Here we’ll review six classes of nutrients important to all athletes: carbohydrate, protein, fat, vitamins, minerals, and water. Three of these nutrients—carbohydrate, protein, and fat—provide energy to fuel activity. The amount of energy needed will vary depending on the athlete’s training and competition schedules. Appropriate energy intake goes hand in hand with appropriate carbohydrate, protein, fat, and alcohol intake.

### THE SIX CLASSES OF NUTRIENTS

Within the context of appropriate energy intake, all athletes should focus on daily carbohydrate intake. An adequate amount of carbohydrate is necessary every day and it is important for athletes to resynthesize glycogen used during exercise before the next training period begins. In addition to the amount of carbohydrate needed, timing of carbohydrate intake is important. For example, carbohydrate consumed during prolonged exercise can be beneficial to performance and a particular carbohydrate food, such as one with a high glycemic index, may be beneficial during recovery. Consuming the right amount of carbohydrate at the right time can be tricky business.

The amount and timing of carbohydrate intake are important factors in improving training and performance.

The amount of protein recommended depends on if the athlete is predominantly endurance trained or strength trained. Athletes need more protein than nonathletes do but not as much as they sometimes imagine. Carbohydrate and protein intakes determine how much fat should be consumed. Fat intake for athletes is usually, but not always, lower than for the general population who are not trying to lose weight. It’s important for athletes to achieve and maintain energy balance. Without overconsuming, they must eat enough carbohydrate, fat, and protein to provide the fuel needed for training and performance.
Vitamins and minerals are essential nutrients that play many roles in the body. Athletes can get sufficient vitamins and minerals from food if they make the right choices. A vitamin or mineral deficiency can hamper performance; altering food intake or consuming a supplement can help athletes reverse the deficiency.

One of the most important nutrients is water. Preventing hypohydration (an insufficient volume of water) is critical for training and performance. Some strength-trained athletes are fine consuming just water, but many endurance athletes benefit from sports beverages that provide the water, carbohydrate, and electrolytes they need to sustain hours of exercise.

An athlete’s diet is generally higher in carbohydrate and lower in fat, moderate in protein, and adequate in fluid and total energy. Many foods contain more than one nutrient, and meeting the recommended amounts requires an integrated approach to diet planning. For example, focusing on dietary protein might lead an athlete to consume a high-protein food that is also high in fat. On the other hand, too great a focus on carbohydrate might result in a diet too low in protein or fat. Sports beverages can be an efficient way to consume both carbohydrate and fluids but over-consumption may lead to too great of a caloric intake. In any case, athletes must get a sufficient amount of energy through their diet. When energy intake is too low, vitamin and mineral intake is usually too low. The key is to obtain all the nutrients needed in the proper proportions within the desired caloric intake.

**Energy**

Carbohydrate, protein, fat, and alcohol are all sources of energy. When these nutrients are consumed, digested, absorbed, and metabolized, the energy becomes available for use by the body. The energy is either used immediately or stored for future use. The scientifically correct terms for the measurement of energy are *Calorie* (capitalized) or *kilocalorie*, but in this text (as in most texts), the more common term calorie is used.

For many people, including some athletes, the term *calorie* carries a negative connotation because it brings to mind weight gain. Athletes should think of energy and calories as positive terms, as energy is needed to fuel activity. Athletes who do not take in sufficient energy run the risk of consuming too few nutrients and seeing their performance decline. However, excess energy intake over time is also not desirable because of the impact excessive body fat may have on training and performance.

Athletes often ask, “How many calories do I need?” Unfortunately, there’s no simple answer to this question. Many factors influence energy balance, including age, gender, body composition, metabolic rate, tissue growth, and the intensity and duration of activity. Table 1.1 compares and contrasts the general energy needs of different groups of people, including sedentary adults, recreational athletes, and endurance- and strength-trained athletes. Since every person is different, we can’t know the exact energy requirements for any individual, but the estimates provide a reasonable guideline. These estimates are for daily energy intake needed to maintain body weight. Notice that some of the ranges are large to accommodate for the substantial differences in energy expenditure due to the intensity and duration of training. The upper ends of the range are associated with the highest levels of training and apply to relatively few athletes.

The intensity and duration of training and the amount of energy used to play a particular sport must be considered when fine-tuning the general recommendations to meet the needs of an athlete in a specific sport. Some sports,
such as baseball, do not require a high-energy expenditure. Other sports, such as professional basketball and distance cycling, are extremely high-energy sports. Training also varies within a sport. Professional and elite amateur athletes train at greater intensity, volume and/or duration than others in the same sport. Endurance athletes expend a large amount of energy in their daily training and in the performance of their sport. Distance cyclists and triathletes may need energy intake in excess of 50 calories per kilogram of body weight per day to maintain body composition. However, some endurance athletes, such as distance runners, restrict energy intake in an effort to attain or maintain a low percentage of body fat. While it may be advantageous in distance running to be a low percentage body fat (extra body fat increases body mass but not power), it is a disadvantage if the athlete does not consume enough energy to fuel training, maintain muscle mass, and receive an adequate amount of nutrients.

Athletes who engage in “stop and go” sports such as basketball or soccer may also need a high calorie intake to match the long hours of training and the demands of competition. Soccer players may cover 8 to 12 km (~5 to 7 miles) during the course of a game, although they are not running continuously.

Strength-trained athletes also may need a large amount of energy. For example, male bodybuilders perform resistance training for several hours each day, and the energy needed to support their large amount of muscle mass is substantial. On the other hand, bodybuilders may reduce energy intake to 30 calories per kilogram of body weight per day as they prepare for a contest and try to reduce body fat. Wrestlers’ energy intakes may be reduced in an effort to make a particular weight category. Energy intake likely changes over the course of the pre-season, competitive season, and post-season.

The general guidelines must be refined to meet the goals of the athletes considering the demands of their sport. Adjustments are made for age, gender, extent of muscle mass, rate of metabolism, growth of muscle, and the intensity and duration of exercise. For example, a 35-year-old female who is maintaining muscle mass and whose metabolic rate is beginning to slow will require less energy than a 20-year-old female who is increasing muscle mass and likely has a higher resting metabolic rate. Each individual must determine the caloric intake that maintains current body composition.

Meeting energy needs should be a top priority for all athletes. Those who chronically consume too little energy often consume too few nutrients, which leads to poor performance. Athletes with daily energy intakes near the bottom end of the guidelines should be particularly cautious. Sports in which some athletes routinely report low energy intakes include figure skating, women’s gymnastics, distance running, swimming, and wrestling. Those who restrict

### Table 1.1 Daily Energy Intake Recommendations

<table>
<thead>
<tr>
<th>Group</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary men and nonpregnant women</td>
<td>Approximately 14 calories per pound or 31 calories per kilogram* of body weight</td>
</tr>
<tr>
<td>Male and nonpregnant female recreational athletes</td>
<td>Approximately 15-17 calories per pound or 33-38 calories per kilogram* of body weight. Needs vary based on body composition and intensity and duration of activity.</td>
</tr>
<tr>
<td>Endurance-trained athletes</td>
<td>35-50+ calories per kilogram* of body weight. Needs vary based on the specific sport and training regime.</td>
</tr>
<tr>
<td>Strength-trained athletes</td>
<td>30-60 calories per kilogram* of body weight. Needs vary based on the specific sport and training regime.</td>
</tr>
</tbody>
</table>

*To convert weight in pounds to weight in kilograms, divide weight in pounds by 2.2. Example: 121 pounds divided by 2.2 kilograms per pound = 55 kilograms.
energy should work closely with a sports dietitian to plan nutrient-rich diets. A low-energy, low-nutrient diet puts athletes at risk for loss of muscle or bone mass, inability to increase muscle or bone mass, menstrual irregularities, fatigue, injury, and illness.

### Carbohydrate

Carbohydrate forms the cornerstone of the exercise nutrition foundation. For optimal training and performance, an athlete must consume enough carbohydrate. Exercise depletes both muscle and liver glycogen stores, and dietary carbohydrate is needed daily to replenish them. A **minimum** of 5 g of carbohydrate per kilogram of body weight daily is recommended to replenish enough muscle glycogen to exercise on consecutive days. However, 6 to 10 grams of carbohydrate per kilogram of body weight per day is recommended for athletes in training so muscle glycogen is fully restored and near maximum levels can be maintained. Carbohydrate recommendations are summarized in table 1.2 (daily total energy intakes are assumed to be adequate).

The range is narrowed based on the intensity and duration of the training. For example, male athletes who train hard (75% of VO2max) for two to three hours per day require 8 to 10 grams of carbohydrate per kilogram of body weight daily. This is true for both strength and endurance athletes, as both types of exercise deplete muscle glycogen. Female athletes who train at this level should consume 6 to 8 grams of carbohydrate per kilogram of body weight daily. The lower carbohydrate intake for women reflects their lower energy needs compared to those of men. If carbohydrate intake were 10 g/kg daily, these females would have difficulty meeting their protein and fat needs and would have little room for dietary flexibility. Athletes who train for shorter periods of time can restore muscle glycogen with a moderate carbohydrate intake (i.e. 5 to 7 g/kg/day).

**6 to 10 grams of carbohydrate per kilogram of body weight daily is recommended for athletes in training.**

Carbohydrate recommendations are sometimes expressed as a percentage of total energy intake. You may read that the athlete’s diet should contain 60 to 70% carbohydrate. Such recommendations are accurate in many cases but

<table>
<thead>
<tr>
<th>Group</th>
<th>Energy</th>
<th>Carbohydrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary men and nonpregnant women</td>
<td>Approximately 14 calories per pound, or 31 calories per kilogram of body weight</td>
<td>45 to 65% of total energy intake, assuming energy intake is adequate</td>
</tr>
<tr>
<td>Male and nonpregnant female recreational athletes</td>
<td>Approximately 15-17 calories per pound, or 33-38 calories per kilogram of body weight (needs vary based on body composition and intensity and duration of activity)</td>
<td>55 to 60% of total energy intake, assuming energy intake is adequate</td>
</tr>
<tr>
<td>Endurance-trained athletes</td>
<td>35-50+ calories per kilogram of body weight (needs vary based on the specific sport and training regime)</td>
<td>6 to 8 grams per kilogram of body weight daily; 8 to 10 g/kg during heavy training and competition. Ultra-endurance athletes typically require a minimum of 8 g/kg during training and need substantially more than 10 g/kg during intense training and competition</td>
</tr>
<tr>
<td>Strength-trained athletes</td>
<td>30-60 calories per kilogram of body weight (needs vary based on the specific sport and training regime)</td>
<td>5-7 grams per kilogram typically adequate for high intensity, short duration training; 8-10 g/kg may be needed to support prolonged training</td>
</tr>
</tbody>
</table>
they can be misinterpreted. Percentages are always distorted when energy intake is low, as shown in figure 1.1. In this figure, the gymnast consumes 70% of her total energy intake from carbohydrate, but she is actually receiving less than the minimum amount of carbohydrate recommended. Because athletes’ body sizes and energy intake vary widely, carbohydrate needs are best based on grams per kilogram of body weight rather than percentage of total energy intake. Consumer recommendations are typically given as a percentage of total energy intake and the current recommendation in the U.S. is 45 to 65 percent of total calories from carbohydrates.³

Because training depletes muscle glycogen stores (see figure 1.2), athletes need to focus on obtaining enough carbohydrate each day. Let’s consider two athletes, Andy and Bill, who begin training with adequate muscle glycogen. After a two-hour training session, approximately half of their muscle glycogen has been depleted. After training, Andy consumes an adequate-energy, high-carbohydrate diet (70% of total energy intake as carbohydrate was the level reported in the study), and muscle glycogen is nearly restored to original

<table>
<thead>
<tr>
<th>Recommended intake</th>
<th>Actual intake</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrate: 294 grams</td>
<td>Carbohydrate: 210 grams</td>
</tr>
<tr>
<td>(6 grams of carbohydrate per kilogram of body weight)</td>
<td>(4.3 grams of carbohydrate per kilogram of body weight)</td>
</tr>
<tr>
<td>Energy intake: 1715 calories per day</td>
<td>Energy intake: 1200 calories per day</td>
</tr>
<tr>
<td>(35 calories per kilogram of body weight)</td>
<td>(24.5 calories per kilogram of body weight)</td>
</tr>
<tr>
<td>Percent energy intake as carbohydrate: 68.5%</td>
<td>Percent energy intake as carbohydrate: 70%</td>
</tr>
</tbody>
</table>

Figure 1.1 How percentages can be deceiving.
levels. Meanwhile, Bill consumes an adequate-energy, low-carbohydrate diet (40% of total energy intake as carbohydrate), which does not provide his body with enough carbohydrates to adequately resynthesize muscle glycogen. On the second day of training, carbohydrate stores are again depleted by exercise. Andy’s high-carbohydrate diet provides enough carbohydrate to help replenish muscle glycogen, but Bill’s diet does not. Andy has sufficient glycogen to continue training. But, after three days of low carbohydrate intake, Bill’s muscle glycogen stores are perilously low, and he will likely feel fatigued or “stale.”

Note in figure 1.2 that even with a high-carbohydrate diet, three days of training results in less muscle glycogen than when training started. Muscle glycogen can be restored to near optimal levels by reducing exercise (a rest day or a light workout) and increasing carbohydrate (modified carbohydrate loading). Carbohydrate loading will be discussed on page 48.

Food sources of carbohydrate include breads, cereals, rice, pasta, fruits, vegetables, dried peas and beans, milk, nuts, and sugar. With the exception of sugar and fruits, these foods also provide some protein. Sports drinks, bars, and gels are sources of carbohydrate marketed to athletes and these forms may be convenient to consume. However, athletes are also encouraged to eat plenty of fruits,
vegetables, and minimally processed whole grains as these foods contain many nutrients in addition to carbohydrate. While proper intake of carbohydrate is extremely important, athletes also need to consume the right amount of protein.

**Protein**

The protein needs for athletes in training are higher than those for sedentary people but not as high as some athletes imagine. Table 1.3 illustrates the recommended range for protein needs for several groups. The Dietary Reference Intake (DRI) for sedentary adults is 0.8 grams of protein per kilogram of body weight daily. Recreational athletes need the same or slightly more than non-athletes (~1.0 g/kg/day). In contrast, daily protein recommendations for most athletes range from 1.2 to 1.7 g/kg (assuming energy intake is adequate). Recommendations for ultraendurance athletes may be as high as 2.0 g/kg/day. Higher intakes have not been shown to enhance training or performance.\(^1\)

**1.2 to 1.7 grams of protein per kilogram of body weight daily is generally recommended for athletes in training.**

Everyone must consume an adequate amount of amino acids (proteins) and energy for maintenance of body tissues. Growth requires additional protein and energy. Other than pregnancy, which supports the rapidly growing fetus, the most important growth state for the adult athlete is usually an increase in muscle mass. Once increased muscle mass and strength have been attained, the amount of protein and energy needed for maintenance is less than what was needed for growth.

Invariably, training and nutrition go hand in hand. Athletes wishing to increase muscle size and strength must perform resistance exercise and consume enough protein (and energy) for muscles to grow. The increase in the

<table>
<thead>
<tr>
<th>Table 1.3 Daily Protein Intake Recommendations</th>
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<tbody>
<tr>
<td><strong>Group</strong></td>
</tr>
<tr>
<td>Sedentary men and nonpregnant women</td>
</tr>
<tr>
<td>Male and nonpregnant female recreational athletes</td>
</tr>
<tr>
<td>Endurance-trained athletes</td>
</tr>
<tr>
<td>Strength-trained athletes</td>
</tr>
</tbody>
</table>
number and size of muscle fibers is one adaptation for which protein plays a supporting role. Resistance training forces muscles to adapt to the stress of exercise. After resistance training is completed, muscle cells begin to increase protein synthesis.

An important area of research is the timing of protein intake after exercise. The first 1 to 2 hours after exercise (the “anabolic window”) is a time when glycogen stores are replenished and protein anabolism takes place. Although the details are still being studied, research has shown that it is advantageous to consume some amino acids immediately after exercise. These amino acids could be in the form of protein foods (e.g. chicken), protein-containing beverages (e.g. milk), or amino acid infusions.\(^5\)

**Resistance training, dietary protein, and sufficient energy intake are needed for muscle growth.**

Prolonged endurance exercise also affects protein metabolism but in a different way. When athletes engage in endurance exercise, muscle glycogen levels become depleted, and the onset of fatigue is inevitable. The body attempts to delay fatigue by using alternative fuel sources. Three amino acids—leucine, isoleucine, and valine—are oxidized and used to fuel the exercise. These amino acids, known as branched-chain amino acids because of their chemical structure, play an important role in providing energy for the body when muscle glycogen stores have been depleted by endurance exercise. The increased usage of these amino acids is one reason why the protein recommendation for ultraendurance athletes may be as high as 2.0 g/kg.\(^6\)

If energy intake is insufficient over a prolonged period of time, such as many months, muscle protein can be broken down to provide energy. Athletes should avoid this situation because the functionality of the muscle will be affected by the loss of protein. Consuming enough carbohydrate and fat will spare body protein from being used for energy. The nutrition goals are clear: an adequate amount of protein and sufficient energy daily.

Researchers conducting studies with resistance-trained athletes found that such athletes need higher levels of dietary protein than sedentary people to maintain positive nitrogen balance.\(^1\,^5\) The body must be in positive nitrogen balance to support growth, including muscle tissue growth induced by resistance training. Researchers also helped answer the obvious question: How much protein do athletes need? Optimal amounts varied from study to study, but recommendations below are supported by scientific evidence and consider the demands of training.

- Generally, athletes performing in endurance-focused sports need 1.2 to 1.6 grams of protein per kilogram of body weight per day. Endurance athletes who lift weights to increase strength and muscle should consume protein at the higher end of this range.
- Athletes in predominantly strength-focused sports need 1.4 to 1.7 grams of protein per kilogram of body weight per day. An athlete in a sport where maximum muscle mass and strength are goals (such as bodybuilding or weightlifting) would use the higher end of this range. The higher end of the range is also recommended to athletes who are restricting energy intake.
- There is no evidence that protein intake higher than the amounts mentioned above (for example, 2.5 g/kg/day) accelerates the rate of muscle protein synthesis.
Nutrients Needed for Training and Performance

• For athletes with normal kidney and liver function, the intake of high protein diets (2.0 to 2.8 g/kg/day) does not appear to have short-term harmful effects. The long-term effects of high protein diets on kidney disease are not known.\(^7\)

_The recommended protein intake for strength-focused athletes is 1.4 to 1.7 grams of protein per kilogram of body weight daily._

Athletes do not need excessive amounts of dietary protein. In the United States and other developed countries, it is not difficult to get enough protein. A 160-pound (72.7 kilograms) sedentary adult needs about 58 grams of protein a day. An endurance athlete of the same weight needs at least 87 grams of protein, and a strength athlete of the same weight could need as much as 124 grams of protein. Four ounces of roasted chicken breast without the skin contains 35 grams of protein—that’s 60% of the protein needed for a 160-pound (72.7 kilograms) sedentary adult. With so many sources of protein to choose from—meat, poultry, fish, milk and milk products, eggs, nuts, dried peas and beans, and soy products—getting the recommended amounts of protein from food is easy. Those at risk for consuming too little protein are usually those who are cutting calories to attain or maintain a low body weight. Sports that pose the greatest risk for low protein intake are wrestling (during the season as a result of drastic reductions in caloric intake), distance running, and for female athletes, gymnastics, figure skating, and dance.

In addition to quantity of protein, quality must be considered. Protein quality is based on the quantity and proportion of amino acids present. Complete protein contains all the essential amino acids in proper quantities and proportions. Animal protein such as meat, fish, poultry, eggs, milk, and cheese are complete proteins, while most vegetable protein—rice, grains, beans—are not, though most soy products are exceptions. Thus, athletes who eat animal protein do not have to worry about protein quality. This includes lacto-ovo vegetarian athletes who choose not to eat meat but eat animal products such as milk and eggs.

Vegan athletes include no animal products in their diet and thus need to keep an eye on protein quality. Soy products are excellent choices, as most provide complete protein. Vegetable protein such as rice, grains, or beans lack one or more of the essential amino acids but can be combined with other vegetable protein to provide the missing essential amino acids. Beans and rice, tofu and rice, or peanut butter and wheat bread are examples of food combinations that provide complementary protein. Complementary vegetable protein needs to be eaten on the same day but not necessarily at the same meal. Ideally, a variety of vegetable protein should be consumed. The recommended protein guideline for vegan athletes is 1.3 to 1.8 grams of protein per kilogram of body weight per day. This slightly higher recommendation is based on the theory that plant protein digestibility is lower than animal protein digestibility.\(^8\)

Many strength athletes consume protein supplements either as pre-made protein drinks, protein powders that they make into drinks, or individual amino acid supplements. These supplements provide amino acids just as protein found in foods do. While protein supplements may be convenient, there is no evidence that they are superior to protein found in food.
Protein is but one important nutrient on a team of important nutrients. While protein supports growth and maintenance of tissue, especially muscle tissue, it can’t be used to build or maintain new tissue if intake of carbohydrate and fat is not adequate.

**Fat**

Fat is an important source of energy for the body, but eating too much fat may affect your health. To provide needed nutrients and reduce risk for chronic disease it is currently recommend that adults consume 20 to 35% of total energy intake as fat. This recommendation is based on many studies that show a relationship between cardiovascular disease and high levels of dietary fat, especially saturated fat. A high fat, high calorie intake, along with low levels of physical activity, has also contributed to a rapidly rising rate of obesity in the United States and other industrialized countries.

Athletes in training engage in high levels of physical activity and are not likely to be obese, but many are unsure how much fat they should consume. As a general rule, if an athlete is consuming sufficient energy, 20 to 25% of his or her total energy intake should be consumed as fat. This recommendation is slightly lower than the general population recommendation because it takes into account higher intakes of both carbohydrate and protein. Table 1.4 compares and contrasts daily fat recommendations. A diet containing 20 to 25% of energy intake as fat will provide essential fatty acids and a feeling of satiety

<table>
<thead>
<tr>
<th>Group</th>
<th>Energy</th>
<th>Carbohydrate</th>
<th>Protein</th>
<th>Fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary men and nonpregnant women</td>
<td>Approximately 14 calories per pound, or 31 calories per kilogram of body weight</td>
<td>45 to 65% of total energy intake, assuming energy intake is adequate</td>
<td>0.8 grams per kilogram of body weight</td>
<td>Not more than 30% of total energy intake</td>
</tr>
<tr>
<td>Male and nonpregnant female recreational athletes</td>
<td>Approximately 15-17 calories per pound, or 33-38 calories per kilogram of body weight (needs vary based on body composition and intensity and duration of activity)</td>
<td>At least 55% of total energy intake, assuming energy intake is adequate</td>
<td>1.0 gram per kilogram of body weight</td>
<td>Enough to meet energy needs after carbohydrate and protein needs are met; often about 25 to 30% of total energy intake</td>
</tr>
<tr>
<td>Endurance-trained athletes</td>
<td>35-50+ calories per kilogram of body weight (needs vary based on the specific sport and training regime)</td>
<td>6-8 grams per kilogram of body weight daily; 8 to 10 g/kg during heavy training and competition. Ultraendurance athletes typically require a maximum of 8 g/kg during training and need substantially more than 10 g/kg during intense training and competition</td>
<td>1.2-1.6 grams per kilogram of body weight</td>
<td>At least 1.0 gram per kilogram of body weight and enough to meet energy needs</td>
</tr>
<tr>
<td>Strength-trained athletes</td>
<td>30-60 calories per kilogram of body weight (needs vary based on the specific sport and training regime)</td>
<td>5-7 grams per kilogram typically adequate for high intensity, short duration training; 8-10 g/kg may be needed to support prolonged training</td>
<td>1.4-1.7 grams per kilogram of body weight</td>
<td>At least 1.0 gram per kilogram of body weight and enough to meet energy needs</td>
</tr>
</tbody>
</table>
without being overly restrictive. For the athlete consuming 3,000 calories daily, 20% of energy intake as fat equals about 65 grams of fat a day.

However, situations vary, and studies show that fat intake in elite athletes may range from 15% to as high as 40% of total energy intake. Some athletes focus on attaining or maintaining a low level of body fat, and restricting calories in the form of dietary fat intake is one way to do that. In sports where weight must be moved, any excess body fat may be detrimental, as excess fat increases body mass but does not increase power. Distance runners strive for a low percentage of body fat so that their running is more efficient. The demands of training require distance runners to consume high levels of carbohydrate so that glycogen stores are adequate and moderate levels of protein to support strength training. In an effort to control energy intake, fat intake is often reduced, and some distance runners consume only 15% of total energy intake as fat. Such a low-fat diet restricts the choice of foods that can be consumed, often does not provide satiety, and may be a health risk.

Limiting fat too much can be a sign that an athlete is losing proper perspective on overall diet. Some athletes become obsessed with keeping fat (and caloric) intake low and become “fat phobic.” This fear of fat intake could be a sign of disordered eating. In some cases, low fat and energy intakes are detrimental to the athlete’s training, performance, and mental well being.

In some precompetition situations, such as wrestling or bodybuilding, where loss of body fat is a goal, fat intake may be temporarily reduced to 15% or less of total energy intake. This severe reduction in fat (and caloric) intake is usually short term, and most wrestlers and bodybuilders do not suffer from long-term disordered eating.

In some sports, such as distance cycling and cross-country skiing, daily training requires an exceptionally high caloric intake. Male athletes in these sports may consume in excess of 5,000 calories daily, and their fat intake may exceed 35% of total energy intake. Fat is the most energy-dense nutrient. When carbohydrate and protein needs are met, fat helps provide the energy needed to support such a high level of training. For these athletes, a higher dietary fat intake is beneficial, as without the fat they would take in too little energy. The type of fat consumed is important and athletes should emphasize the consumption of monounsaturated and polyunsaturated fats and deemphasize the intake of saturated fats. The intake of trans fats should be as low as possible.

In the face of a food supply loaded with fat, athletes must usually limit, but not eliminate, dietary fat. Everyone needs to consume enough dietary fat to provide the essential fatty acids, linoleic acid, and linolenic acid. Essential fatty acids cannot be manufactured by the body and must be included in the diet. Only a small amount is needed daily (equivalent to approximately one tablespoon of oil), as the body can store essential fatty acids. Linoleic acid is an omega-6 fatty acid found in leafy green vegetables, grains, seeds, nuts, and vegetable oils such as corn or safflower oil. Linolenic acid is an omega-3 fatty acid found in canola and soybean oils, seeds, nuts, and soybeans. Omega-3 fatty acids, a group that includes linolenic acid, EPA, and DHA, appear to be beneficial to the heart, especially when consumed in the proper proportions. EPA and DHA are found in salmon, sardines, tuna, and shellfish. In the United States, people consume too few omega-3 fatty acids and too many omega-6 fatty acids (1 gram omega-3 fatty acids to 4 grams omega-6 fatty acids is recommended). Consuming more fish, approximately 10 ounces per week, would help people to achieve the proper balance. To reduce exposure to mercury, it is recommended that up to 12 ounces per week of lower mercury fish (e.g. shrimp, canned light
tuna, salmon, pollock, catfish) be consumed and that high mercury fish (e.g. shark, swordfish, king mackerel, tilefish) be avoided. More information can be found at the Environmental Protection Agency website (www.epa.gov).

At least 1.0 grams of fat per kilogram of body weight daily is recommended for athletes in training.

Carbohydrate and protein recommendations for athletes are made on a gram-per-kilogram-of-body-weight basis. Yet fat recommendations are generally expressed as a percentage of energy intake. Some sports nutritionists are beginning to make fat recommendations based on a kilogram-of-body-weight basis. A good starting point is to recommend that athletes consume at least 1.0 gram of fat per kilogram of body weight. This figure may be adjusted on an individual basis but in general provides for an adequate intake of fat and allows athletes to take in the recommended amounts of carbohydrate and protein.

The proper amount of fat in an athlete’s diet is really a balancing act. On one hand, athletes need to consume enough fat to provide the essential fatty acids and a feeling of satiety after a meal. On the other hand, athletes need to limit fat consumption so that carbohydrate and protein needs are met but fat and energy intakes are not excessive. Maintaining proper energy balance is critical for all athletes and helps to ensure adequate vitamin intake.

Vitamins

The 13 vitamins known to be essential are traditionally classified as fat-soluble (vitamins A, D, E, and K) or water-soluble (B vitamins and vitamin C). Athletes generally categorize vitamins according to their function. Table 1.5 summarizes the exercise-related functions of vitamins and minerals. Many of the B vitamins are needed for energy metabolism. Without them, energy contained in carbohydrate, protein, and fat could not be broken down and used by cells. The antioxidant vitamins (vitamins A, C, and E) help protect the body’s cells from the harmful effects of oxygen. Vitamin D is classified as a hormone and recognized as an important factor in the building and maintenance of healthy bones.

Obtaining sufficient vitamins and minerals from food is possible if athletes consume enough energy to maintain body weight and choose foods that are excellent sources of these essential compounds. Nutrient-dense foods such as fruits, vegetables, and whole grains are naturally rich in vitamins. People who engage in exercise may need slightly more vitamins than those who are not physically active. This increased need can easily be met by consuming more energy in the form of nutrient-dense foods. Athletes may face two problems, however: (1) they may not eat enough of the foods that are naturally rich in vitamins, especially fruits and vegetables or (2) they may restrict their energy intake in an effort to attain or maintain a low percentage of body fat.

When energy intake is low, or the intake of fruits, vegetables, and whole grains is poor, athletes may be at risk for consuming too few vitamins. If so, they often consider taking a vitamin supplement. They should first try to reverse the situation that puts them at risk for vitamin deficiencies, namely consuming too little energy and too few nutrient-rich foods. Vitamin-deficient athletes who are unwilling or unable to make dietary changes may benefit from a multivitamin supplement that will provide the nutrients missing in their diets. There is no evidence that vitamin supplements enhance performance if the athlete is receiving enough vitamins from food.
<table>
<thead>
<tr>
<th>Vitamin/mineral</th>
<th>Recommended adult* daily intake</th>
<th>Recommended adult* daily upper level</th>
<th>Exercise-related issues</th>
<th>Other considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thiamin (B&lt;sub&gt;1&lt;/sub&gt;)</td>
<td>Males: 1.2 mg</td>
<td>None yet established</td>
<td>Necessary for energy release from carbohydrates, specifically as part of the coenzyme that converts pyruvate to acetyl CoA</td>
<td>Athletes on low-calorie diets or those who do not consume nutrient dense carbohydrate foods are at risk for deficiency</td>
</tr>
<tr>
<td></td>
<td>Females: 1.1 mg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Riboflavin (B&lt;sub&gt;2&lt;/sub&gt;)</td>
<td>Males: 1.3 mg</td>
<td>None yet established</td>
<td>Necessary for energy release from carbohydrates and fats, specifically as part of coenzymes in the Krebs cycle</td>
<td>Athletes on low-calorie diets are at risk for deficiency</td>
</tr>
<tr>
<td></td>
<td>Females: 1.1 mg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Niacin (B&lt;sub&gt;3&lt;/sub&gt;)</td>
<td>Males: 16 mg</td>
<td>35 mg</td>
<td>Necessary for breakdown of carbohydrates in the muscle; promotes the formation of fats</td>
<td>A 75-mg dose will produce a “niacin rush”—flushing, burning, tingling—and will block the release of free fatty acids from adipose cells</td>
</tr>
<tr>
<td></td>
<td>Females: 14 mg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pyridoxine (B&lt;sub&gt;6&lt;/sub&gt;)</td>
<td>Ages 19-50: 1.3 mg</td>
<td>100 mg</td>
<td>Necessary for metabolism of proteins; necessary for breakdown of muscle glycogen</td>
<td>Athletes on low-calorie diets are at risk for deficiency</td>
</tr>
<tr>
<td></td>
<td>Males 50+: 1.7 mg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Females 50+: 1.5 mg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pantothenic acid</td>
<td>5 mg</td>
<td>None yet established</td>
<td>A component of acetyl CoA, the principal substrate in the Krebs cycle that is necessary for the breakdown of carbohydrates, fats, and proteins for energy</td>
<td>No known dietary deficiencies</td>
</tr>
<tr>
<td>Folate (folic acid)</td>
<td>400 mcg</td>
<td>1,000 mcg</td>
<td>Necessary for proper red blood cell formation</td>
<td>In an effort to reduce the number of birth defects, women of childbearing age are encouraged to consume 400 micrograms daily</td>
</tr>
<tr>
<td>Vitamin C</td>
<td>Males: 90 mg</td>
<td>2,000 mg</td>
<td>Increases the absorption of iron; acts as an antioxidant</td>
<td>Eating vitamin C-containing fruits and vegetables is highly encouraged</td>
</tr>
<tr>
<td></td>
<td>Females: 75 mg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin D</td>
<td>Ages 19-50: 5 mcg</td>
<td>50 mcg or 2,000 IU</td>
<td>Necessary for calcium absorption, regulates the uptake and deposition of calcium in the bone</td>
<td>Exposure to ultraviolet light should provide sufficient vitamin D</td>
</tr>
<tr>
<td>Note: This vitamin is potentially toxic</td>
<td>Ages 51-70: 10 mcg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ages 70+: 15 mcg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin E (alpha tocopherol)</td>
<td>15 mg</td>
<td>1,000 mg or 1,000 IU</td>
<td>May decrease exercise-induced oxygen damage to the muscles</td>
<td>Research continues because study results are mixed; athletes who choose to supplement should not exceed 200 mg daily</td>
</tr>
<tr>
<td>Calcium</td>
<td>Ages 19-50: 1,000 mg</td>
<td>2,500 mg</td>
<td>Major mineral in bone crystal, necessary for proper muscle contraction</td>
<td>Consuming adequate calcium in the diet is recommended but supplements may be necessary for some people to obtain recommended amounts</td>
</tr>
<tr>
<td></td>
<td>Ages 50+: 1,200 mg</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iron</td>
<td>Females ages 19-50: 18 mg</td>
<td>45 mg</td>
<td>A component of hemoglobin that is necessary for the delivery of oxygen to muscles</td>
<td>Athletes with iron-deficiency anemia will tire regardless of their fitness levels</td>
</tr>
<tr>
<td>Note: This mineral is potentially toxic</td>
<td>Males and females 50+: 8 mg</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Athletes can obtain sufficient vitamins from food alone if energy intake is adequate and they choose a variety of vitamin-rich foods such as fruits, vegetables, and whole grains.

Athletes may already be taking a supplement in the form of fortified food. Many breakfast cereals have vitamins and minerals added and may contain “100% of the Daily Value” for many nutrients. Some orange juice is fortified with vitamins C and E or the mineral calcium. Additionally, products marketed to athletes, such as energy bars, may contain the same amount of vitamins found in a supplement.

Studies have shown that the vitamin status of athletes varies. Several studies of athletes consuming food but not supplements have documented that none of the athletes studied were deficient in thiamin, riboflavin, niacin, or vitamin B₆. These studies would support the contention that athletes can, and do, obtain sufficient B vitamins from food alone. Male athletes are more likely than female athletes to meet their B vitamin needs because their caloric intake is higher and they consume more food. Other studies have found that as low as 4% and as high as 59% of athletes consuming food but not supplements are deficient in one of the B vitamins. Vitamin supplementation may be warranted for some of these athletes.

The antioxidant vitamins, vitamins A, C, and E, are known to counteract the harmful effects that oxygen has on tissues. Athletes who train hard consume more oxygen and are at greater risk for oxidative tissue damage. The body does respond to strenuous training with increased antioxidant enzyme activation, but it is not known if the body is able to meet the increased need for antioxidants with increased enzyme activity alone. Some researchers have suggested that supplements of vitamins C and E are warranted, but not all researchers agree. A 2006 review article of studies of endurance athletes who consumed antioxidant vitamins supplements found that the results were not clear-cut and that the current body of evidence is insufficient to recommend antioxidant supplements to endurance athletes at this time. The one area of agreement was that athletes should consume foods that are rich in antioxidants.

Athletes can obtain the antioxidant vitamins easily by eating fruits, vegetables, nuts, and whole grains and will also benefit from other compounds that are known to possess antioxidant activity (such as lycopene found in tomatoes). Some endurance athletes limit fat intake, and since fat such as vegetable oils and nuts are sources of vitamin E, this practice can leave them with low

<table>
<thead>
<tr>
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<th>Recommended adult* daily upper level</th>
<th>Exercise-related issues</th>
<th>Other considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc</td>
<td>Males: 11 mg Females: 8 mg</td>
<td>40 mg. See your physician before taking zinc supplements</td>
<td>Performs many roles as a component of nearly 100 enzymes, including the building and repair of muscle and the proper functioning of the immune system</td>
<td>Athletes with low energy intakes are at risk for deficiency. Low zinc intake is frequently seen in individuals with disordered eating.</td>
</tr>
</tbody>
</table>

Note: This mineral is potentially toxic

*Adult refers to males and nonpregnant females 19 years of age and older. Pregnant and nursing females have higher requirements that are not shown here.

The recommended values are based on Dietary Reference Intakes (DRI) and Tolerable Upper Intake Levels (UL) from the Food and Nutrition Board, Institute of Medicine, The National Academies. The full text of the report is available at www.nap.edu.

Legend: mg = milligrams; mcg = micrograms
Adapted, by permission, from Marie Dunford, 2001, Exercise Nutrition, (Champaign, IL: Human Kinetics), 43.
vitamin E intakes. For these athletes, adequate dietary vitamin E (15 mg/day) or a vitamin E supplement of up to 200 milligrams per day is recommended.

Vitamin D, a vitamin that acts like a hormone, plays an important role in bone health. The body can synthesize vitamin D via ultraviolet light. When ultraviolet rays from the sun shine on the skin, a cholesterol compound is converted to a precursor that is eventually converted to vitamin D. Athletes who train outdoors should have no problem obtaining sufficient vitamin D. Those who train indoors, have very little sun exposure, and always use sunscreen need to consume vitamin-D fortified foods such as milk or may need to take supplemental vitamin D.

**Minerals**

Although at least 20 minerals are known to be important for humans, athletes tend to focus on a small number of them. Calcium receives much attention because of its central role in bone health throughout life. Iron, considered a trace mineral because the body contains only about 2.5 grams of it, is vital to blood formation. Zinc performs many roles, including the building and repair of muscle and the proper functioning of the immune system. Four minerals—sodium, potassium, chloride, and magnesium—command attention because of their roles in maintaining fluid balance.

Calcium and phosphorus are the two major minerals found in bone crystal. Because bone is constantly being remodeled, there is a need for sufficient calcium throughout life and not just during childhood and adolescence, when the bones are growing in length. Athletes do not need more calcium than nonathletes do, but calcium needs for adults in general are high (1,000-1,200 mg daily). Studies have shown that male athletes generally consume enough calcium, whereas female athletes often consume less than recommended levels. The low calcium intake reported by female gymnasts and distance runners is particularly worrisome. Low calcium intake by females is often a result of low energy intake, but it may also result from the elimination of milk and milk products from the diet. For those athletes who do not receive sufficient dietary calcium, calcium-fortified foods or supplements are recommended.

Iron is part of hemoglobin and thus intimately involved with the delivery of oxygen. The need for iron appears to increase with strenuous exercise, especially for endurance athletes. The body is able to store iron, so if iron stores are adequate an increased need does not necessarily mean that the athlete will be deficient. Athletes who deplete their iron stores are at risk of developing iron-deficiency anemia, a condition known to impair performance. This condition, once diagnosed by a physician, is easily treated with iron supplements. The iron supplements reverse the iron-deficiency anemia and replenish iron stores, but this is a process that takes about three to six months. Periodic screening to determine iron status is recommended.

Most male athletes consume adequate iron in their diets and do not develop iron-deficiency anemia. Female athletes, who lose iron with monthly menstruation and who often have low dietary iron intakes, are at greater risk for iron deficiency than males. The risk for iron deficiency in females is greater in sports where energy intakes are routinely low. Females who avoid animal sources of iron such as meat, fish, and poultry also tend to be at greater risk. These animal sources contain heme iron, a type of iron that is particularly well absorbed. Vegetarian athletes consume the less well-absorbed non-heme iron. Female athletes should have their iron status monitored by their physicians since some, but not all, may develop iron-deficiency anemia.11
Zinc is needed only in small quantities but is a necessary part of nearly 200 enzymes. Studies have shown that impaired immune function can occur with a mild zinc deficiency. It is recommended that adult men consume 11 milligrams of zinc daily, while adult women need 8 milligrams daily. A diet that includes animal foods and sufficient energy typically supplies women 9 milligrams of zinc daily and men 13 mg per day. The diets of female athletes, especially those with low energy intakes, may not be providing enough zinc. Low zinc intake is frequently seen in individuals with disordered eating.

Including more zinc-rich foods, such as red meat, milk, and seafood, is one way to increase the amount of zinc provided to the body. Zinc supplements should be taken with caution as they may interfere with the absorption of other nutrients, especially copper and iron. If supplemental zinc is consumed it should be limited to 15 milligrams per day.

Females are at a greater risk for mineral deficiencies than males—especially if energy intakes are too low.

Sodium, potassium, chloride, and magnesium are minerals known as electrolytes. Electrolytes, which have either a positive or negative charge, are necessary to maintain proper fluid balance. Although all of the electrolytes are found in food, athletes often associate them with sports beverages. Adding electrolytes to sports beverages has been a result of substantial scientific research in the area of water and electrolyte balance. When athletes sweat, water, sodium, chloride, and potassium are lost from the body. Substantially more water is lost than electrolytes, and loss of body water is critical, as body temperature is affected and heat illness may result. The loss of electrolytes is usually corrected during the post-exercise recovery period when athletes consume electrolytes in sports beverages or add a small amount of salt (sodium chloride) to their foods, most of which contain some potassium.

Loss of significant amounts of sodium during exercise is a concern for slow marathon runners and ultraendurance athletes. Sodium lost in sweat and urine coupled with low sodium, high water intake during hours of continuous exercise may result in a condition known as hyponatremia. The large amount of water consumed in an effort to prevent dehydration along with a low intake of sodium may result in the dilution of sodium in the blood. During exercise, these athletes generally consume a sports drink that contains sodium. After exercise, they are careful to replenish the sodium that was lost, typically by eating salty snacks or salting their food.

Water and Other Fluids

Water is often called the most important but least-emphasized nutrient. The goal is proper hydration. Prevention of hypohydration (insufficient amount of body water) and heat illness are important goals for all athletes. The American College of Sports Medicine (ACSM) and the National Athletic Trainers’ Association (NATA), in an effort to promote optimal performance and health, have published position papers on exercise and fluid replacement. These position papers are the basis for nutritional recommendations for fluids that appear below. These recommendations serve as guidelines that must be adjusted to individual tolerances. Many factors must be considered when consuming fluids, including volume, frequency, concentration, timing, and presence of electrolytes. Each athlete should develop an individualized plan, which is fine-tuned through trial and error. Overconsumption of water can lead to hyponatremia.
Nutrients Needed for Training and Performance

(low blood sodium) in endurance athletes so athletes should NOT be advised to “drink as much as you can.”

- Drink approximately 500 ml of fluid, two to three hours before exercise. (500 ml ≈ 17 ounces ≈ 2 cups)
- Drink 150 to 350 ml of fluid at 15 to 20 minute intervals during exercise, beginning at the onset of exercise. (150 to 350 ml = 5 to 12 ounces. 8 ounces = 1 cup)
- Drink > 450 to 675 ml for every pound (0.5 kg) lost during exercise. (450 to 675 ml = 15 to 22 ounces = 2 to 3 cups)
- Fluids are typically better tolerated if they are cool, flavored, and taken in smaller volumes more frequently, however, individual tolerances and preferences are the most important factors.
- Carbohydrate or electrolytes, such as sodium, should be included in beverages consumed by athletes engaged in exercise for an hour or more.

**All athletes should be concerned about hypohydration (insufficient volume of body water).**

When athletes swallow a beverage, they think they will be well hydrated because they have put fluid into their body. But to properly understand hydration, imagine the gastrointestinal tract as still being on the outside of the body. The water and electrolytes from the beverage must be emptied from the stomach, absorbed by the gastrointestinal tract, and reach the plasma (the watery portion of the blood) and the cells before they can be effective. Rates of gastric emptying and intestinal absorption are important considerations, as until gastrointestinal absorption occurs cells cannot benefit from the fluid or nutrients consumed.

Hypohydration is a frequent hazard for athletes and can be life threatening, especially when exercising in the heat. But hypohydration can occur in any training or performance situation, including exercising in the cold or in the water. Studies have shown that athletes who are hypohydrated fatigue earlier, use glycogen more rapidly, and impair their ability to sweat and regulate body temperature.\(^\text{14}\)

Some athletes voluntarily dehydrate to make weight (e.g. wrestlers, boxers, and lightweight rowers) or improve appearance (bodybuilders). Mild hypohydration in wrestlers may be reversed before competition, as there is time to rehydrate after weigh-in. Time may be too short to reverse more severe hypohydration, and in these instances wrestlers compromise both their performance and health. In 1997, three college wrestlers died as a result of severe hypohydration.\(^\text{16}\) Bodybuilders strive for maximum muscle definition, and many use diuretics to shed additional body water prior to a contest. Diuretics are powerful medications that force the body to excrete water and, often, electrolytes such as sodium and potassium. Dehydration and electrolyte imbalances can occur, and a few bodybuilders have died from the overuse of diuretics in an effort to voluntarily dehydrate.

**Voluntary dehydration leading to severe hypohydration can result in poor performance, illness, and even death.**
Athletes are often confused about the best fluid for consumption. Should they consume water or a sports drink? There is no single correct answer, as the demands of training and performance must be considered for each sport. A sprinter may choose water before a race, but a distance runner would benefit from a pre-race carbohydrate drink. The volume consumed will vary based on the athlete’s ability to tolerate fluid in the stomach. There will be differences among teammates performing the same exercise. Coaches should emphasize fluid intake but should recognize that individual differences exist. One size does not fit all.

**Water or sports beverage?**

*It depends on the sport and the individual.*

Prior to the 1960s, water was the only fluid-replacement beverage available. Athletes drank water before and after exercise and were usually prohibited from drinking water during exercise. Restricting water during exercise, especially exercise in the heat, resulted in several deaths and is a practice that is not recommended today under any circumstances. In the 1960s, Dr. Robert Cade, a physician-researcher at the University of Florida, formulated a sports drink designed to replace nutrients lost through sweating. This product was marketed as “Gatorade” (named after the team mascot, an alligator) and was the first sports drink of its kind. The drink contained glucose and electrolytes, notably sodium, chloride, and potassium. Over the years, manufacturers of Gatorade and other sports drinks have reformulated and designed new products to reflect the current research in fluid and electrolyte balance and to meet athletes’ nutritional needs given the demands of their training and competition.

Today, sports beverages generally contain water, carbohydrate, and electrolytes, and there are many drinks to choose from. One category of sports drinks targets athletes who benefit from carbohydrate and fluid before or during exercise. These drinks contain 6 to 8% carbohydrate because greater concentrations would be emptied slowly and could cause gastrointestinal distress. The carbohydrate is in the form of glucose, glucose polymers (chains of glucose), sucrose, fructose, maltodextrin, high-fructose corn syrup, or a combination of these. These drinks contain about 15 grams of carbohydrate in an 8-ounce (1 cup or 240 ml) serving.

A small number of sports drinks could be referred to as “high-carbohydrate sports beverages.” These beverages also contain water and electrolytes (predominantly sodium) but have more carbohydrate than those described above. Each 12-ounce (1 1/2 cups or 360 ml) drink contains about 70 grams of carbohydrate; these drinks are consumed when athletes need a significant carbohydrate source, such as several hours before exercise, immediately after exercise, and during carbohydrate loading.

Some sports drinks are better described as “meal replacement beverages.” These drinks are consumed as a pre- or post-exercise meal or as a meal replacement if the athlete finds it difficult or inconvenient to eat. These beverages are high in carbohydrate, moderate in protein, low in fat, and they contain electrolytes, notably sodium and potassium. They are a convenient source of nutrients, especially for athletes with rigorous training schedules who need a high-energy diet (more than 3,000 calories daily).

Sports beverage manufacturers keep a careful watch on the scientific publications related to fluid, carbohydrate, and electrolyte intake and improved performance. They have successfully developed drinks that help athletes meet
the demands of their training. There are significant differences between the categories, although few differences appear to exist among the drinks within a category. In some cases water is still the most appropriate beverage, but sports beverages are often beneficial and have been shown to improve performance in many circumstances.\textsuperscript{17}

“Energy” drinks have risen in popularity and are marketed to people who experience fatigue. Most contain about 30 grams of carbohydrate and 110 to 140 calories in 8 ounces (1 cup or 240 ml). Although these drinks do provide carbohydrate, the energized feeling is more likely a result of the 75 to 80 mg of caffeine. In the past, athletes have been advised to avoid caffeine intake because of its diuretic effect. It is now believed that a daily caffeine intake of up to 300 mg does not negatively affect fluid balance. However, caffeine is a central nervous stimulant and too much can cause an athlete to feel jittery. Athletes need to determine their individual tolerance for caffeinated beverages.

**PHYSIOLOGICAL PROCESSES THAT INFLUENCE FOOD AND FLUID INTAKE**

Once food is in the body, several physiological processes occur. These include gastric emptying, intestinal absorption, possible gastrointestinal upset, and regulation of blood glucose. All these factors must be considered to ensure that food and fluid intake enhances performance rather than diminishes it.

Once consumed, food rapidly leaves the mouth and travels to the stomach. In the stomach the food mixes with hydrochloric acid and other gastric secretions that contain digestive enzymes. This food mixture (chyme) leaves the stomach and enters the small intestine, a process known as gastric emptying.

Many factors can affect the rate at which the chyme empties. One important factor is volume. In most cases, the larger the volume, the faster the gastric-emptying process occurs. However, there is a point at which the stomach cannot empty the contents any faster. Food or beverages that remain in the stomach when exercise begins often makes the athlete feel “heavy” and uncomfortable. Exercise intensity also influences gastric emptying. Exercise greater than 70\% of VO\textsubscript{2} max will slow the release of chyme from the stomach. Timing of food intake is important to ensure that food has passed out of the stomach before the start of intense exercise. Exercise intensity less than 70\% of VO\textsubscript{2} max does not appear to affect the rate of gastric emptying.

*Timing of food intake is important.*

*Food remaining in the stomach when intensive exercise begins usually is a problem.*

A third factor that influences how quickly the chyme leaves the stomach is the composition of the food. Carbohydrate and protein appear to empty at the same rate, but fat moves out of the stomach more slowly. About 98\% of the fat consumed in the diet of an average person will eventually be absorbed. The rate of fat absorption, however, is slow, taking many hours to complete. The presence of fat in the stomach delays the rate of gastric emptying, and fat consumed two to four hours earlier may still be in the stomach.

From the stomach, chyme moves into the duodenum and continues through the small intestine. Nutrients are absorbed rapidly (within 30 minutes) once
they leave the stomach. Exercise intensity up to 75% of \( \text{VO}_{2}\max \) does not appear to slow intestinal absorption. At intensities greater than 75% of \( \text{VO}_{2}\max \), competition for blood flow between the active muscles and the gastrointestinal tract results in a small decrease in absorption time. This slight slowing of absorption appears to be a minor factor.

The gastrointestinal tract is sensitive to changes in the athlete’s emotional state. Nervousness before competition can reduce appetite. Anxious athletes who eat may find that food passes through the gastrointestinal tract faster due to overstimulation of the parasympathetic nervous system. This overstimulation results in less water being absorbed from the food traveling through the small intestine. Excess water in the intestinal tract leads to loose stools.

*Nervousness before competition can reduce appetite.*

When only fluid is consumed, it immediately leaves the mouth and travels to the stomach. Little fluid is absorbed from the stomach, so rapid gastric emptying of fluid is advantageous. Exercise intensity, fluid volume, and nutrient composition of the fluid are three factors that influence the rate at which the fluid will empty from the stomach. Intense exercise (75% of \( \text{VO}_{2}\max \) or greater) slows gastric emptying. Figure 1.3 illustrates the effect of fluid volume on gastric emptying. Ordinarily, the greater the volume, the faster the fluid empties. This is true for fluid volumes up to approximately 600 ml (approximately 2-1/2 cups or 24 ounces). Sipping fluid is better than not consuming fluid, but the best strategy is to take larger volumes, if tolerated. Optimal gastric emptying appears to occur when 400 to 600 ml of fluid is in the stomach. However, an athlete consuming fluid during intense exercise must make sure the volume is

![Figure 1.3](image-url)  
*Figure 1.3  Effect of fluid volume on gastric emptying.*
not too great, as gastric emptying may be delayed, and too much fluid in the stomach is uncomfortable.

The nutrient composition of the fluid may also affect gastric emptying. Adding nutrients, such as carbohydrate or sodium, changes the osmolality (concentration) of the solution. If the osmolality is too high, gastric emptying is delayed. Sports beverage manufacturers are careful to formulate their products so that any decrease in gastric emptying is small. Carbohydrate beverages should contain less than 8% carbohydrate to minimize the delay in gastric emptying.

Fluid empties from the stomach into the intestinal tract, where it is absorbed. The rate of intestinal absorption of water is affected by the presence of carbohydrate and sodium. Glucose and sodium speed up water absorption, so their presence in sports beverages is advantageous. Although carbohydrate solutions may slightly decrease the rate of gastric emptying, the decrease is more than offset by the increase in gastrointestinal absorption. Carbohydrate in beverages also provide a source of energy during endurance exercise.

When carbohydrate from foods or fluids is consumed, digested, and absorbed, blood glucose levels temporarily increase to above the normal range (hyperglycemia). This hyperglycemia is a signal to the pancreas to secrete insulin, which mediates the uptake of glucose into cells. As glucose is transported from the blood to cells, blood glucose levels return to the normal range of 70 to 110 mg/dL (euglycemia). If blood glucose levels fall below the normal range (hypoglycemia), the pancreas secretes glucagon. Glucagon stimulates the breakdown of liver glycogen and the release of glucose into the blood. This additional blood glucose resolves the hypoglycemia, and euglycemia is once again achieved.

Not all carbohydrate foods elicit the same glycemic response. Some carbohydrates are quickly absorbed and contribute to a rapid rise in blood glucose (high glycemic response), while others are absorbed slowly, and the rise in blood glucose is also slow (low glycemic response). In some, but not most, people, a rapid rise in blood glucose results in an oversecretion of insulin. Glucose rapidly leaves the blood, causing hypoglycemia. If glucagon response is slow, it may take time for an euglycemic state to be attained.

The glycemic response of many carbohydrate foods has been quantified, a measure known as glycemic index. A food with a high glycemic index results in a rapid rise in blood glucose and insulin. This would be advantageous to an athlete after exercise to help resynthesize glycogen rapidly (see chapter 4).

The regulation of blood glucose in response to carbohydrate intake is just one example of the close relationship between food intake and the body’s physiological processes. Protein is also subject to various physiological responses. When protein foods are consumed, the digestive process breaks the food protein down into amino acids. These amino acids are absorbed and transported to the liver and some are released to become part of the amino acid pool (the remainder are used by the liver). The amino acid pool is not a single storage site, as its name suggests, but rather the amount of amino acids in blood and fluid that surrounds tissues. Protein from food, as well as protein found in body tissues, eventually contribute to the amino acid pool.

Protein tissues in the body are in a constant state of change. When cellular protein is broken down, amino acids are added to the pool. When cellular protein is being synthesized, cells obtain the amino acids they need from the amino acid pool. Body protein is synthesized and broken down daily, but the rate of synthesis and degradation changes in response to several conditions.
One major influence is resistance exercise. During resistance exercise, protein synthesis slows, while protein breakdown is accelerated. The muscle proteins that are broken down are added to the amino acid pool. After resistance exercise is completed, protein synthesis increases (using amino acids from the pool). There is a net gain in the amount of muscle protein, as more protein is synthesized than was broken down. Thus, resistance training in the presence of adequate protein and energy intake results in an increase in the protein content of the exercised muscle. Some researchers suggest that it is advantageous to consume some amino acids immediately after exercise so that the amino acid pool is temporarily increased.

As you can see, athletes must consider how exercise influences the body’s response to the intake of food and beverages. The timing of food and fluid intake, particularly carbohydrate and water consumption, can significantly affect training and performance. The nutritional goals of the athlete are different before, during, and after training or competition, and food and fluid intake varies at those times as well. The intensity and duration of exercise are factors that must be considered, and the physiological responses made by the body cannot be overlooked. Because timing is so important, nutrient recommendations for athletes are often made in reference to three separate time frames: before exercise, during exercise, and after exercise.

**SUMMARY**

Athletes look to good nutrition to help them improve their training and performance. Sufficient carbohydrate intake is critical and enough must be consumed daily to resynthesize the glycogen that is used during exercise. The amount of protein required will vary depending on the athlete’s training. Athletes need more protein than nonathletes, and strength-trained athletes typically need more than endurance-trained athletes. There appears to be no advantage to consuming excessive amounts of protein, and athletes can easily meet their protein needs by consuming protein foods.

The fat content of an athlete’s diet is generally consistent with health recommendations made to all people. The athlete who wants to lose body fat often reduces fat intake, but too great a restriction of fat could negatively impact performance and health. Low energy (calorie) intake can also mean that vitamin and mineral intakes are inadequate. Athletes can obtain sufficient vitamins from food if enough energy is consumed, and if they choose vitamin-rich foods such as fruits, vegetables, and whole grains. Male athletes generally consume enough minerals such as calcium, iron, and zinc, but female athletes, again because of their low energy intakes, are at greater risk for deficiencies.

Hypohydration is a critical issue for all athletes, because it is a major factor that contributes to fatigue and risk of heat illness. Many athletes benefit from sports beverages because they provide water and carbohydrates, but some athletes can meet their fluid needs by drinking plain water. For some athletes, large losses of sodium and overconsumption of water can result in hyponatremia, a serious medical condition.
REFERENCES


