercise (Kersick et al., 2009). It is worth noting that, whether the training has the objective of increasing muscle strength through resistance training, maximizing oxygen consumption through cycling, or an increased lactate threshold in running and/or speed walking, the recovery processes and adaptation, such as an increase in muscle contractile proteins, capillarization, increasing the number and size of mitochondria, and the increase of enzyme activity, all involve protein synthesis, so as indicated by Ivy and colleagues (Kersick et al., 2009), CHO intake is not the only important factor after exercise.

For resistance training, the ideal dose of essential amino acids and CHO necessary to optimize the protein balance is not currently known, although the findings of Daniel Moore et al. (2009) are encouraging with respect to the dose needed to maximize protein synthesis of muscle protein (Figure 7). These researchers found that protein synthesis peaked at a dose of 20 g of protein (232 mg/kg-1) after strength training in young and trained subjects.

Figure 7: Fractional Protein Synthesis of Plasma Albumin (FSR) after Resistance Training in Response to Increasing Amounts of Dietary Protein



Source: Moore et al., 2009, p. 165.

The mean values (with different letters) are significantly different from each other ($p < 0.01$, $n = 6$).

It should also be noted that studies using similar techniques to measure the kinetics of protein during resistance training have used only 6 g of essential amino acids (EAA), 6 g of essential amino acids plus 6 g of nonessential amino acids (NEAA), 12 g only essential amino acids, 17.5 g whey protein, 20 g casein, 20 g whey protein, 40 g of a mixture of amino acids and 40 g of only essential amino acids, and all have found similar increases in synthesis and protein balance (Kerksick et al., 2009). While the relationship between CHO and PRO requires further investigation, a practical approach that is often used involves consuming supplements containing CHO + PRO in a 3:1 or 4:1 relation within 30 min after exercise, which translates into 1.2 to 1.5 g per kg of CHO (e.g., dextrose, sucrose, maltodextrin, glucose) with 0.3–0.4 g of quality PRO per kg, containing all the essential amino acids (Kersick et al., 2009).

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