# 1 Good Eating Habits in Sport

## Joaquín Dosil and Juan José Crespo



> Despite having reached a relatively high level in my sport, there is still a lack of nutritional guidance. Sometimes the conversation crops up at training and people give you the odd piece of advice about what you should eat, what you shouldn't, and any supplements they assure work wonders for them. But nobody puts all of this lose information together and applies it to you, as an individual athlete, in a structured manner. Coaches are often too quick to say when you are a little over weight, telling you to 'watch what you're eating', or even that you are too skinny, 'make sure you're eating enough'. What's the real practicality of these remarks? All too often the first comments I hear from fellow female athletes following a bad training session or race is 'I'm too fat'. Perhaps this indicates the constant underlying risk of eating disorders in sport.
>
> International Athlete (middle-distance running)

## 1.1 Introduction

The demands of today's ever-increasingly professional sports world lead athletes to thrive for perfection in all aspects of their preparation. In this quest for peak performance, the traditional coach–athlete training model has become somewhat dated. Gradually sport is incorporating a wider range of professionals into teams and clubs (physical trainers, physiotherapists, doctors, psychologists, nutritionists . . .), recognising the need for specialist guidance in the different aspects of athletes' performance.

*Eating Disorders in Athletes* Joaquín Dosil

Eating is a conscious and voluntary action, influenced by cultural, economic and social factors. Undoubtedly, nutrition has an impact on the health and can prove either detrimental or beneficial to an athlete's performance. Whilst doctors and nutritionists are responsible for prescribing the most adequate 'diets' for each individual athlete, psychologists work to prevent environmental influences from provoking eating disorders. Likewise, given their role as team/group coordinators, coaches may act as *behaviour observers*, consulting the relevant specialists if they suspect eating alterations. This somewhat utopian vision is intended to form a vital link in the process of optimizing sports performance. Since the prevailing reality reveals many nutritional errors are still being made in sport, this chapter endeavours to provide a source of basic information for coaches and athletes alike, promoting the role of the many professionals working in this field.

## 1.2 A balanced diet in sport

Nutritional control evaluates the dietary intake of athletes, verifying its suitability for the physical demands of their daily sports activity. The principal aim is to avoid the deficiencies or excesses that can hinder performance and general health. Whilst the primary objective of any nutritional strategy is to attain the necessary energy intake for an athlete (quantity), the secondary objective is to nourish the organism with the 45 essential nutrients: 13 vitamins, 9 amino acids, 21 minerals and 2 fatty acids (quality).

### *1.2.1 What is a balanced diet?*

To survive, the human body requires energy, certain substances to maintain and replace tissues, as well as regulating metabolic reactions, and water. These basic needs are met by nutrients found in the different foods we consume. The main nutrients are: *macronutrients* (carbohydrates, lipids and proteins) and *micronutrients* (vitamins and minerals).

Whilst the function of carbohydrates and lipids is principally energetic, proteins have an important structural role, and vitamins and minerals assist in the body's regulatory mechanism.

Regarding nutritional requirements, the World Health Organization (WHO, 2003) stipulates the following objectives for the general population: 55–75 per cent carbohydrates, 15–30 per cent fats, and 10–15 per cent proteins.

In terms of body tissues, muscles have the greatest capacity to produce and employ the energy generated through adenosine triphosphate (ATP), the organism's 'energetic currency'. Since the concentration of ATP in the muscles is extremely limited (5 mmol/kg), there are four metabolic methods for renewing it: phosphorcreatine, anaerobic glycolysis, aerobic glycolysis (glucose/glycogen), and lipolysis (fatty acids). These energetic substrata are produced by certain nutrients, found in the foods we consume (principally carbohydrates and lipids), and are stored within the organism.

Athletes present exceptional nutritional requirements, which vary according to age, gender and body composition, as well as the type, intensity, frequency and duration of the physical activity. Although diet had already been related to physical performance at the beginning of the twentieth century, it was not until well into the 1960s and beginning of the 1970s, that the physiological bases of sports performance were scientifically established.

Adequate nutritional intake is a factor determining sports performance (American Dietetic Association, 2000). Moreover, an adequate diet should provide the sufficient number of total calories, 10–15 per cent of which should originate from proteins (1–1.5 g/kg of weight) 20–30 per cent from fats, and 60–70 per cent from carbohydrates (Katch, 1985).

### *1.2.2 Energy requirements*

The calorie requirements of each individual athlete may be determined by estimating the *base metabolism (BM)*, the *dynamic-specific action (DSA)* of the nutrients (10 per cent average for the three macronutrients), the *additional calorie consumption* during day-to-day activities, and the *calorie consumption during physical and/or sporting activity*. The BM can be estimated using the Harris–Benedict (1919) formula:

$$\text{Male base metabolism} = 66.5 + 13.8 \times \text{weight (kg)} + 5.0 \times \text{height (cm)} - 6.8 \times \text{age (years)}$$

$$\text{Female base metabolism} = 65.1 + 9.5 \times \text{weight (kg)} + 1.8 \times \text{height (cm)} - 4.7 \times \text{age (years)}$$

Recording the various daily physical activities and calculating the energy expenditure of each, consulting the relevant tables, is one way of estimating additional calorie requirements (Ainsworth *et al.*, 1993; McArdle *et al.*, 1991).

Athletes, compared with more sedentary individuals, present an average additional energy expenditure of 500–1000 kcal/h of exercise (Brouns, 1995). Therefore, an athlete immersed in a high-intensity exercise programme cannot operate off the same diet as the rest of the general population.

Finally, regarding energy requirements, nutritional evaluation is another relevant aspect. In the sports context, and particularly in sports medicine, the body mass index (BMI) is frequently employed to relate athletes' weight in kilograms to their height in metres squared:

$$\text{BMI} = \text{weight (kg)}/\text{height (m}^2)$$

The BMI allows coaches to objectively measure their athletes' physical state at any given point of the season. An individual is considered malnourished if the BMI falls below 18.5 kg/m$^2$, and normal if the reading lies between 18.5 kg/m$^2$ and 24.9 kg/m$^2$. Nevertheless, the characteristics of each sporting discipline must not be disregarded, since the physical biotypes of each may vary, altering the normal limits.

### 1.2.3 Forming a nutritional plan

Without imposing notable changes in athletes' eating patterns, a dietary plan may be elaborated through the following steps:

1. Estimate the athlete's energy requirements using the pertinent formulas and tables.
2. Divide the calories into macronutrient categories.
3. Convert the calories into grams (proteins, 4 kcal/g; carbohydrates, 4 kcal/g; fats, 9 kcal/g).
4. Divide the nutrients into food groups (dairy products, meat/fish/eggs, cereals/potatoes, vegetables, fruit, and fats). The nutritional pyramid and food composition tables prove useful here.
5. Prepare each mealtime (4 or 5 daily intakes).
6. Adapt the food quantities according to the reference measurements.

Despite being somewhat problematic, many professional athletes use reference-eating models, often provided by coaches and teammates. Athletes from different sports seek diverse objectives through their nutrition (see Table 1.1). For example, whilst cyclists aim to renew the energy lost through daily physical exertion, gymnasts seek a minimum ideal weight to compete more effectively.

In certain sports, in which athletes seek an extremely thin body, especially in predominantly female disciplines (e.g. gymnastics, synchronised swimming, artistic ice-skating, distance running, dancing, or horse riding), energy intake often fails to meet recommendations, producing nutritional deficits in the majority of cases (Otis *et al.* 1997; West, 1998; Hobart & Smucker, 2000). On many occasions, such insufficiencies oblige athletes' doctors to take correctional measures, including the employment of vitamin and mineral supplements.

In particular physiological conditions, such as adolescence, nutrition plays a vital role in growth and sexual development. Many athletes, especially females, already compete at elite level during their early adolescence (10–13 years of age), when they should be attending to three fundamental aspects: the pubertal growth spurt (higher protein and calcium requirements), changes in body composition (increased fat percentages in girls) and other individual alterations influenced by the social environment (Santrock, 2004). Up to 11 years of age, the recommended daily energy intake is the same for boys and girls; from 11 to 14 years, boys are recommended to consume 300 kcal/day more than girls; and between 15 and 18 years, this difference rises to 800 kcal/day. In Spanish adolescents, 10–15 per cent presents with an

**Table 1.1** Factors influencing the pursued nutritional objectives in sport. The energetic consumption and proportion of macronutrients consumed in different sports

| Objectives of diet in sport | Factors influencing diet in sport | Average daily energetic consumption in different sports: (% of carbohydrates, fats and proteins) |
|---|---|---|
| Replacement of energy resources | Prioritization of nutritional objectives | Cycling: 5000–7000 kcal (64% – 26% – 10%) |
| Provision of the 45 essential nutrients | Macronutrient absorption | Marathon: 4000–5000 kcal (50% – 36% – 14%) |
| Repair and maintenance of bodily tissues | Control of non-nutritional energetic elements, e.g. alcohol | Football: 3300–3900 kcal (45% – 40% – 14%) |
| Organic regeneration and growth | Daily distribution of total calorie intake | Skiing: 4900–7100 kcal (46% – 40% – 14%) |
| Maintenance of the immune system's capacity and response to exercise-induced stresses | Eating habits and availability of quality food items | Swimming: 4400–5500 kcal (47% – 42% – 11%) |
| Prevention of injuries and avoidance of hyper-calorie nutrition, dehydration, etc. | Number of daily training sessions: the time frame of food intake | Gymnastics/dance 1600–1900 kcal (49% – 36% – 15%) |

Source: Villa and Navas (2002).

iron deficit, only 40 per cent of boys and 15 per cent of girls meet the recommended daily calcium intake, and 10–40 per cent fail to comply with the required ingestion of vitamins A, B, and folic acid (Lozano de la Torre & Muñoz, 1995).

Given the exceptional physical demands of elite sport, nutritional awareness is essential for everyone involved in this context. Moreover, such knowledge should be much more abundant and exhaustive than for rest of the general population. Nevertheless, given the lack of information and the physical stress placed upon their organisms, athletes often find themselves 'destitute' in this respect.

This chapter now proceeds to describe the most important elements in athletes' diets: macronutrients, micronutrients and liquids. Such basic nutritional knowledge should be common throughout the sporting community, helping to prevent eating disorders.

## 1.3 Nutrients required by humans and athletes

Unlike eating, nutrition is a combination of processes through which the organism receives, transforms and employs dietary substances contained within foods. In order to provide the necessary quantity of nutrients, each individual's food intake, whether an athlete or not, should be sufficient in energy, varied, balanced and, of course, enjoyable.

### 1.3.1 Macronutrients

There are three macronutrient groups: *carbohydrates*, *fats* or *lipids*, and *proteins*. The organism's two principal energy sources are fats and carbohydrates. In a state of rest, fat is the primary energy supplier, but as physical exercise increases, the role of carbohydrates becomes more significant, constituting the most important fuel in high-intensity physical activities, such as difficult training sessions and competitions (Table 1.2).

The main characteristics of each macronutrient group are described below.

*Glycogen/glucides, or carbohydrates* Carbohydrates (CH) constitute one of the most important energy resources in human nutrition. For the majority of athletes, they represent the principal energy source for muscular contraction and even the general population are aware of the benefits of a carbohydrate-rich diet (e.g. pasta is often referred to as 'athletes' food'). Its components (carbon, hydrogen and oxygen) are linked in a formula, generally abbreviated as: $C_n(H_2O)_n$ – hence its classic denomination.

Carbohydrates may be distinguished according to their structure and chemical characteristics, or how easily they can be digested and absorbed into the body. From a structural perspective, the following classification can be made:

- Monounsaturated carbohydrates: the most commonly found are hexodes (six carbons), glucose, fructose and galactose.
- Saturated carbohydrates: two units of monounsaturated carbohydrates joined together. The most commonly found are: maltose, sucrose and lactose.
- Polyunsaturated carbohydrates: produced through the polymerization of ten or more glucose units. From a nutritional perspective, the following may be high-

**Table 1.2** The approximate required proportions of macronutrients in different sports. Reproduced from Villa and Navas (2002), courtesy of McGraw-Hill, Madrid

| Macronutrients | Athletes conducting short physical efforts at high intensities (sprinters, weight lifters) and technical sports (figure skating, rhythmic gymnastics) | Athletes conducting prolonged physical efforts at elevated intensities (marathon runners, cyclists, cross-country skiers . . . ). |
|---|---|---|
| Carbohydrates | 50–55% | 60–70% |
| Fats | 30% | 18–28% |
| Proteins | 15–20% | 12% |

lighted: starch, glycogen, dextrose and dietary fibre. These have a slower absorption rate than saturated and monounsaturated carbohydrates. Dietary fibre is composed of certain oligounsaturated carbohydrates (stachyose, raffinose) and polyunsaturated carbohydrates (cellulose, mucilage, pectin, insulin), which cannot be absorbed into the human intestine, but play an important role in intestinal functioning.

One of the classification criteria for carbohydrates, known as the 'glycaemic index' (Jenkins *et al.*, 1993) determines the increase in glycaemia above the base levels, which is produced 2 h after ingesting a food element containing 50 g of carbohydrate (compared to 50 g of glucose). Foods with an elevated glycaemic index (>85) include bread, rice, muesli, potatoes, glucose polymers, banana, and cornflakes. Foods with a moderate glycaemic index (60–85) comprise pasta, biscuits, grapes, pastries and cakes. Foods with a low glycaemic index (<60) are peas, figs, ice cream, and dairy products in general. The glycaemic index varies according to gastric emptiness, protein and fat contents of the foods, the size of the starch molecule and even how the food has been prepared (hence, the nutritional impact of cooking methods).

Carbohydrates are directed towards the digestive tract before being converted, almost exclusively, into glucose (fructose and galactose are also absorbed). Glucose is then distributed around the organism through the blood, with two main destinations (Barbany, 2002):

- One part is accumulated as glycogen reserves in the liver (80–100 g) and muscular fibre (400–500 g).
- Another part is used in certain cells (neurons and **haematites**), as a form of fuel.
- The rest is directed to fatty tissues, where it is transformed into triglycerides to stimulate the insulin hormone (lipogenesis).

At rest, the consumption of glucose is extremely low. However, it is used constantly during physical activity. During prolonged periods of exercise at intensities surpassing 60 per cent of the *maximum oxygen consumption* ($VO_2$ max), there is a lineal relationship between the exercise intensity and the muscular glycogen consumption rate. Moreover, in physical activities around 80–85 per cent of the $VO_2$ max, this material constitutes the principal substratum (Coyle, 1995). During intermittent physical exercise at maximum intensities, the work capacity may be enhanced through a carbohydrate-rich diet, or hindered by a diet lacking in this macronutrient (Maughan & Poole, 1981; Jenkins *et al.*, 1993). According to various authors (Saltin & Karlsson, 1972; Bergstrom & Hultman, 1967; Bergstrom *et al.*, 1967; Hermansen *et al.*, 1967; Karlsson & Saltin, 1971, and Stepto *et al.*, 2001), at exercise intensities around 65–90% of the $VO_2$ max, the appearance of fatigue is directly related to the diminishment of muscular glycogen. Furthermore, Del

Castillo (1998a) considers that carbohydrates should constitute 50–70 per cent of the daily energy provision in the diets of endurance athletes. Today, the importance of a high carbohydrate diet during the 3 days prior to a competition has been demonstrated (Noakes, 1993), since it increases the glycogen reserves, directly improving physical performance.

When physical exercise is carried out for more than 45 minutes, it is preferable to have previously ingested foods containing 20 g of carbohydrates for each hour of exercise. Nevertheless, it may also be necessary to take in hydration during the physical activity itself, such as some form of liquid preparation containing 4–8 per cent glucose.

Prior to a competition, numerous studies (e.g. Brotherhood, 1984) recommend an easily digestible low-in-fat snack, containing a moderate level of carbohydrates, which should ideally be eaten 3–4 h beforehand.

Jimenez *et al.* (1998) offers a detailed description of certain foods with high and low carbohydrate contents (Table 1.3).

**Table 1.3** The glucose contents of some foods

| Food | Carbohydrate content (g per 100g) |
|---|---|
| Sugar | 99.5 |
| Rice | 77.0 |
| Pasta, semolina. | 76.5 |
| Honey, biscuits, flour, raisins | 75.0 |
| Dates | 73.0 |
| Jam | 72.0 |
| Chocolate | 65.0 |
| Beans | 60.0 |
| Chickpeas, lentils | 58.0 |
| White bread | 55.0 |
| Chestnuts | 40.0 |
| Peanuts | 26.0 |
| Bananas | 20.0 |
| Potatoes | 19.0 |
| Grapes, cherries | 17.0 |
| Peas | 16.0 |
| Hazelnuts, walnuts | 15.0 |
| Pears | 14.0 |
| Apples, peaches, pineapple | 12.0 |
| Plums, apricots, onions | 10.0 |
| Mandarins, oranges, carrots | 9.0 |
| Beetroot, Brussels sprouts | 8.0 |
| French beans, strawberries | 7.0 |
| Melon | 6.5 |
| Grapefruit | 6.0 |
| Mushrooms | 4.0 |

Training induces changes in the enzymatic activity (above all, those related to glycogen synthesis), which assists the storage of muscular glycogen (Acheson *et al.*, 1998; Bloom *et al.*, 1987), and provokes an increase in energy resources, principally employed in high-intensity physical efforts. Therefore, given their better-developed enzymatic systems, athletes engaged in training regimes have a greater capacity to accumulate glycogen than non-athletes.


**Figure 1.1**

*Lipids and fats* Lipids, principally energetic nutrients, have a variable chemical structure and are insoluble in water. In the human body, 95 per cent of these are *triglycerides* (the combination of a glycerol nucleus and three fatty acids). Depending on the length of their chain, fatty acids may be classified in the following manner: short chain (4–6 carbon atoms), medium chain (8–10 carbon atoms) and long chain (12 or more carbon atoms). These may then be divided into two groups, according to whether there are double links between the carbon atoms: saturated and unsaturated. If they present a double link, they are termed *monounsaturated fats* and if they comprise two or more double links, they are termed *polyunsaturated fats*. Saturated fats are solid or semi-solid and have a higher fusion point (they mainly originate from animals: egg yolk, margarine, lard); whilst unsaturated fats have a lower fusion point, meaning they are liquid at room temperature (they mainly originate from vegetable sources). Likewise, it is important to highlight the existence of fatty acids, which cannot be produced in the organism and therefore, must be provided by the diet. The essential fatty acids are: *alpha-linolenic* and *linoleic*.

In addition to triglycerides, other substances have similar characteristics, but contain phosphor, nitrogen or glucides (combined lipids: phosphor-lipids, lecithin/pectin, glucolipids and sterols).

Fats constitute an important energy source (9 kcal/g). Moreover, they are a vital part of the human diet, since they contain essential fatty acids, a vehicle for ingesting liposoluble vitamins. Some of these fatty acids, such as cholesterol, are precursors of hormones. In addition to carbohydrates, fats represent the principal source of energy during prolonged exercise, although their mobilization is much slower. The organism has three forms of depositing fats: in the fatty tissues, in the intermuscular areas and in the circulating triglycerides.

For sportspeople engaged in a high-intensity training regime, fats should not constitute more than 25 per cent of total calorie intake, and saturated fatty acids should not surpass 10 per cent of total calorie intake, in order to avoid hypercholesterolemias (Williams, 1995). Moreover, it is recommended that the intake of cholesterol is limited to around 300 mg/day.

Taking supplements containing medium-chain triglycerides, in order to save carbohydrates, has been proved useless and even damaging, failing to improve the use of fatty acids; this favours weight loss in strength sports.

Resistance training induces a metabolic adaptation, tending towards an increase in the oxidation of triglycerides, hence reserving carbohydrates.

Table 1.4 details a series of commonly consumed foods and their corresponding fat contents expressed in percentages (Jiménez *et al.*, 1998).

Regarding plasmatic lipids, it is widely recognised that regular exercise (training) significantly increases the levels of high-density lipoprotein (HDL) cholesterol when an individual carries out moderate to intense training sessions (Durstine & Haskell, 1994; Elwood *et al.*, 1993; Lakka & Salonen, 1992; Word *et al.*, 1988). Likewise, habitual exercise induces beneficial effects on cardiovascular health.

*Proteins* Proteins are formed by amino acids, molecules containing carbon, hydrogen, oxygen and nitrogen (Wooton, 1988). Since amino acids are necessary for synthesizing hormones, enzymes and antibodies, as well as assisting in growth processes and the development of organs and tissues, they may be considered an essential element in any diet. Human life is not possible without proteins. They constitute

**Table 1.4** The fat contents of some foods

| Food | Fat content (per 100g) |
|---|---|
| Butter | 83.0 |
| Vegetable margarine | 83.5 |
| Egg yolk | 33.0 |
| Cream | 30.0 |
| Pork | 16.0 |
| Eggs | 12.0 |
| Ox meat | 7.4 |
| Full-fat milk | 3.9 |
| Chicken | 3.0 |

the basic substrata of any living cell and are responsible for a diverse range of functions, such as transporting oxygen and hydrogen, or the formation of contractile material in the muscles, etc. As with fats, there are a series of amino acids that the organism is unable produce naturally, and which must be consumed through the diet. These are therefore denominated essential amino acids (isoleucine, leucine, lysine, methionine, phenylalanine, threotine, tryptophan and valine). Others, although generated in the organism, do not reach sufficient quantities (arginine and histidine), and must also be provided by the diet, since a lack of these substances can provoke diverse neurological disorders: spasms, altered muscular coordination, atrophies, developmental disorders in some organs – such as the liver or the testicles – or alteration to growth patterns, etc. (Muñoz & López Meseguer, 1998).

**Figure 1.2**

Adults require approximately 0.8–1.0 g/kg of weight a day of proteins, in order to compensate for daily losses. Nevertheless, athletes generally require a higher protein input compared to more sedentary individuals. In strength and speed athletes, these requirements rise to 1.2–2.0 g/kg a day; whilst in endurance sports, this amount is in the region of 1.2–1.4 g/kg, reaching figures of around 1.5–2.0 g/kg

**Table 1.5** Foods with elevated protein contents

| Food | Protein contents (per100 g) |
|---|---|
| Chicken | 26.0 g |
| Lentils | 24.0 g |
| Prawns | 22.0 g |
| Lean meat, cheese | 21.5 g |
| Cold meat | 21.0 g |
| Almonds | 20.5 g |
| Chickpeas, tuna, liver | 20.0 g |
| Beans | 19.5 g |
| Salmon | 19.0 g |
| Squid | 18.0 g |
| Anchovies | 17.0 g |
| Hake | 16.0 g |
| Sole, cereals | 15.0 g |
| Walnuts | 13.5 g |
| Eggs | 13.0 g |
| Pasta | 12.0 g |
| Brown bread | 9.0 g |
| White bread, condensed milk | 8.5 g |
| Rice | 8.0 g |
| Milk | 3.5 g |

Source: Muñoz & López Meseguer (1998).

when training sessions last for more than 3h, or in ultra-resistance competitions (Ecónomos *et al.*, 1993). Expressed in terms of total calorie intake, proteins should constitute 15 per cent, reaching 20 per cent in strength and speed athletes. Daily intakes exceeding 2–2.5 g/kg, so common in bodybuilding, do not appear to provoke an increase in body mass nor muscular strength (Lemon, 1995), although adequate strength training would serve this purpose (Girard, 2000; Roy *et al.*, 2000). Moreover, such an elevated protein intake could potentially lead to altered calcium levels, as well as hepatic and kidney overload.

The oxidation of proteins provides 3–18 per cent of the energy consumed during prolonged physical effort (Decombaz *et al.*, 1979), especially once glycogen reserves have been used up.

Table 1.5 contains some common foods containing elevated protein content per 100 g.

### *1.3.2 Micronutrients*

Micronutrients comprise vitamins and minerals. Their main functions are regulatory and they provide no energetic value. In developed countries, the majority of micronutrients are met through the diet, although some situations demanding higher intakes (sport, pregnancy . . .) can produce deficiencies. Consequently, the use of vitamin and mineral supplements amongst sportspeople is very common.

*Vitamins* Vitamins are organic substances required by the organism in very small amounts in order to carry out specific functions. The discovery of the 13 essential vitamins for the organism culminated in 1941 with the recognition of folic acid as being essential (Bässler *et al.*, 2002).

Vitamins are usually classified as fat-soluble or water-soluble. Fat-soluble vitamins include vitamins A, D, E and K. These are stored in body tissues, principally in the liver, and excessive intakes can produce cellular damage in the liver, kidneys and heart. Water-soluble vitamins include the B group vitamins and vitamin C. These are not stored within the body and in the case of excessive ingestion can usually be eliminated through the urine. However, if the organism is unable to eliminate the B group vitamins, an overload can lead to numbness, altered movement or even limb paralysis; and in the case of vitamin C, the consequences may include gastroenteritis, diarrhoea, colitis and kidney stones.

An adequate and varied diet should cover all the body's vitamin requirements. Nevertheless, in certain circumstances, such as defective absorption, or excessive expenditure, vitamin deficiencies may appear, provoking negative effects on sports performance. Therefore, in some cases, an increased ingestion of vitamins is justified, whether this implies altering the diet or complementing it with vitamin supplements. For example, in weight division sports (wrestling, horse riding, etc.), or those requiring low weight for successful performance (gymnastics, dancing, etc.), it may become necessary to complement the normal diet with extra vitamin supplements. Moreover, given their important role in producing haemoglobin and red blood cells, a combined iron and vitamin C supplement may be required by female athletes who suffer from heavy menstruation (vitamin C facilitates the absorption of iron into the body).

Table 1.6 describes the fat-soluble and water-soluble vitamins, the body's daily vitamin requirements, and the foods rich in each (Arnhein, 1994).

The consumption of certain vitamins may prove insufficient for some elite sportspeople (Burke & Read 1993; Mataix 1992), who suffer more easily from the most common vitamin deficits than the non-sporting population. The most widespread deficiency is a lack of the B group vitamins, especially in low-calorie diets (Delgado, 1998). Administering vitamin supplements has not yet been proved to improve physical performance (Burke & Read 1993; Williams 1995). Nevertheless, a lack of any vitamin almost certainly heeds sports performance (principally vitamin B1 and vitamin C) (Belko *et al.*, 1983).

*Minerals* Around 5–6 per cent of the organism is made up of minerals. The main dietary mineral elements may be classified in two groups:

- *Macronutrients*: calcium, magnesium and phosphorus. These must be ingested on a daily basis in relatively large amounts.

**Table 1.6** Vitamin requirements and corresponding food sources

| Fat-soluble vitamins | Requirements | Food sources |
|---|---|---|
| A | | |
| Pro-vitamin A (β carotene)<br>Vitamin: Retinol | Male adult: 1000 μg<br>Female adult: 800 μg<br>Children:400–1000 μg | Liver, cream, butter, whole milk, egg yola, green and yellow vegetables, yellow fruit, enriched margarine |
| D | | |
| Pro-vitamins: ergosterol, 7-dehydrocholesterol<br>Vitamins: D2 and D3 | 5–10 μg | Enriched milk, enriched margarine fish oils, sunlight on the skin |
| E | | |
| Tocopherol | Adults: 8–10 mg<br>Children: 3–10 mg | Vegetable oils |
| K | | |
| K1<br>K2<br>K3 | Adults: 65–80 μg<br>Children: 15–65 μg | Cheese, egg yolk, liver, green leafy vegetables |
| **Water-soluble vitamins** | **Requirements** | **Food sources** |
| Thiamine (B1) | 1.1–1.5 mg | Pork, beef, liver, whole or integral seeds, pulses |
| Riboflavin (B2) | 1.2–1.7 mg | Milk, liver, pulses, fruits |
| Niacin (nicoinic acids, nicotinamide), vitamin B3 | 15–19 mg | Meat, peanuts, integral cereals |
| Vitamin B5 | 4–7 mg | Liver, eggs, milk, integral cereals |
| Vitamin B6 | 1.6–2.0 mg | Corn, wheat, meat, liver, eggs, fish |
| Biotin, vitamin B8 | 30–100 μg | Egg yolk, liver, meat and fish |
| Folic acid – B9- | Adults: 150–180 μg<br>Children: 50–180 μg | Liver, green leafy vegetables |
| Vitamin B12 | 2.0 μg | Liver, meat, dairy products, eggs, cheese |
| Ascorbic acid (vitamin C) | 60 mg | Citrus fruits, vegetables |

Source: Arnhein (1994).

- *Micronutrients* or *oligoelements*: iron, iodine, cobalt, copper, fluoride, manganese, and zinc. These elements are required in much smaller quantities.
- *Electrolytes*: including sodium ($Na^+$), potassium ($K^+$) and chlorine ($Cl^-$).
- *Trace elements*: these exist, and are required, in tiny quantities, e.g. selenium, molybdenum.

Iron plays a vital role in maintaining the system responsible for transporting oxygen around the body and assists the body's capacity to conduct muscular work. It is the most commonly lacking mineral in the diet of the general population, especially amongst women. Anaemia, produced through an iron deficiency, the most frequent in female athletes, has negative repercussions on physical performance (Hinton *et al.*, 2000), particularly in resistance activities (Malczewska *et al.*, 2000). Various factors contribute to an iron deficiency and a reduction in haemoglobin levels in athletes, including: profuse sweating, abundant menstrual flow, reduced iron absorption in the digestive system, an increase in the destruction of red blood cells due to mechanical trauma, low iron consumption, etc. It is important to highlight a true anaemia termed *pseudo-anaemia*, shown by some athletes (Newhouse & Clement, 1990), which is caused by an increase in plasma volume linked to physical activity itself. On the other hand, when there is an iron deficiency (inadequate intake and absorption), it becomes important to boost iron levels through the diet, and when this measure proves insufficient, with iron supplements under medical supervision.

Another important element is calcium. The human body contains approximately 1200 g of calcium, of which 99 per cent forms part of the skeletal system and 1 per cent is contained in intra- and extracellular fluids. This small proportion represents the metabolically available reserve. As with iron, when calcium intake is reduced, the plasma levels are maintained at the expense of a reduced absorption rate into the bones. Hence, the plasma levels are never a true indicator of the state of calcium reserves. During physical exercise, calcium plays an important role in muscular contraction. Its intake depends on the diet, the consumption of calcium-rich foods, as well as the total energy and nutrient intake. Although physical exercise has a stimulating effect on bone mineral density, female athletes with low-energy diets or those engaged in weight loss programmes can suffer amenorrhoea and low bone density, accompanied by an increased risk of stress fractures (Beshgetoor *et al.*, 2000).

### *1.3.3 Water*

Water is the main component of the human body, constituting 50–70 per cent of total body weight (2/3 intracellular water and 1/3 extracellular water). It is the principal substance in metabolic processes (it transports oxygen, nutrients, and hormones; assists the dissipation of internal heat, determines arterial tension and the cardiovascular function). A decrease in body water of just 20 per cent can cause death (Delgado *et al.*, 1999). In order to maintain the daily balance of water in the organism, intake should be equivalent to loss. A daily liquid intake of 1 ml per calorie spent is recommendable (Del Castillo, 1998a). For example, if an individual spends 3000 kcal/day, the suggested water intake is 3 litres.

During physical exercise, and especially in conditions of extreme heat, the body protects itself from overheating through the evaporation of sweat. During this process, a large quantity of liquids and electrolytes are lost, more so in humid atmospheres, and in order to avoid dehydration, athletes must replace these through the consumption of water, juices or isotonic and hypotonic drinks. The quantity of liquid lost through sweating can range from hundreds of millilitres to over 2 litres per hour. In competition, high-resistance athletes, such as those participating in ultra-marathons, present the most significant weight loss through dehydration (Noakes *et al.*, 1988). However, playing other sports such as football can also produce significant liquid losses (Maughan & Leiper, 1994). The degree of liquid reduction depends on various factors: age, sex, climate and acclimatization, level of training, exercise intensity, and body surface area (the number of active sweat glands).

Dehydration increases the muscle temperature, which in turn increases the use of glucose in the muscles, favouring a reduction in the generation of free fatty acids (González-Alonso *et al.*, 1997). Body temperatures above 41°C can cause death.

The effects of advanced dehydration (–4 per cent of body weight) cause the lactic threshold to appear prematurely at lower exercise intensities, accelerating the appearance of fatigue (Kenefick *et al.*, 2002). However, despite this being common knowledge, a recent study (Gonzalez-Gross *et al.*, 2001) showed that approximately 32% of athletes do not drink anything at all during training sessions.

**Figure 1.3**

The more evident symptoms of dehydration, such as having a dry mouth, appear once 3% of fluids have been lost; a fluid loss of 4 per cent produces a 20–30 per cent reduction in physical capacity (Greenleaf, 1992). Nonetheless, an adequate liquid intake in athletes engaged in training or competition serves to prevent the emergence of dehydration-related fatigue (Sawka *et al.*, 1984). Based on these facts, the following guidelines are recommended before, during and after a competition (modified from American College of Sports Medicine (ACSM), 2000):

- Two hours beforehand: drink 500 ml of water, isotonic drinks or juices.
- 5–10 minutes beforehand: drink 200 ml of water.
- During: for competitions lasting less than an hour, the fluid intake rhythm should be 200 ml per 15–20 minutes; in competitions lasting 1–1.5 hours, 150 ml per 15 min; and in competitions lasting over 3 hours, 200 ml per 20 min. The composition of the liquid ingested should include 0.5–0.7 g/litre of sodium, and 1.1 g of carbohydrates per kg of body weight, per hour.
- Whenever possible, the liquid ingested should contain 5–7.5 per cent carbohydrates per 100 ml of water, since they have a similar gastric emptying rhythm to water (Epstein & Armstrong, 1999; McArthur & Feldman 1989; Maughan & Noakes, 1991; Maughan, 1993; Taylor *et al.*, 1999).
- The temperature of the drink should be cold (between 7 and 13°C)
- Liquids should be consumed before the sensation of thirst appears, in order to maintain hydration.
- Immediately after each competition it is advisable to drink 500 ml of water, or a carbohydrate-rich drink (isotonic drink or diluted juices), continuing with 250 ml every 15 min. The quantity of liquid consumed should equal the weight loss produced through exercise.
- Post-competition hydration can be improved by consuming foods rich in water (fruit, vegetables, salads, soups).

Specialists affirm that an adequate pre-competition diet does not compensate for an inadequate one during the prolonged training process (USOC, 1998). Therefore, athletes must be nutritionally aware and maintain these basic ‘nutritional rules’ throughout the training cycle, not just prior to an important competition.

## 1.4 Ergogenic aids

Ergonic assistance is defined as any method (nutritional, physical, mechanical, psychological or pharmaceutical) used to improve the body’s capacity to carryout a determined physical effort or to enhance overall sports performance (McArdle *et al.*, 1991). In competitive sport, involving heavy training and competitive workloads, it is logical for athletes to use legal and harmless ergogenic aids to counteract the potential nutritional deficiencies produced through such intensive physical efforts. However, this should always be done under medical supervision. Nevertheless, in recreational sport, a balanced and varied diet, sufficient in calories and nutrients, should be enough to cover the additional demands of physical activity. Approximately 50 per cent of the general population have reported taking some form of dietary supplements, while 76 to 100 per cent of athletes in some sports are reported to use them (Ahrendt, 2001).

With the exception of caffeine, creatine, sodium bicarbonate, carbohydrates and the correct hydration in situations of caloric stress, few nutritional supplements have been proved to be effective (Burke *et al.*, 2000). Moreover, the World Anti-Doping Agency (WADA) prohibits none of the aforementioned substances.

Creatine is a combination of amino acids and is found in animal food sources. Additional intake and the organism's own capacity to produce creatine serve to replenish the body's phosphor-creatine reserves (95 per cent in the muscular cells). A supplement of 20–25 g per day, during 5–7 days, has been proved to effectively increase the amount of creatine in the muscles (Maughan, 1995, Kreider *et al.*, 1998), as well as improving performance in short intermittent physical effort (Balsom *et al.*, 1993; Greenhaff, 1995). Its most common side effect is fluid retention, frequently causing body weight to rise by 1–3 kg. Juhn (2003) indicates that creatine is ergogenic in repetitive anaerobic cycling sprints but not in running or swimming.

Caffeine is a methylxanthine, which produces stimulating effects on the central nervous system, increasing an individual's alertness (Clarkson, 1993). An additional supplement of 3–9m g/kg does not produce any noticeable side effects, except in cases of gastrointestinal intolerance. What is more, caffeine produces the following ergogenic effects: greater resistance to fatigue (Graham and Spriet, 1991; Spriet 1995), enhanced performance in certain aerobic activities (Juhn, 2003) and in short sports events (Wiles *et al.*, 1992). In sports carried out in hot conditions, it is important to consider the diuretic effects of caffeine. Positive effects may be noted on performance by taking a dose of 1.4–2.7 mg of caffeine per 0.453 kg, 1–2 h prior to the physical effort. Therefore, a 79 kg man will need 245 to 472 mg of caffeine. This level can be obtained by drinking 680 g of tea or two cups of coffee (Michela, 2007). Caffeine is found naturally in chocolate, coffee, and tea, and is frequently added to foods such as soft drinks (Table 1.7).

**Table 1.7** The average amount of caffeine in beverages

| Beverage | Average caffeine (mg) |
|---|---|
| Coffee, brewed, drip method, 8 ounces (0.24 l) | 165 |
| Coffee, instant, 8 ounces (0.24 l) | 95 |
| Tea, 10 ounces brewed (0.30 l) | 80–120 |
| Iced tea, 12 ounces (0.35 l) | 70 |
| Hot cocoa, 8 ounces (0.24 l) | 5 |
| Diet Pepsi | 35 |
| Pepsi Cola | 40 |
| Coca-Cola | 45 |
| Diet Coke | 45 |

Source: Michela (2007).

Given its capacity to neutralise the pH of lactic acid, sodium bicarbonate is used in high intensity physical effort lasting 1–10 min, which produce high quantities of this substance in the muscles (Bouissou *et al.*, 1988; Matson & Tran, 1993). Some of the mild side effects, such as diarrhoea or nausea, can be avoided by using sodium citrate (McNaughton & Cedaro, 1992).

Other ergogenic aids, whose benefits have not been proved scientifically, include: amino acids, arginine, ornithine and lysine, as well as antioxidants and hydroxyl-methyl-butyrate. A wide range of supplements, which have not been scientifically tested, are freely available, such as ginseng, chromium picolinate, carnitine, coenzyme Q10, inosine, or medium-chain triglycerides (Burke *et al.*, 2000). In order to avoid the abusive use of these legal substances, which on rare occasions contain illegal ingredients, such as hormones and/or precursors of anabolic steroid hormones, athletes should always follow the guidance of a sports doctor and/or nutritionist, who is fully aware of their nutritional requirements and is qualified to recommend the use of such ergogenic aids.

## 1.5 The need for nutritional information for athletes

In many cases, the much-needed nutritional control for athletes is non-existent. Along the road to high performance, athletes adapt their diets according to the 'advice' they acquire from the sporting context itself, which as will be seen in the corresponding chapter, is not always adequate. Nutritional guidance is vital to prevent eating disorders, and coaches and parents should know it (Gilbert, 2005).


**Figure 1.4**

Nutritional guidance is absolutely necessary throughout an athlete's sports career, even more so once submitted to the demands of elite competition, where carelessness in the nutritional aspect can be enough to provoke periods of low performance. Therefore, it is recommended that coaches, who usually constitute the main reference point for athletes (given the lack of economic resources in the majority of cases), have the adequate knowledge of the basic nutritional requirements of their athletes, applying it accordingly and consulting with the relevant professionals where necessary.

In a previous study (Dosil, 2003), a survey was conducted with nine of the most practised sporting disciplines in Europe, in which athletes were asked about the degree of nutritional information they had received throughout their sports career. The results of this survey are detailed in Table 1.8.

In general terms, and in light of these results, the lack of nutritional information in the majority of sports may be highlighted. Two-thirds of the sportspeople surveyed had not received any information about nutritional aspects, a worrying statistic considering how important it is for athletes to follow an adequate diet. This apparent shortfall of information is similar to that encountered by Dosil (2000) in a survey with 267 athletes participating in aerobics, athletics, basketball, judo, physical conditioning, rugby and taekwondo. This study showed how 56.8 per cent of subjects claimed to have received no nutritional guidance of any sort. Focusing further on the results in Table 1.8, it may be noted that rhythmic gymnastics obtained the worst results in terms of nutrition-related guidance. This result proves somewhat contradictory to the participatory predominance of very young athletes, in a sport characterised by its strict aesthetic criteria, which provokes a tendency towards eating disorders. Other sporting disciplines such as athletics, basketball, bodybuilding or swimming also present some elevated results, reflecting a more general lack of information. Nevertheless, in those cases where athletes had received some form of nutritional guidance, it is important to identify where this came from. Dosil (2000) forms the following conclusions:

**Table 1.8** The degree of nutritional information received by athletes in different sports

| Sport | No information received (%) | Information received at some point (%) |
|---|---|---|
| Football | 58.7 | 41.3 |
| Swimming | 69.2 | 30.8 |
| Judo/wrestling | 62.7 | 32.8 |
| Aerobics | 59.1 | 40.9 |
| Athletics | 72.5 | 27.5 |
| Basketball | 72.1 | 27.9 |
| Rhythmic gymnastics | 79.2 | 20.8 |
| Body building | 77.8 | 22.2 |
| Rowing/canoeing | 50 | 50 |
| Total | 66.8 | 33.2 |

- In all of the sports studied, the coach/monitor provides the most nutritional guidance to athletes. Sherman *et al.* (2005) support this statement, indicating how the coach plays a fundamental role in identifying and managing athletes with disordered eating.
- Doctors/nutritionists are not usually active in grass-roots sport, and few athletes resolve their nutritional doubts with the help of the adequate professionals.
- Families (parents and siblings) have more influence over eating habits in fitness sports such as aerobics, whilst in other disciplines; it is the coach who provides the most nutritional guidance.
- Although relatively low, other individuals/sources appear to have some influence over athletes' nutrition: books, television, the Internet, partners, psychologists, conferences, etc.

## 1.6 Conclusions

Together with physical, technical and psychological capabilities, nutrition is fundamental for adequate sports performance. The incorporation of nutritionists and/or sports doctors in teams and clubs, and the consequent elaboration of personalised diets, would constitute an important achievement, undoubtedly improving the health of athletes and increasing their performance.

Advances in physical activity and sports science have brought to light a series of conditioning aids, which have lacked the deserved recognition in the past. Old beliefs, still rife in some sectors of sport, that defend the principle that what makes athletes perform better is hard work and physical repetition, have been dismissed, opening the doors to new concepts of more integrated training methods.

Specialists in this field agree that in order to reach peak performance, an exhaustive multi-faceted preparation is required. The degree of professionalism in sport is increasing, demanding more hours of competition preparation. Part of this process includes so-called 'invisible training', which refers to the variables affecting and complementing physical training. Hence, nutrition, rest, or social relationships, etc. have been proved to have a direct effect on training and competition performance. Therefore, it is imperative for athletes and coaches alike to attend to these aspects, increasing their awareness where relevant and avoiding the potential consequences of neglecting them.

Inadequate diets or eating-related disorders negatively affect sports performance and what is worse, the lives of athletes. Informing about these issues, with a view to preventing and eradicating these problems, represents the ultimate aim of this publication.