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CHAPTER

12

Endurance and Ultra-endurance Athletes

Key Questions Addressed

- What is different about endurance athletes?
- What energy systems are utilized during endurance exercise?
- Are total energy needs for endurance athletes different than for other types of athletes?
- Are macronutrient needs different for endurance athletes?
- How important are carbohydrates to endurance athletes?
- Are protein needs different for endurance athletes?
- Should endurance athletes eat more fats to meet their energy needs?
- Are vitamin/mineral needs different for endurance athletes?
- Why are fluids critical to endurance performance?
- What meal planning/event logistics need to be considered during endurance events?

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You Are the Nutrition Coach

Adam is a 14-year-old distance swimmer. He swims with a club team and competes regularly. The team's weekly yardage ranges from 30,000–35,000 yards with 2–3 days of dry land exercises. Several months ago, Adam decided to cut out all junk food from his diet in hopes of improving his swimming performance. After making the dietary change, his times for the 200 butterfly, 500 freestyle, and 1-mile freestyle began to improve and he was feeling good! Another result of his dietary changes and hard efforts in the pool was a 28-pound weight loss in 6 months, dropping to a mere 140 pounds for his 5′11″ frame. His mother and coach became concerned with his weight loss, afraid that he had lost too much and was also losing muscle mass, which would eventually hurt his performance. In addition to these concerns, Adam was approaching the time for a switch to the high school team, which meant more yardage in the pool and more dry land exercises. Adam was open to eating more food to keep his weight and strength stable, but was unsure of how to do it in a healthy way.

Questions

- What are Adam's daily calorie needs?
- Should Adam begin eating ice cream, candy bars, and other high-calorie "junk" foods again in order to increase his daily calorie intake?
- What advice would you give Adam?

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What is different about endurance athletes?

In general, endurance is one of the basic components of physical fitness. As a result, most athletes have to possess some degree of muscular and cardiorespiratory endurance to perform in their respective sports. **Muscular endurance** is the ability of a muscle or group of muscles to repeatedly develop or maintain force without fatiguing. **Cardiorespiratory endurance** is the ability of the cardiovascular and respiratory systems to deliver blood and oxygen to working muscles, which in turn enables the working muscles to perform continuous exercise. In other words, a person who possesses good cardiorespiratory fitness will be able to perform higher intensity activity for a longer period of time than a person with poor cardiorespiratory fitness.

muscular endurance The ability of a muscle or group of muscles to repeatedly develop or maintain force without fatiguing.

cardiorespiratory endurance The ability of the cardiovascular and respiratory systems to deliver blood and oxygen to working muscles, which in turn enables the working muscles to perform continuous exercise. It is an indicator of a person's aerobic or cardiovascular fitness.

Obviously, endurance is important to almost all athletes, even those involved in sports requiring short, intermittent bursts of intense anaerobic activity that are repeated over the course of an hour or more. Because so many sports require endurance, clarification is needed regarding which athletes fall into the category of "endurance and ultra-endurance athletes." For the purposes of this chapter, **endurance athletes** are those who are engaged in continuous activity lasting between 30 minutes and 4 hours. **Ultra-endurance athletes** are a subgroup of endurance athletes that engage in extremely long bouts of continuous activity lasting more than 4 hours.

endurance athlete An athlete who participates in sports involving continuous activity (30 minutes to 4 hours, as defined in this chapter) involving large muscle groups.

ultra-endurance athlete A subgroup of endurance athletes that engage in extremely long bouts of continuous activity lasting more than 4 hours. Ironman triathletes and ultra-marathoners are examples of this group of endurance athletes.

Because of the duration and continuous nature of their sports, endurance athletes expend a tremendous number of calories not only during competition, but also in their preparatory training. For example, energy expenditures of 6,000 to 8,000 kcals/day are not out of the ordinary for ultra-endurance athletes. This puts a tremendous drain on energy reserves that must be replenished after daily training bouts, making diet a key factor not only for athletic success, but also for overall health. Failure to maintain adequate dietary intake of nutrients can quickly result in chronic fatigue, dehydration, increased risk for illness (e.g., upper respiratory infection) and injuries, as well as muscle wasting.

Although endurance sports require high calorie intakes, they do not give athletes a license to eat indiscriminately. Although eating enough calories to offset the energy demands of their sport may sometimes be difficult, athletes must pay careful attention to dietary composition and the timing of consumption to help ensure their success. For the ultra-endurance athlete, not only is their training diet crucial, but so is their nutrient consumption during lengthy competitions. This chapter focuses on the dietary requirements of these "high caloric need" endurance and ultra-endurance athletes.

What energy systems are utilized during endurance exercise?

As with most sports, all three energy systems (i.e., phosphagen, anaerobic, and aerobic) are working to contribute energy during endurance exercise. However, the primary energy system relied upon during endurance exercise is the aerobic system (shown on the right side of Figure 12.1). As discussed in Chapter 2, the chemical energy our bodies rely upon is adenosine triphosphate (ATP). The aerobic energy system has an almost unlimited capacity for producing ATP. The downside is that the aerobic system cannot produce ATP very quickly; as a result, the speeds at which endurance and ultra-endurance activities are carried out are slower relative to that of anaerobic athletes. However, with appropriately designed training programs, the aerobic energy system of muscles can be improved, thus enabling higher rates of ATP production. The rate of aerobic ATP production is known as **aerobic power.** The faster the rate of ATP production, the higher the aerobic power demonstrated by that athlete. Elite endurance athletes exhibit remarkable aerobic power. They can sustain relatively high-velocity movements for hours that an untrained individual may only be able to maintain for several minutes before fatiguing.

aerobic power The rate of aerobic ATP production. It is usually represented by the fastest pace or rate of physical activity an athlete can sustain and is an indicator of cardiorespiratory fitness.

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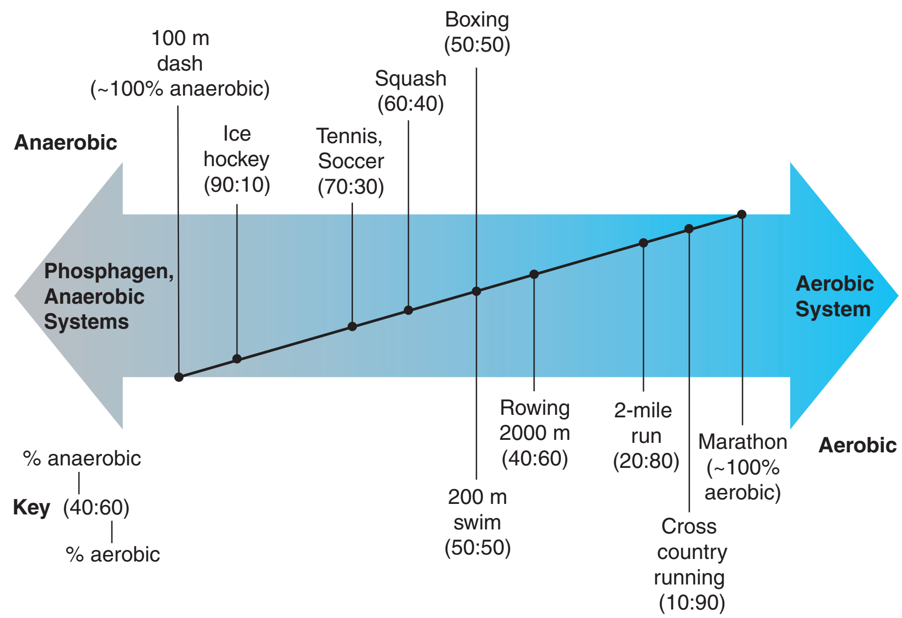

Figure 12.1 The anaerobic-aerobic continuum. The primary energy system relied upon during endurance exercise is the aerobic system.

Are total energy needs for endurance athletes different than for other types of athletes?

One of the main concerns for endurance athletes is matching energy consumption with energy expenditure. Long distance, strenuous exercise requires a large number of calories. Elite athletes can potentially burn more than two to three times the number of calories as their untrained, weight-matched counterparts. If these calories are not replaced daily, energy for training and the ability to perform during competitions will decline.

How are daily energy needs calculated for endurance athletes?

To estimate the total energy needs for an endurance athlete, use the resting energy expenditure (REE) equations presented in Chapter 10 and reviewed in **Table 12.1**.

For example, Bill is a 35-year-old marathoner, running 60–80 miles a week. His weight has been stable at 140 pounds for the last 12 months. Using the calculation presented in Table 12.1, Bill's daily calorie needs are:

1. Calculation for 35-year-old men: REE = (11.6 × BW) + 879
2. Convert pounds of body weight to kilograms = 140 ÷ 2.2 = 63.6 kilograms
3. Bill's REE = (11.6 × 63.6 kg) + 879 = 737.8 + 879 = 1,616.8 calories
4. Multiply the REE by the activity factor of 1.6–2.4 = 1,616.8 × (1.6–2.4) = 2,587–3,880 calories per day

The daily calorie range calculated for Bill is quite large—a difference of 1,293 calories. Bill can use this range to adjust his intake based on his daily volume of running. Rest and recovery days will require approximately 2,500–2,800 calories, whereas high mileage or hard workout days will require an intake of 3,600–3,900 calories. With a weekly mileage of 60–80 miles, Bill is running about 10–12 miles a day. Therefore, on most days he will need to consume a diet providing calories at the high end of his estimated range in

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Knowing how to estimate the daily energy needs for an endurance athlete is a crucial first step to developing a dietary plan that provides enough calories to meet training and competition energy needs.

TABLE 12.1 Resting Energy Expenditure (REE) Calculations and Activity Factors

Gender and Age	Equation (BW in kilograms)	Activity Factor
Males, 10–18 years	REE = (17.5 × BW) + 651	1.6–2.4
Males, 18–30 years	REE = (15.3 × BW) + 679	1.6–2.4
Males, 30–60 years	REE = (11.6 × BW) + 879	1.6–2.4
Females, 10–18 years	REE = (12.2 × BW) + 749	1.6–2.4
Females, 18–30 years	REE = (14.7 × BW) + 496	1.6–2.4
Females, 30–60 years	REE = (8.7 × BW) + 829	1.6–2.4

Source: World Health Organization, Report of a Joint FAO/WHO/UNU Expert Consultation.[37]

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order to perform well and recover completely from workouts.

Even though the activity factors of 1.6–2.4 will cover most recreational and competitive athletes, the range may not estimate calories appropriately for all athletes. For example, cyclists participating in staged races that last from 1 to 3 weeks may burn calories in the 7,000–8,000 calorie per day range. If Bill, from the previous example, was a stage racing cyclist, to reach this calorie range, an activity factor of 4.3–4.9 would be appropriate. On the other end of the spectrum, endurance athletes who want to lose weight may find that an activity factor of 1.4–1.6 estimates an appropriate calorie level. Therefore, use the calculation guidelines while also making individualized adjustments for specific athletes.

It can sometimes be challenging for athletes to increase their daily intake to match their actual caloric needs. Training, work/school, sleep, and other nonsport activities take time away from preparing and eating meals and snacks. Some athletes also complain about feeling too full and not being able to comfortably add more calories to meet their needs. Also, strenuous effort during training or competition tends to decrease appetite, causing athletes to eat small meals and snacks. Athletes in these situations are looking for quick, easy, and nutrient-dense ways to increase their calories while enjoying their food and not spending all day in the kitchen. Meal plans should be created that fit the daily schedule of the athlete and incorporate nutrient- and calorie-dense meals/snacks that are within the cooking/preparation skills of the athlete.

When planning meals for individuals needing to increase calories, a balance of macronutrients is essential. If an athlete increases mainly carbohydrate- and fiber-rich foods, the result is a feeling of fullness and bloating. If protein-rich foods are the focus, the endurance athlete may neglect to fully replenish glycogen stores, ultimately hindering training and racing. Too many fat-rich foods can delay gastric emptying, potentially disrupting training sessions due to a sense of fullness, stomach cramps, or diarrhea. By balancing the macronutrients and increasing carbohydrates, protein, and fat in proportional amounts, athletes can reap the benefits of increasing total calorie intake while feeling good and performing well.

Training Table 12.1 presents sample meal plans for three different calorie levels—3,000, 4,000, and 5,000 calories. Note that as the number of calories increases, the frequency of meals and snacks increases as do the number of calorie-dense foods. Three meals plus

Training Table 12.1: Example Menu Plans for 3,000, 4,000, and 5,000 Calories

3,000 Calories

Meal/Snack	Food/Beverage	Carbohydrate Content (g)
Breakfast	2 cups raisin bran	94
	1 cup skim milk	12
	1 banana	28
Lunch	4 oz turkey and cheese sandwich	27
	6 oz low-fat yogurt	34
	¼ cup trail mix	23
	1 plum	9
	1 apple	21
During workout	20 oz sports beverage	48
Postworkout snack	½ peanut butter sandwich	15
	12 oz chocolate milk	39
Dinner	2 cups pasta	78
	¾ cup marinara sauce	15
	6 oz chicken breast	0
	2 cups steamed broccoli	9
	12 oz skim milk	18
	Total Calories = 2,973	Total carbohydrates = 470 g *61% of total calories*

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Training Table 12.1 Continued

4,000 Calories

Meal/Snack	Food/Beverage	Carbohydrate Content (g)
Breakfast	Smoothie:	
	2 frozen bananas	55
	2 cups skim milk	24
	2 scoops protein powder	27
Snack	Orange	15
	Granola bar	29
Lunch	2 cups chili	54
	4 oz roast beef sandwich	25
	2 cups fruit salad	61
During workout	32 oz sports beverage	76
Postworkout snack	6 oz yogurt	34
	½ cup dry cereal	13
Dinner	6 oz salmon	0
	2 cups wild rice	70
	3 cups salad with dressing	17
	16 oz skim milk	24
Snack	1½ cups frozen yogurt	73
	½ cup frozen blueberries	9
	Total Calories = 4,016	**Total Carbohydrates = 606 g** *59% of total calories*

5,000 Calories

Meal/Snack	Food/Beverage	Carbohydrate Content (g)
Breakfast	2-egg omelet with cheese	5
	2 pieces of toast with 1 T butter	47
	12 oz orange juice	39
Snack	1 cup mixed nuts and raisins	67
Lunch	2 hamburgers with buns	69
	16 oz skim milk	24
	2 pieces fresh fruit	52
Snack	Smoothie:	
	2 cups frozen mixed fruit	42
	1 cup pineapple juice	35
	8 oz yogurt	46
	2 scoops protein powder	27
During workout	48 oz sports beverage	114
Dinner	2 pieces lasagna	75
	2 pieces garlic bread	26
	2 cups green beans and carrots	22
	16 oz skim milk	24
Snack	8 oz skim milk	12
	3 oatmeal raisin cookies	23
	Total Calories = 4,992	**Total Carbohydrates = 749 g** *59% of total calories*

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several snacks distributes caloric intake throughout the day, preventing athletes from feeling "stuffed" or uncomfortable after eating. Calorie-dense foods increase energy intake considerably, without large increases in the volume of food consumed.

How many calories should be consumed during endurance training or competition?

The number of calories expended while participating in endurance sports varies. The energy requirements for an individual can be estimated based on the sport, the intensity and duration of activity, and the body weight of the athlete. However, often it is not physically or logistically possible for an athlete to fully match his or her energy expenditure with intake while exercising. Movement (e.g., running, biking), mental focus (e.g., mountain biking, race car driving), and lack of feasibility (e.g., swimming, rowing) can create circumstances where athletes are unable to meet their calorie needs. It can not only be extremely challenging for an athlete to physically consume enough food to match energy expenditure during activity, but also difficult for the body to digest high volumes of food without developing nausea or cramping. Therefore, it is more practical and realistic to develop a plan based on the nutrition basics needed for endurance performance: carbohydrates, fluids, and sodium.

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>
> Matching energy expenditure during exercise with energy intake may not be practical or feasible for endurance and ultra-endurance athletes. It is more important to develop a nutrition plan that focuses on the performance requirements of carbohydrates, fluids, and sodium rather than achieving energy balance.

For example, a 125-pound half-marathoner running a 6:30 minute/mile pace will burn approximately 775 calories in 1 hour of continuous running.[51] If this athlete were trying to match his energy needs by consuming a sports beverage (containing 50 calories per 8 ounces), he would need to drink 124 fluid ounces in 1 hour! An average range of fluid intake that can be consumed comfortably and safely for most athletes is approximately 24–48 ounces per hour—three to five times this amount is needed to obtain 775 calories. However, if the nutrition plan was based on fluid and carbohydrate needs, the requirements could be easily met. As mentioned in Chapter 3, it is recommended that athletes consume approximately 1.0–1.1 grams of carbohydrates per minute during exercise. Therefore, this athlete would need 60–66 grams of carbohydrates per hour. Assuming the sports beverage used contains 14–15 grams of carbohydrates per 8 fluid ounces, the runner would need to drink only about 34 fluid ounces per hour to meet his carbohydrate needs. Thirty-four fluid ounces per hour is much more manageable than 124 fluid ounces.

How many calories are required after a training session or competitive event?

A general guideline for endurance athletes is to consume 200–300 calories immediately following a training session or competitive event. This small snack should be followed by a substantial meal within the next 1 to 2 hours, supplying more calories, macronutrients, micronutrients, and fluids. Two hundred to three hundred calories is not a large amount of food and can be easily obtained by eating half of a sandwich, a large glass of milk, or a glass of 100% juice. Often, athletes complain of not wanting to eat immediately following exercise—especially intense exercise. However, the suggestion of consuming a small snack versus a full meal is often perceived as more manageable, is generally well-tolerated, and puts the recovery wheels in motion.

Are macronutrient needs different for endurance athletes?

The main difference between the diets of endurance athletes and those of athletes in other sports is in the quantity of food consumed, not necessarily the macronutrient composition of the diet. The extreme caloric demand of long-duration training, day in and day out, stresses the body's energy reserves, particularly the glycogen stores. Therefore, carbohydrates play a key role in the endurance athlete's diet. Similar to other athletes with high calorie needs, dietary fats are valuable for providing extra calories in a small volume of food. Another consequence of high calorie demands that is unique to endurance athletes is the use of protein for energy production. Proteins are not typically used by the body for energy production; however, they can play an energetic role, contributing up to 15% of the calories required during endurance and ultra-endurance sports. The bottom line is that endurance athletes need the same macronutrients as other athletes except in larger quantities so that the energy requirements of their sport can be met. The upcoming sections will outline more specific recommendations and guidelines for carbohydrate, protein, and fat intakes for endurance and ultra-endurance athletes.

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How important are carbohydrates to endurance athletes?

Carbohydrates are crucial to endurance athletes not only because they are an important energy source, but also because carbohydrates play a role in the rapid metabolizing of fats for energy. If the liver and muscles are depleted of glycogen, the endurance athlete experiences extreme fatigue (see Figure 12.2). This is called "hitting the wall," also known as **bonking.** When bonking occurs the athlete can no longer generate the energy needed to maintain his or her race pace and his or her perception of effort is greatly increased. The end result is a catastrophic decrease in performance.

bonking A condition in which the endurance athlete experiences extreme fatigue and an inability to maintain the current level of activity. It is also known as "hitting the wall" and results when the body has depleted muscle and liver glycogen levels.

Carbohydrate stores in the body are limited, and because of the long-duration and repetitive muscle activity involved with endurance training and sport performance, the need for carbohydrates is increased. In fact, the time to exhaustion during endurance exercise is directly related to the initial levels of stored glycogen in the muscles (see Figure 3.8 in Chapter 3). In addition, carbohydrates are also necessary for normal functioning of the central nervous system. Maintenance of blood glucose levels is important in preventing mental fatigue because nerve cells rely on blood glucose for energy. For these reasons, it is difficult to overstate the importance of adequate carbohydrate intake for daily training as well as performance in competition. For the endurance athlete, carbohydrates are truly the "master fuel."

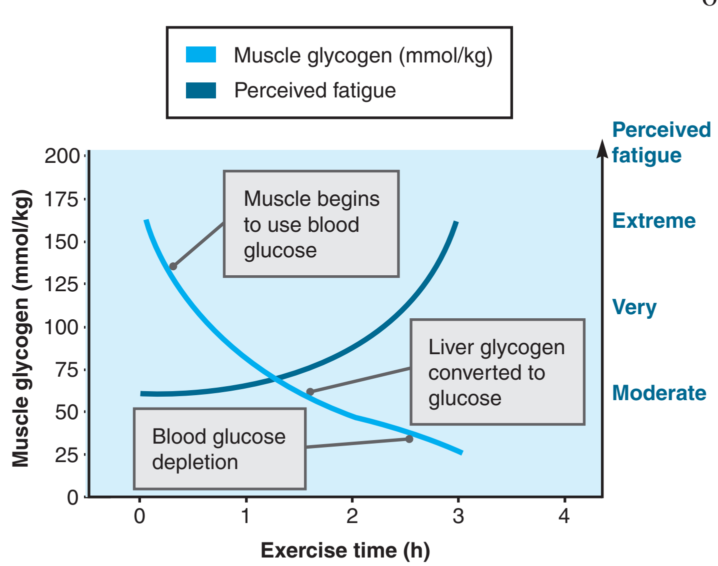

Figure 12.2 Glycogen depletion and the sensation of fatigue. If the liver and muscles are depleted of glycogen, the endurance athlete experiences extreme fatigue.

How are daily carbohydrate needs calculated for endurance athletes?

Current daily carbohydrate recommendations for endurance athletes range from 5–10 grams of carbohydrates per kilogram of body weight.[8,40,41] Applying this recommendation for Tony, a moderately active, 22-year-old male who weighs 150 pounds:

> 150 pounds ÷ 2.2 = 68.1 kilograms (kg) of body weight
>
> 68.1 kg ÷ 5–10 g of carbohydrate per kg = 340–680 g of carbohydrates per day

The recommended 340–680 grams is a large range! To narrow the recommendation for practical purposes, the calculated carbohydrate requirements need to be compared to the total calorie requirements of the athlete. Using the equation from Table 12.1, Tony's calorie needs are estimated to be 2,753–3,442 calories per day:

> 1. REE = (15.3 × BW) + 679
> 2. REE = (15.3 × 68.1) + 679 = 1,721
> 3. Tony's total energy needs = REE × activity factor = 1,721 × (1.6–2) = 2,753–3,442 calories per day

To establish a narrower range for a carbohydrate recommendation, determine the percentage of total calories coming from carbohydrates at each end of the spectrum. For example, knowing that each gram of carbohydrates has 4 calories, 340 grams of carbohydrates equals 1,360 calories, which is about 50% of 2,753 calories. Endurance athletes should generally aim for 50%–65% of their total calories from carbohydrates. Therefore, the recommendation of 340 grams of carbohydrates providing 50% of the estimated total daily calories is appropriate. However, the high end of the carbohydrate recommendation would not be appropriate for a 2,753-calorie diet, supplying nearly 99% of total calories (680 grams × 4) ÷ 2,753) × 100 = 99%! Even at the high end of the estimated calorie range (3,442 calories), 680 grams of carbohydrate would be supplying 79% of the total calories, which is generally too high for a balanced daily diet. Athletes should aim to meet both total calorie and carbohydrate requirements while maintaining a balance of all macronutrients. Recommendations for carbohydrates, as well as protein and fat, should always be compared to total calorie estimations.

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How should endurance athletes carbohydrate load before competition?

Carbohydrate loading is often cited as an effective way of maximizing muscle glycogen stores prior to an endurance event. As noted earlier, increasing muscle glycogen levels can increase the time to exhaustion and thus prevent or delay bonking (see Figure 3.8 in Chapter 3). In the 6 to 7 days leading up to a competition, endurance athletes should be **tapering** and resting their muscles. When tapering, endurance athletes decrease the volume and intensity of their training. During the taper, the percentage of carbohydrates consumed each day should slowly increase from about 45%–55% of total calories to 65%–70%. This progression allows for carbohydrate storage within the muscles to be maximized while training time is minimized. The combination of rest and a full fuel tank produces an athlete who is mentally and physically fresh and nutritionally energized for race day.

tapering A scheduled decrease in the volume and intensity of training 6 or more days prior to competition. The purpose is to allow for recovery from training and replenishment of glycogen stores in the liver and muscle.

A carbohydrate intake of approximately 8–10 grams of carbohydrates per kilogram of body weight, or about 500–600 grams of carbohydrates per day, is required to maximize glycogen stores. However, a further increase in carbohydrate intake may not necessarily further increase glycogen stores. Costill et al.[8] found that glycogen stores were similar when athletes consumed either 525 grams or 650 grams of carbohydrates per day. This study suggests that carbohydrate intake greater than 600 grams per day may not provide additional ergogenic benefits. For a 150-pound athlete, a range of 8–10 grams of carbohydrates per kilogram of body weight can be calculated as follows:

1. Convert pounds to kilograms: 150 ÷ 2.2 = 68.2 kg
2. Calculate carbohydrate needs: 68.2 kg × 8–10 grams carbohydrates/kg = 546–682 grams of carbohydrates per day

Because research has shown that consumption of greater than 600 grams of carbohydrates per day may not be beneficial, it should be recommended that this 150-pound athlete consume 546–600 grams of carbohydrates in the days leading up to a competition. If the athlete feels that energy is running low during workouts, or recovery is slow, then the grams of carbohydrates can be increased gradually until an ideal quantity within the range is realized. Training Table 12.1 uses the 3,000-, 4,000-, and 5,000-calorie per day example menus to demonstrate the quantity of food needed to reach approximately 500–600 grams of carbohydrates per day.

During a tapering period, the decrease in calorie expenditure in the days leading up to an event needs to be realized and factored into a carbohydrate loading plan. The percentage of total calories contributed by carbohydrates should increase in the days leading up to an event, approaching 8–10 grams of carbohydrates per kilogram of body weight. However, due to a decrease in calorie needs, total calories need to be cut in order to prevent weight gain and a feeling of sluggishness. The best way to decrease calories without sacrificing overall nutrition and the nutrients for recovery is to cut back on fat intake temporarily (until the event). Protein is needed to repair muscle tissue and therefore should not be decreased dramatically in order to cut calories. Because fiber intake should be moderated in the days leading up to an event, juices, milk, smoothies, and other liquid forms of carbohydrates are ideal for use during a taper.

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Keep in mind that the suggested range of 500–600 grams of carbohydrates is not an absolute number for all athletes. Daily nutrition plans must be developed on an individual basis and recommendations may fall above or below this range.

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Juices, milk, smoothies, and other liquid forms of carbohydrates are ideal for endurance athletes during a taper and carbohydrate loading.

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Athletes who are competing several times a week do not have time to taper for 7 days while increasing carbohydrate intake. These athletes should ensure an adequate consumption of carbohydrates on a daily basis, which can also effectively keep glycogen stores near their maximum.

Should carbohydrates be consumed in the hours or minutes prior to endurance activities?

Research has demonstrated that consuming carbohydrates in the hours leading up to an endurance training session or competition is critical for optimal performance, especially during activities lasting longer than 2 hours.[9,17] Carbohydrates consumed prior to exercise increase blood glucose, which leads to a sparing of muscle and liver glycogen, thus enhancing endurance performance. The question for endurance athletes is not if they should consume carbohydrates prior to exercise, but rather when and how many carbohydrates should be consumed.

Even though it appears obvious in the research that pre-exercise carbohydrate consumption can prevent fatigue, the reality is that many athletes choose to forego consuming any food, including carbohydrates, prior to training or competitions. Athletes need to be educated on the detrimental effects of this behavior. After an overnight fast, liver glycogen stores are depleted, which can lead to premature fatigue during exercise.[35] Some athletes justify not consuming carbohydrates before training because they plan to consume carbohydrate-rich sports beverages, gels, or bars during exercise. Although consuming these products during exercise is clearly advantageous, it does not completely negate the need for a pre-exercise meal.[6]

A recent study by Chryssanthopoulos et al.[7] examined the effects of a pre-exercise meal and carbohydrate consumption during endurance running as compared with running on an empty stomach (no pre-exercise meal) and no carbohydrate supplementation during exercise. The authors reported a 9% increase in running capacity when a meal (containing 2.5 grams of carbohydrates per kilogram of body mass) was eaten 3 hours prior to exercise versus when no meal was consumed. An additional endurance benefit (22% increase) was observed when the subjects ate a carbohydrate-rich meal 3 hours prior to exercise and consumed a 6.9% carbohydrate beverage during running, as compared to those who did not eat a pre-exercise meal and did not drink the sports beverage during running. Endurance athletes are encouraged to consume a well-rounded, carbohydrate-rich pre-exercise meal, and then continue consuming carbohydrates during exercise in order to optimize performance.

When is the ideal time to consume carbohydrates prior to endurance training or competition?

The ideal time for consuming carbohydrates prior to exercise has been debated. Popular thought has led to the recommendation of consuming carbohydrate-rich foods in the 2–4 hours leading up to exercise and avoiding carbohydrates, specifically high glycemic foods/beverages such as glucose, in the hour immediately prior to activity. The reasoning for this advice has been that the combined effects of insulin (secreted in response to the high glycemic index products) and muscle contraction mediated glucose uptake (physical activity) would result in hypoglycemia immediately prior to or at the onset of exercise and thus negatively affect performance. However, a review of the current literature has revealed that only one study has reported a decrease in performance, whereas a majority of the studies have shown either no impact or enhancement of up to 20% on subsequent endurance performance.[21]

A recent article studying the impact of precarbohydrate feedings on a series of 4,000-meter swims performed by triathletes confirmed a positive impact on performance when carbohydrates are consumed within an hour of exercise. Smith et al. (2002) examined the effect of consuming a 10% glucose solution 5 minutes prior to a 4,000-meter swim, the same solution 35 minutes prior to the swim, or the equivalent volume of a placebo, on swim time to completion. Although no statistical significance was found between the trials, the findings were meaningful, revealing a difference ranging from 24 seconds to 5 minutes in 8 out of the 10 subjects studied when either glucose protocol was followed compared with placebo. The reported time difference would make an impact on the final placement of a triathlete performing a similar distance swim in an Ironman distance race (3.8 km swim distance).

The timing of a pre-exercise carbohydrate meal will vary greatly based on the quantity of carbohydrates consumed and an athlete's individual tolerance. Athletes typically consume their pre-exercise meal as

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Endurance athletes should experiment and aim to eat far enough in advance that food digests well before competition, thus minimizing stomach and intestinal discomfort, but not so far in advance that hunger ensues.

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close as 30 minutes before the initiation of endurance exercise to as long as 4 hours prior. In general, the greater the quantity of carbohydrates consumed, the longer an athlete should leave between eating and the beginning of an exercise session. It has been suggested that athletes consume greater than 2 grams of carbohydrates per kilogram of body weight prior to endurance exercise in order to have a positive impact on performance.[15,16] For a female endurance athlete weighing 125 pounds, the quantity of carbohydrates required prior to a long-duration training session or competition would be 114 grams, calculated as follows:

1. Convert pounds to kilograms = 125 ÷ 2.2 = 56.8 kg of body weight
2. The minimum amount of carbohydrates needed prior to exercise = 2 × 56.8 kg = 114 g

As noted in the 3,000-calorie meal plan presented in Training Table 12.1, 114 grams can easily be obtained by eating 2 cups of raisin bran, 1 cup of skim milk, and a banana, which provides a total of 133 grams of carbohydrates.

Once an athlete knows the optimal quantity of carbohydrates to eat before endurance training, the athlete can then experiment with varying time periods between eating and exercise. The athlete should aim to eat far enough in advance to ensure the food digests well before exercising, thus minimizing stomach and intestinal discomfort, but not so long that hunger ensues. Therefore, the optimal timing of a pre-exercise carbohydrate-rich meal or snack will ultimately be determined by each athlete.

Should the endurance athlete consume carbohydrates during endurance activities?

As glycogen stores in the body are depleted, muscles rely more heavily on blood glucose for fuel, especially after 2–4 hours of continuous physical activity.[10] In order to maintain blood glucose for oxidation and continued energy production, athletes need to ingest carbohydrates while exercising. Although consuming enough carbohydrates during exercise can enhance endurance performance, ingesting too many carbohydrates can lead to stomach cramping, intestinal discomfort, and diarrhea, all of which can hinder performance. It is critical that athletes know their carbohydrate needs during activity and practice the ingestion of carbohydrate-rich foods and fluids during training to establish a nutrition plan based on personal preferences and tolerances.

As stated earlier in this chapter, carbohydrate needs during exercise are estimated at 1.0–1.1 grams of carbohydrates per minute of activity, or 60–66 grams of carbohydrates per hour. Some athletes can easily consume and digest upwards of 75–85 grams of carbohydrates per hour, whereas others can barely stomach 45–55 grams. Athletes need to experiment with varying quantities of carbohydrates surrounding the 60–66 gram range to determine the best estimate for them individually. Carbohydrates can be consumed through a variety of foods and fluids such as sports drinks, energy bars, energy gels, fruits, granola bars, fig cookies, and even sandwiches. In addition to individual preferences, a nutrition plan needs to be developed with the limitations of the sport in mind. Refer to the section "What meal planning/event logistics need to be considered during endurance events?" at the end of this chapter for several examples of nutrition plans developed to meet the nutritional needs of endurance athletes while factoring in the inherent limitations of the sport.

Is carbohydrate intake important during the recovery period after endurance training or competition?

Carbohydrates are critical for recovery from endurance exercise. Repeated exercise sessions of long duration can deplete muscle glycogen stores. If glycogen stores are not replenished, performance in subsequent training or competitive sessions will suffer. Carbohydrates should be consumed as soon as possible after exercise in adequate amounts for glycogen replenishment, based on individual needs.

To optimize the replenishment of glycogen after endurance exercise, carbohydrates should be consumed as soon as possible after exercise—ideally within 15–30 minutes after exercise. The short time between cessation of exercise and carbohydrate consumption allows for digestion, absorption, and delivery of carbohydrates to the muscles for storage when muscles are most receptive to glycogen storage. Endurance athletes who train daily at high intensity levels or for a long duration need to consume adequate amounts of carbohydrates within this time frame to be prepared for the next exercise session.

Endurance athletes should consume approximately 1.1 grams of carbohydrates per kilogram of body weight (0.5 grams/pound) within 15–30 minutes after exercise. For example, a 130-pound athlete in training for a marathon should consume approximately 65 grams of carbohydrates after exercise, and a 160-pound marathoner would need 80 grams of carbohydrates. Whenever possible, ath-

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TABLE 12.2 Sample Postexercise Carbohydrate Options

Food	Carbohydrates (in grams)
1 orange	15
1 cup soy milk	15
2 sheets graham crackers	20
2 small fig cookies	22
1 cup animal crackers	24
½ cup applesauce	25
1 cereal bar	25
1 cup chocolate milk	26
½ whole grain bagel	26
1 cup apple juice	27
1 whole banana	28
1 cup cranberry juice	36
1 cup fruit yogurt	40
12 oz carbohydrate energy drink	78

Note: Combine a high carbohydrate fluid with a high carbohydrate solid food to obtain approximately 0.5 g carbohydrates per pound of body weight within 30 minutes after exercise.

letes should focus on consuming whole food carbohydrates, juices, and low-fat dairy products to meet postexercise carbohydrate needs. Some athletes are not hungry after a long exercise session and may feel uncomfortable eating within 30 minutes after exercise cessation. In this case, athletes can consume high-carbohydrate beverages that are usually more tolerable than whole foods. This encourages rehydration as well as carbohydrate replenishment. **Table 12.2** provides some examples of both fluid and whole food combinations of carbohydrate sources to help endurance athletes meet their needs immediately postexercise. By following the guidelines for both the amount and timing of carbohydrate consumption after endurance exercise, athletes will recover quickly and perform well in their next training session.

There are many supplements marketed to endurance athletes for recovery from training sessions and competitive events. Before purchasing and using one of these supplements, consider the following:

- *How much carbohydrate is supplied in the supplement?* Some of the recovery supplements do not provide an adequate amount of carbohydrates. Athletes should calculate the number of grams they require and then determine whether the supplement is adequate.
- *What are the levels of other nutrients in the supplement?* Look on the Supplement Facts label for the %DV (% Daily Value) of the various nutrients supplied in one serving of the product. If specific vitamins or minerals are present in quantities greater than 100%–200% DV, the quantities are excessive and in general should be avoided.
- *How much does the supplement cost?* Supplements of any kind can cost two to three times as much as whole foods, milks, and juices. If an athlete is on a limited budget, whole foods are generally more affordable and often supply a variety of nutrients.
- *Are foods and beverages available?* Supplements, especially those that do not require refrigeration, are very useful when athletes are traveling or away from home. Powders, bars, and liquids can be transported easily, carried in a gear bag, and consumed quickly after exercise when other options are not available. However, if whole food, juice, or milk/alternative options are available, athletes should choose these items over supplements.

gaining the performance edge

Carbohydrates are truly the master fuel for endurance athletes. Individual needs should be calculated for daily consumption, as well as for before, during, and after training. Through trial and error, athletes will discover their individual tolerances, which should be built into the overall nutrition plan.

Are protein needs different for endurance athletes?

The dietary protein requirement for athletes has been a subject of debate for years, particularly for strength and power athletes. However, protein is important to the endurance athlete as well. Contrary to popular belief, recent research suggests that endurance athletes may actually require more protein than their resistance training counterparts. Tarnopolsky et al.[43] found that endurance athletes required approximately 1.4 grams of protein per kilogram of body weight in order to maintain nitrogen balance—a level higher than that needed by the resistance-trained subjects in the study. Although endurance athletes do not possess or strive to build the muscle mass of strength and power athletes, research has clearly demonstrated that endurance training results in increased protein turnover in the body. The trauma of repeated contractions and high impact activities can increase protein breakdown during exercise. Additionally, because of the huge energetic demands of endurance training

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it is now realized that some proteins are mobilized for energy. Protein is not typically used as a source of energy for the body; however, when caloric expenditure is high, the body will turn to proteins to supplement its energy needs. This reliance on proteins for energy is exacerbated when an athlete's diet is not adequate to maintain energy balance and/or carbohydrate intake is low. After endurance exercise, protein synthesis has been shown to increase 10%–80% within 4–24 hours.[4] Due to the rise in protein catabolism during activity and protein synthesis after exercise, appropriate daily protein intake is important. Endurance athletes should focus on consuming adequate quantities of protein daily to achieve a positive protein balance, which is important for muscle maintenance and recovery after daily training and competition.

How are daily protein needs calculated for endurance athletes?

Several factors need to be considered when determining daily protein needs for endurance athletes. A general recommendation proposed by Lemon[30,31] based on a review of the literature, as well as Tarnopolsky et al.'s finding stated previously, suggests endurance athletes should aim to consume 1.1 to 1.4 grams of protein per kilogram of body weight daily. Others have recommended a higher daily intake ranging up to 1.8–2.0 grams per kilogram of body weight for a greater safety margin.[53,54] Anywhere from 1.1 to 2.0 grams per kilogram can be appropriate for endurance athletes. The final recommendation for an individual should be based on the following:

- *How many hours a week and how intensely is the athlete training?* The greater the number of hours and the higher the intensity, the more protein an athlete will need. Recreational athletes should be encouraged to consume approximately 1.1–1.4 grams of protein per kilogram of body weight, whereas elite athletes should aim for daily intakes closer to 1.8–2.0 grams per kilogram.
- *Is the athlete aiming to lose, maintain, or gain weight?* Often endurance athletes are trying to lose weight in an attempt to increase their speed in sports such as long-distance running, duathlons, or cycling. When combining intense training and weight loss, protein needs will increase to the higher end of the spectrum (1.6–2.0 grams per kilogram). Athletes attempting to gain weight will also need more protein daily in order to build new tissue (1.6–2.0 grams per kilogram). Those with the goal of maintaining their weight will require a more moderate level of protein (1.1–1.5 grams per kilogram).
- *Is the athlete in a state of overtraining?* Due to the nature of endurance sports and the higher volume of training, endurance athletes are more likely than other athletes to experience the effects of overtraining. Individuals who are overtrained feel fatigued, sore, and stale due to the inability of muscles to completely recover from long, intense training sessions. These individuals can benefit from higher daily intakes of protein, aiding in the repair and recovery of muscles and tissues.
- *Is the athlete consuming adequate carbohydrates?* For all endurance athletes, emphasis should be placed on consuming enough carbohydrates, as well as adequate total calories, in order to spare protein. Without adequate carbohydrates and total energy, proteins are used at a higher rate for energy production, thus increasing total daily requirements for dietary protein. However, if glycogen stores are high, carbohydrates are consumed during activity, and total calorie needs are met, protein can be spared and daily intake will remain moderate. The importance of carbohydrates for protein sparing was demonstrated in a study conducted by Lemon and Mullin.[29] The researchers revealed that protein accounted for 4.4% of the energy needed to complete 1 hour of cycling at 60% VO_2max in a glycogen loaded state versus 10.4% of the energy required in a glycogen depleted state. The bottom line: Athletes should ensure carbohydrate intake is adequate while incorporating moderate amounts of protein on a daily basis.

Refer to **Table 12.3** for daily protein recommendations for endurance athletes.

How can a daily meal plan be developed to meet the protein needs of an endurance athlete?

Dave is a competitive cross-country skier who trains 3 hours a day, 6–7 days a week. Dave is 22 years old and weighs 170 pounds. In order to develop an example meal plan for Dave, the first step is to determine Dave's daily energy needs and protein requirements. The second step is to show Dave how he can put the recommendations into practice by developing an example meal plan that provides ade-

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TABLE 12.3 Daily Protein Recommendations for Endurance Athletes

Activity Level	Daily Protein Recommendation (g protein/kg body weight)
Recreational athlete, *exercising 10–12 hours per week*	1.1–1.3
Competitive amateur athlete, *training 12–20 hours per week*	1.4–1.7
Elite athlete, *training and competing 20+ hours a week*	1.7–2.0

quate calories and protein. Following the energy requirement equations listed in Table 12.1 and the protein requirement calculations presented in Table 12.3, Dave's needs can be calculated as follows:

1. *Determine Dave's calorie and protein needs:*

a. For a 22-year-old male, the energy estimation equation is:

REE = (15.3 × BW) + 679

Dave's body weight is 170 pounds or 77.2 kilograms

REE = (15.3 × 77.2) + 679 = 1,860 calories × (activity factor of 1.6–2.4)

Total energy needs = 1,860 × (1.6–2.4) = *~3,000–4,500 calories per day*

Dave's average energy needs = (3,000 + 4,500) ÷ 2 = *3,750 calories per day*

b. For an athlete exercising about 20 hours per week, the protein needs are:

Protein needs = 1.7–2.0 grams or protein per kilogram of body weight

Protein needs = (1.7–2.0) × 77.2 kilograms = *131–154 grams of protein per day*

Dave's average protein needs = (131 + 154) ÷ 2 = *143 grams or protein per day (15% of total calories)*

2. *Develop a meal plan to supply adequate calories and protein per day:* Modifying the 4,000-calorie example menu presented earlier in this chapter, a meal plan can be developed that meets Dave's needs for 3,000–4,500 calories per day as well as his requirement for 131–154 grams of protein each day. See **Training Table 12.2** for an example meal plan that meets Dave's total calories and protein requirements.

Training Table 12.2: Dave's Meal Plan

Meal/Snack	Food/Beverage	Protein Content (grams)
Breakfast	Smoothie:	
	2 frozen bananas	2
	2 cups skim milk	16
	1 scoop protein powder	8.5
Snack	2 oranges	2
	Granola bar	4
Lunch	1 cup chili	22
	3 oz roast beef sandwich	22.5
	2 cups fruit salad	4.5
During workout	48 oz sports beverage	0
Postworkout snack	6 oz yogurt	8
	1 cup dry cereal	2
Dinner	4 oz salmon	21
	2 cups wild rice	13
	3 cups salad with dressing	5
	16 oz skim milk	16
Snack	1½ cups frozen yogurt	10
	1 cup frozen blueberries	0
	Total Calories = 3,750	**Total Protein = 156 grams** *16% of total calories*

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What is the effect of consuming protein prior to endurance activities?

As established earlier in this chapter, carbohydrates consumed prior to endurance activities are critical to optimal endurance performance. Is protein intake just as important? The answer depends on when the protein is consumed.

Protein-rich foods consumed in the preactivity meal 2–4 hours prior to the initiation of endurance exercise contributes to a feeling of satiation and a slowing of digestion, thus maintaining energy levels for a longer period of time. In addition, some studies have suggested that protein consumption prior to exercise is beneficial in regards to the provision of **branched chain amino acids (BCAAs).** It has been suggested that consuming BCAAs before exercising might delay fatigue during exercise via a mechanism involving the attenuation of central fatigue; however, the effect of consuming BCAAs immediately prior to exercise has so far been shown to be small at best.[12,34] Carbohydrate-rich foods should still take center stage in the preactivity meal to supply the muscles with glucose for energy, while protein assumes a supporting role. Consuming too much protein before exercise can lead to a sluggish feeling due to a lack of carbohydrates as well as dehydration due to increased urine production to flush out the byproduct of protein breakdown, urea.

branched chain amino acids (BCAA) A group of amino acids whose carbon side chain, unlike other amino acids, is branched. The branched-chain amino acids include leucine, isoleucine, and valine.

If protein-rich foods are consumed within an hour of endurance exercise, some researchers have shown a negative impact on performance. Wiles et al.[50] reported a higher oxygen consumption rate during various exercise intensities as well as an increased rating of perceived exertion when subjects consumed a moderate-to-high protein meal within 1 hour of exercise. No negative effects were shown when the same quantity of protein was consumed 3 hours prior to exercise. Therefore, it appears that moderate protein intake before exercise is beneficial if consumed with adequate quantities of carbohydrates several hours prior to exercise. By consuming carbohydrates, protein, and very small amounts of fat before exercise, athletes can maintain a balance and variety of foods within one meal, which is the goal for all meals throughout training.

Should proteins be ingested during endurance activities?

A significant amount of research has demonstrated that amino acids are secreted from the muscle, oxidized, and metabolized during exercise, thus implying their usage and importance during endurance activities.[20,28] A majority of this research has focused on the BCAAs—leucine, valine, and isoleucine.

The magnitude of BCAA usage is an important consideration for endurance athletes. It has been reported that a mere 2 hours of exercise at 55% VO_2max oxidizes close to 90% of the daily total requirement for at least one of the BCAAs.[14] It appears that as endurance training intensity increases, the use of BCAAs also increases proportionately.[44] These studies reveal that amino acids are used during endurance exercise and thus suggest a need for increased overall daily protein intake for athletes. However, is it essential and beneficial to be consuming protein *during* an activity versus before and after training and competitions?

Some research has suggested that the consumption of protein during exercise may enhance endurance performance. Several theories have arisen:

- *Usage of protein for energy production:* Utilization of BCAAs and provision of Krebs cycle intermediates have been suggested as the pathways for energy production and metabolism with protein ingestion.[49]
- *Increased stimulation of insulin secretion:* A combination carbohydrate-protein supplement has been found to stimulate insulin secretion after prolonged exercise.[46,52] This rise in plasma insulin has been hypothesized to lead to an increased glycogen synthesis, thus aiding in recovery from exercise. Recent researchers have suggested that it is possible that a similar action may occur during exercise—that protein (with carbohydrate) ingestion during exercise might increase insulin secretion and in turn spare muscle and liver glycogen usage during exercise. Some studies have found an ergogenic effect of adding protein to a carbohydrate supplement during exercise; however, they have failed to directly correlate insulin levels or any other plasma or metabolic reason for the enhanced performance.[55]
- *Suppression of central fatigue (see Figure 12.3):* During endurance exercise there is a decrease in plasma BCAAs. At the same time, tryptophan is unloaded from albumin at a higher rate into the plasma. BCAA and tryptophan compete for the same transporters across the blood-brain barrier; therefore, when BCAA levels decrease, a higher percentage of tryptophan can attach to the transporters, increasing

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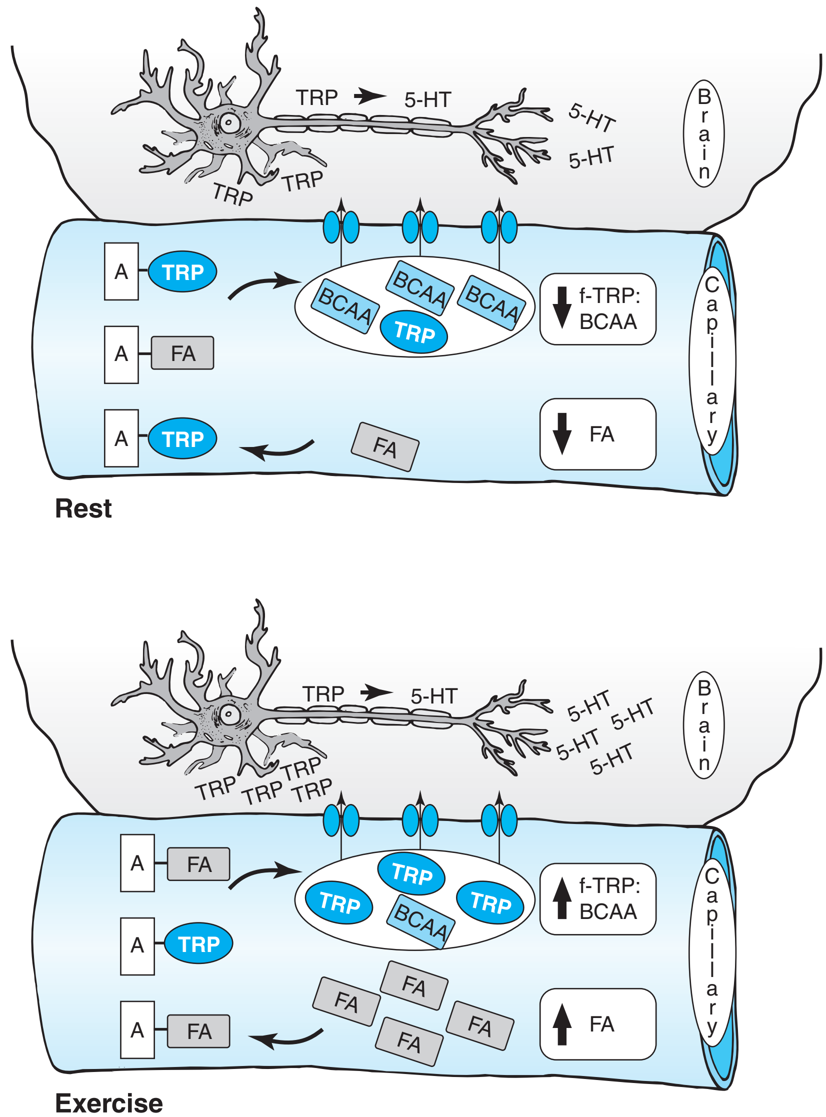

Figure 12.3 Suppression of central fatigue. A decrease in branched chain amino acids (BCAA) levels can cause an increase in the brain's uptake of tryptophan (TRP). Tryptophan converts into serotonin (5-HT), which has a relaxation effect, resulting in fatigue and ultimately the cessation of exercise. A = albumin, FA = Fatty acid, f-TRP = Free tryptophan.

the brain's uptake of tryptophan. Tryptophan converts into serotonin, which has a relaxation effect, ultimately causing an athlete to feel fatigued and eventually cease exercising.[11] Some researchers have suggested that the ingestion of BCAAs during exercise will maintain the plasma concentration and thus delay fatigue and enhance endurance performance. This theory has been supported in some studies and refuted in others.[2,3,33,45] More research is needed to draw definitive conclusions.

These theories and relevant research are still in their infancy and require more studies to clarify the actions of ingested proteins and amino acids during exercise and their associated mechanisms and effects on performance.

Regardless of actual performance benefits from ingesting amino acids, foods and drinks containing protein can be beneficial to consume during endurance activities, especially ultraendurance events, from a practical standpoint. Items containing some protein in general will be less sweet but more salty than the typical endurance sport fare. When a training session or competition continues for 4–24 hours, flavor fatigue is of great concern because when an athlete stops ingesting calories, energy levels will soon plummet. Many sports nutrition products have a sweet flavor, and therefore salty foods are generally a welcomed change of taste. Conversely, if too much protein is consumed, gastric emptying can be delayed, which can cause stomach cramping and delayed absorption of nutrients. Some practical ideas for items that have moderate amounts of protein, are easily digestible, and are compact for carrying during activities such as hiking, daylong bike trips, or adventure races include energy bars, sesame sticks, peanut butter sandwiches, peanut butter crackers, meat jerky, trail mix, and mixed nuts.

Is protein needed for recovery from endurance exercise?

Although not as critical as carbohydrate consumption, protein consumption after endurance exercise aids in the recovery process. Several proposed roles of protein after endurance exercise include enhancing the insulin response to accelerate glycogen synthesis and rebuilding damaged muscle tissue.

Research began with the investigation and discovery that protein added to a carbohydrate supplement can enhance the insulin response, suggesting a hastened delivery of nutrients into the cells versus carbohydrates alone.[38,42] Further studies then explored whether the increase in insulin levels correlated with greater amounts of glycogen several hours postexercise. A study completed by Zawadzki et al.,[52] mentioned in Chapter 5, is often cited when justifying the need for protein after exercise to

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maximize glycogen levels. The researchers reported that after several hours of cycling, the athletes who consumed a combination carbohydrate and protein supplement had higher levels of glycogen than the cyclists who consumed only carbohydrates. However, it should be noted that the combination supplement had more total calories than the carbohydrate-only supplement, which may have contributed to the enhancement, not necessarily the pairing of protein and carbohydrates. Regardless, protein-rich foods consumed after exercise will provide a unique profile of nutrients as well as supply amino acids needed for muscle repair.

Researchers at Indiana University (Karp et al.[61]) studied chocolate milk compared to traditional carbohydrate replacement beverages as a recovery aid following exhaustive exercise in nine endurance-trained cyclists. Subjects performed an interval workout to deplete muscle glycogen, followed by 4 hours of recovery and then an endurance performance trial to exhaustion. Subjects consumed an equivalent amount of carbohydrates (1 g/kg body weight) from a traditional ready-to-drink carbohydrate replacement drink or chocolate milk immediately after the depletion exercise and again 2 hours later. Results showed that consumption of chocolate milk after exercise was equal to or better than traditional carbohydrate drinks in time to exhaustion and total work for the endurance trial to exhaustion. More research is needed to determine if the combined protein and carbohydrates in chocolate milk, instead of carbohydrates alone, helped improve these athletes' performance during the endurance trial phase of the study. Chocolate milk is highly palatable and inexpensive compared to many ready-to-drink sport supplements. This research could prove valuable for athletes to practically and inexpensively apply recovery nutrition to their daily diet.

The repetitive nature of endurance sports has led to the recommendation to consume protein after exercise to repair muscle tissue. Especially after repetitive eccentric movements, such as running, muscles may experience microtrauma requiring amino acids as building blocks to repair the damage. Some research suggests that the microtrauma to the muscle cells contributes to muscle soreness after exercise. Therefore, if protein-rich foods consumed immediately after endurance exercise supply amino acids for hungry muscles, muscle soreness may be decreased.

Similar to carbohydrate foods, protein-rich foods should be consumed within 15–30 minutes post-exercise to maximize the delivery of nutrients to the muscles. Approximately 6–20 grams of protein immediately following endurance exercise appears to be sufficient to initiate the recovery process. Continuing to consume protein in subsequent meals throughout the day will supply the total daily requirements of protein for an athlete and thus aid in the continuous rebuilding and repair of tissues before the next endurance exercise bout.

Should endurance athletes eat more fats to meet their energy needs?

Because the body relies on fats for energy and the energy requirements for endurance athletes are high, one might be foolishly misled into thinking that fat intake should be of prime importance in the diet of endurance athletes. Numerous studies have demonstrated that endurance training does indeed cause metabolic adaptations that enables the body to rely more heavily on fat metabolism for energy during exercise (see Figure 3.7 in Chapter 3). This is an important adaptation because it decreases the drain on the body's somewhat limited carbohydrate reserves (Figure 12.4). However, the onset of fatigue during endurance training and competition is not caused by exhausting the body's fat reserves; in most cases it is due to depletion of carbohydrate stores. Therefore, increasing the percentage of calories from fats in the diet does little to enhance performance because it is the availability of carbohydrates that ultimately limits the metabolizing of fats in relation to delaying the onset of fatigue.

However, some researchers have suggested that a high-fat diet, either consumed for a single meal or for several weeks, may actually be advantageous to endurance athletes. The theory is that because fat usage during exercise is due in part to the concentration of free fatty acids in the plasma, if blood levels can be increased, more fats will be used for energy, sparing carbohydrates and possibly enhancing endurance performance. Studies have investigated the ergogenic benefit of short-term and long-term high-fat diets to determine whether increasing the fat content of one meal or the daily diet can cause the body to adjust and adapt to become a higher fat-burning machine.

Several methodical strategies have been used in short-term high-fat studies. Most of the research showing a positive result from a single high-fat meal has included the infusion of heparin. Heparin stimulates lipoprotein lipase activity, which in turn in-

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creases the plasma levels of free fatty acids in the blood. Because the infusion of heparin before endurance activities is not considered a sound medical practice, these studies provide little relevant information to the practical world of endurance sports. In the studies that involve strictly high-fat meals and subsequent tests of endurance (without heparin injections), most show no benefit over a high-carbohydrate meal.[36,39]

fat loading The dietary practice of eating a diet high in fats (i.e., > 60% of total daily calories) 3 to 5 days prior to competition.

The effect of **fat loading** (i.e., consuming high levels of fat in the diet) on endurance performance has been evaluated in studies of high-fat diets consumed for 3–5 days prior to exercise. Studies have compared the effect of a high-fat diet (more than 74% of total calories) versus a high-carbohydrate diet (more than 77% of total calories) on performance tests to exhaustion. Results have consistently shown that high-fat diets have a negative impact on endurance performance.[15,18,27] At this time, fat loading cannot be recommended as a method of improving performance in endurance activities.

Another set of studies has focused on the effect on endurance performance of a high-fat diet consumed for 1–4 weeks. It appears that individuals consuming a high-fat diet for this moderate length of time can adapt to using more fat for fuel, and thus increase time to exhaustion in endurance tests. Lambert et al.[28] studied five endurance cyclists who consumed either a high-fat diet (76% of total calories) or a high-carbohydrate diet (74% of total calories). After 2 weeks on the diet, the subjects consumed a normal diet for 2 weeks and then consumed the opposite diet plan for 2 weeks. After each 2-week experimental set, the cyclists performed a Wingate power test, a high-intensity exhaustion test (90% of VO_2max), and a moderate-intensity exhaustion test, cycling at 60% of VO_2max. No difference was noted on the power test or the high-intensity test. However, the cyclists performed better in the moderate-intensity cycle test (increased endurance) when consuming the high-fat diet. The authors attributed the benefit to a lower respiratory exchange ratio, meaning the individuals were relying more on fats for energy than carbohydrates. However, it should be noted that the endurance test was performed after two other intense physical tests, with little rest between tests, which can impact endurance performance and thus make the interpretation of these results difficult. Other studies have suggested a benefit from a moderate- or high-fat diet, but with varying levels of fat intake, the use of trained and untrained subjects, and different testing/diet protocols, comparisons are difficult and drawing conclusions has been challenging.[23,48]

Finally, long-term studies (>7 weeks) on the effects of a high-fat diet on endurance performance have failed to show an ergogenic benefit.[22] In addition to inconsistent results from short-term to long-term high-fat consumption, high-fat diets should be evaluated based on the following:

- Fat takes longer to digest, and therefore high-fat meals put the athlete at higher risk for gastrointestinal issues during exercise.
- High-fat diets can lead to flavor fatigue relatively quickly, causing an athlete to stray from the prescribed diet, thus making a long-term plan impractical.
- High-fat diets have been shown to negatively affect cardiovascular health long term, and therefore are not generally recommended.

Currently, the available research does not support a widespread recommendation for athletes to consume a high-fat meal prior to endurance exercise or to follow a high-fat diet plan. More research is needed to fully understand the effects of high-fat meals on endurance athletes and the mechanisms involved. Dietary fat provides additional calories necessary for athletes with high daily energy expenditures. Foods that contain fat also provide vitamins and minerals that are essential to optimal sport performance in endurance events. Endurance athletes can consume moderate amounts of fat, if desired, so long as dietary fat does not replace the carbohydrates and protein necessary for success in endurance exercise.

How are daily fat needs calculated for endurance athletes?

For endurance athletes, fat requirements are generally calculated after determining carbohydrate and protein needs. Carbohydrates are the main fuel in the body for endurance sports and protein is critical for repairing muscle tissue after long-duration activities, especially weight-bearing sports. Therefore, both macronutrients take precedence over fat. However, the importance of dietary fat should not be downplayed—fatty acids are critical for meeting total energy needs, obtaining essential fatty acids, and absorbing fat-soluble vitamins from foods and beverages.

One of the main functions of fat in the endurance athlete's diet is to provide a concentrated source of

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energy. For athletes training 3–6 hours or more a day, energy needs can climb into the 4,000–6,000 calorie range. Consuming enough food to meet these energy needs can be challenging, especially if an athlete is aiming to meet these needs with predominantly carbohydrates and protein. Meeting high energy needs with mainly carbohydrate- and protein-rich foods will require an athlete to eat very large volumes of food that can cause gastrointestinal discomfort. The large volume of food may also be challenging from a schedule standpoint, requiring an athlete to eat 6+ meals and snacks a day; eating that frequently becomes difficult when 3–6+ hours a day are spent exercising. Conversely, fat-rich foods are calorie-dense, allowing an athlete to consume more calories with less food and without feeling too full or bloated.

As with any athlete, moderate amounts of fat must be consumed on a daily basis in order to obtain the essential fatty acids provided in food. Endurance athletes—especially those trying to lose weight or body fat—often become too focused on carbohydrates and lean protein sources, while attempting to minimize or eliminate fat intake. Athletes need to remember that fat is a healthy part of a daily diet. Essential fatty acids provide energy, help to produce hormones in the body, surround all nerves contributing to proper nerve function, and aid in the absorption of fat-soluble vitamins and antioxidants.

Fat-soluble vitamins—vitamins A, D, E, and K—are all critical nutrients for an endurance athlete. Vitamins A and E are classified as antioxidant vitamins, helping to neutralize oxidative damage that occurs during exercise. Vitamin D works closely with calcium to provide structure and strength to bones—essential for weight-bearing activities and the prevention of stress fractures. Vitamin K has the role of helping blood to clot. Cuts and gashes can occur during some endurance sports, such as mountain biking or adventure racing, and an athlete will be thankful that their blood can clot properly, ceasing the flow of blood and allowing the injury to heal. All of these vitamins cannot be absorbed to their full capacity if not consumed with a small amount of dietary fat.

In summary, fat is important in an endurance athlete's diet, but only moderate amounts are needed. If carbohydrate needs are calculated at 50%–65% of total calories, and protein needs fall between 12% and 20%, then the remaining calories should be contributed by fat—approximately 20%–35% of total calories. Most often, fat needs for endurance athletes will be calculated at the lower end of this range. However, if calorie needs are very high, fat intake at 30%–35% of total calories will ensure adequate total calories, a feeling of satiety, and a decrease in the total volume of food that needs to be consumed in one day.

For example, Brooke is a cyclist, riding 150–200 miles a week. She is 30 years old, is 5′8″, weighs 132 pounds, and wants to maintain her weight. In order to calculate her fat needs:

1. *Determine her total energy needs:*

   REE = (14.7 × 60 kg) + 496
   = 1,378 × (1.6–2.4) = ~2,200–3,300

   Brooke's average calorie needs
   = *2,750 calories per day*

2. *Determine her carbohydrate (CHO) needs:*

   5–10 grams carbohydrates × kilograms of body weight = 5–10 g × 60 kg = 300–600 grams

   Brooke's average carbohydrate needs = *450 grams of carbohydrates per day (65% of total calories)*

3. *Determine her protein needs:*

   Training 12–20 hours per week = 1.4–1.7 grams of protein per kilogram of body weight (1.4–1.7) × 60 kg = 84–102 grams of protein

   Brooke's average protein needs = *93 grams of protein per day (14% of total calories)*

4. *Determine her fat needs:*

   Remaining calories based on percentage = 100 – 65 (CHO) – 14 (protein) = 21% of total calories from fat

   21% of 2,750 = 577.5 calories ÷ 9 kcal/gram of fat = *~64 grams of fat per day*

In summary, for endurance athletes, calculate total energy needs first. Then, determine carbohydrate and protein requirements in total grams as well as a percentage of total calories. The remaining percentage of calories should come from fat. Double-check the calculations to ensure that fat intake does not fall below 20% of total calories, to prevent fatty acid deficiencies, and does not exceed 30%–35%, for heart health and overall dietary balance. The ranges for carbohydrates, protein, and fat provide a wide spectrum of appropriate options in order to develop a nutrition plan that incorporates balance, variety, and moderation while simultaneously providing enough fuel for an athlete to remain energetic, fresh, and recovering well from hard workouts and competitions.

Should fats be eaten while performing endurance activities?

During low-to-moderate-intensity activities, a majority of energy is derived from fatty acids in the

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Figure 12.4 Endurance training causes metabolic adaptations that enable the body to rely more heavily on fat metabolism for energy during exercise. This is an important adaptation because it decreases the drain on the body's somewhat limited carbohydrate reserves.

blood. Because fats are such an important fuel source, it would seem logical that consuming fats (long-chain triglycerides) while competing in endurance sports would be a good practice. However, other factors must be taken into consideration regarding fat intake during competition. First, depleting the body's fat stores, even on the leanest of individuals, is not a likely scenario and thus not an energetic cause of fatigue. Additionally, fatty foods are slow to digest, delay gastric emptying, and may cause gastrointestinal cramping and diarrhea—none of which will enhance performance. Despite the negative effects of consuming dietary fats during endurance exercise, some researchers have suggested that ingestion of **medium-chain triglycerides (MCTs)** may be beneficial by sparing endogenous carbohydrate stores and enhancing endurance performance. MCT supplements marketed to endurance athletes have suggested benefits such as increased energy levels, enhanced endurance, increased fat metabolism, and lower body fat levels. Although these claims sound appealing, research has not been able to consistently support these statements.

medium-chain triglycerides (MCT) A glycerol molecule with three medium-chain fatty acids attached.

An early focus of research was centered on the fact that MCTs can be oxidized as rapidly as exogenous glucose. The theory derived from this fact was that MCTs could potentially spare the usage of muscle glycogen as well as exogenous glucose during endurance exercise, thus delaying fatigue. Two different studies[13,25] from the early 1980s with similar methodology revealed similar results. Both studies compared the effects of consuming 25–30 grams of MCTs or 50+ grams of carbohydrates before 1 hour of exercise at 60%–70% VO_2max on substrate utilization and glycogen sparing. The amount of carbohydrates and fat used during the hour of exercise was virtually identical across experimental groups and glycogen stores were not spared.

The next step was for researchers to investigate the effects of larger quantities of MCTs to determine if earlier studies did not find a benefit due to low dosages. It should be noted that earlier studies documented preliminary findings of gastrointestinal intolerances of MCTs at doses higher than 50–60 grams.[25] Despite this information, future studies were completed with doses upwards of 85 grams of MCTs. The first study performed by Van Zyl and associates[47] studied the effects of glucose, MCT, or glucose plus MCT ingestion during cycling. Six endurance-trained cyclists performed a 2-hour bout of cycling at 60% VO_2max, followed by a 40-kilometer time trial. While cycling on separate occasions, the subjects consumed one of three beverages in random order: 10% glucose, 4.3% MCT, or 10% glucose + 4.3% MCT solution. The MCT-only beverage negatively affected the time trial performance by 5.3 minutes, while the combination beverage improved performance by 1.7 minutes compared to glucose alone. Unfortunately, muscle glycogen levels were not directly measured in this study, and therefore the glycogen sparing theory of MCTs could not be confirmed.

A follow-up study was performed by Jeukendrup and associates,[26] once again testing cyclists consuming glucose only, MCT only, or a combination beverage. Several differences in experimental design were implemented as compared to the Van Zyl study[47]:

1. A 5% MCT solution was used instead of a 4.3% solution (the 10% glucose solution remained the same).
2. A placebo group was included.
3. The time trial after the 2 hours of cycling at 60% VO_2max involved the maximum amount of work produced in 15 minutes versus the time to complete a 40-kilometer distance.
4. Carbohydrate and protein utilization during exercise was measured.

The authors found no difference in performance amongst the placebo, glucose, and glucose + MCT trials. However, they did find a 17%–18% decrease in performance when cyclists consumed the MCT-only beverage. The MCT beverage also did not alter

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carbohydrate or protein utilization during exercise, thus not sparing glycogen stores. It was documented that several subjects vomited during the MCT trials and others suffered from diarrhea.

In conclusion, long-chain triglycerides are not recommended for consumption during endurance sports. Small amounts may be consumed during ultra-endurance events lasting more than 4–6 hours without consequence; however, the amount should remain minute, with the focus placed primarily on carbohydrates and secondarily on protein. Some examples of fat-containing foods that may be tolerated during long-duration activities include peanut butter sandwiches, trail mixes, and sesame sticks. Intake of these foods should be tested during training and incorporated based on individual tolerance. Although a few researchers suggest a benefit of consuming small amounts of MCTs during endurance activities, the results have not consistently shown improvements in endurance performance. Although greater amounts may have a more significant impact on substrate utilization, large quantities of MCTs have also been shown to increase gastrointestinal distress. At this time, a recommendation cannot be made for endurance athletes to consume MCTs prior to and during training or competition.

Is fat needed for recovery from endurance exercise?

Unlike carbohydrates and protein, it is not essential to replace fat used during endurance exercise by consuming certain quantities or types of fat immediately following training or competition. The body's stores of fat are so great that they will not be depleted in an exercise session, even after prolonged endurance events. Because ingesting carbohydrates and protein is the main priority after endurance training, allowing the replacement, restoration, and replenishment of muscles, fat should be kept to a minimum. Fat causes the stomach to empty more slowly than do carbohydrates and protein, which could potentially delay the delivery of nutrients to the muscles in a timely fashion. However, fats add flavor to foods and create a sense of satiety, and therefore can be included in small amounts in the postexercise meal or snack.

Are vitamin/mineral needs different for endurance athletes?

Endurance athletes need higher levels of various nutrients, including some vitamins and minerals, as compared to their sedentary counterparts. But are specific vitamins and minerals of greater importance to endurance athletes versus team sport or strength/power athletes? Although all vitamins and minerals are needed in adequate amounts for proper health and bodily functioning, a handful of vitamins and minerals are in the spotlight for endurance athletes: B vitamins, iron, calcium, vitamin C, vitamin E, sodium, and potassium.

Why are the B vitamins important for endurance athletes?

B vitamins, specifically thiamin, riboflavin, and niacin, are involved in energy production pathways and thus are required in higher amounts for endurance athletes.[57] Thiamin plays a role in the conversion and utilization of glycogen for energy and the catabolism of branched-chain amino acids. Riboflavin is highly involved in the production of energy from carbohydrates, proteins, and fats for both health and performance. Niacin is a component of two coenzymes: nicotinamide adenine dinucleotide (NAD) and nicotinamide adenine dinucleotide phosphate (NADP). These coenzymes are involved in oxidation-reduction reactions required for the progression of metabolic pathways toward the synthesis of fatty acids and glycogen.

Increased intake of these B vitamins is important on a daily basis, but is not necessarily required during exercise. The key is for endurance athletes to consume thiamin-, riboflavin-, and niacin-rich foods throughout the day, at meals and snacks. See **Table 12.4** for examples of thiamin-, riboflavin-, and niacin-rich foods.

Why is iron important for endurance athletes?

Iron is best known for aiding in the formation of compounds essential for transporting and utilizing oxygen (myoglobin and hemoglobin), and is therefore critical for aerobic activities and endurance training. Iron deficiency is one of the most common nutrient deficiencies in the United States and therefore deserves special mention to and the attention of endurance athletes. Due to the nature of endurance sports, athletes experience an increased loss of iron. **Hematuria,** or the presence of hemoglobin or myoglobin in the urine, is due to a breakdown of red blood cells. The breakdown of red blood cells, also known as **hemolysis,** results in the release of hemoglobin and ultimately its elimination from the body via urine. Hemolysis, which is believed

hematuria The presence of hemoglobin or myoglobin in the urine. Hematuria is an indicator of hemolysis.

hemolysis The breakdown of red blood cells.

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TABLE 12.4 Key Vitamins and Minerals for Endurance Athletes

	Importance Related to Endurance Sports	Food Sources	Critical Consumption Time Frame
Vitamins			
Thiamin	Energy production	Fortified and whole grains, legumes, wheat germ, nuts, pork	Daily meals and snacks
Riboflavin	Energy production	Milk, yogurt, bread and cereal products, mushrooms, cottage cheese, and eggs	Daily meals and snacks
Niacin	Energy production	Beef, poultry, fish, legumes, liver, seafood, fortified and whole grain products, mushrooms	Daily meals and snacks
Vitamin C	Antioxidant	Citrus fruits, berries, melon, tomatoes, green leafy vegetables, bananas, sweet potatoes	Daily meals and snacks as well as after intense, long training sessions
Vitamin E	Antioxidant	Nuts, seeds, wheat germ, fortified cereals, strawberries	Daily meals and snacks as well as after intense, long training sessions
Minerals			
Iron	Oxygen-carrying compounds and energy-producing enzymes	Beef, poultry, fish, soy products, dried fruits, legumes, whole grains, fortified cereals, green leafy vegetables	Daily meals and snacks
Calcium	Bone strength	Milk, yogurt, cottage cheese, hard cheese (and nondairy alternatives), fortified foods, and juices	Daily meals and snacks
Sodium	Electrolytes lost in sweat	Table salt, condiments, canned foods, processed foods, fast foods, smoked meats, salted snack foods, soups	Daily meals and snacks, during workouts lasting longer than 4 hours, after exercise to replenish sodium losses
Potassium	Electrolytes lost in sweat	Fruits, vegetables, coffee, tea, milk, and meat	Daily meals and snacks, small amounts during exercise, after exercise to replenish potassium losses

to be at least partially due to repeated impact, is common in distance runners.[58] Nonimpact endurance sport athletes, such as rowers or cyclists, can also experience hemolysis due to loss from the intestinal wall, in urine or feces, due to an irritation caused by equipment and body friction, oxidative stress caused by the formation of free radicals, and/or the consumption of nonsteroidal anti-inflammatory drugs.[58,59] Iron can also be lost through sweat. Endurance athletes lose a lot of sweat on a daily basis, further justifying an increased emphasis on adequate daily intake of iron.

Endurance athletes should focus on consuming iron-rich foods on a daily basis at meals and snacks. Similar to B vitamins, it is not necessary to consume iron-rich foods during activities. See Table 12.4 for examples of iron-rich foods.

Why is calcium important for endurance athletes?

Calcium is widely recognized as a bone strengthening mineral. However, calcium's role in endurance performance extends beyond the skeleton. Calcium helps to produce fibrin, the protein responsible for the structure of blood clots. It is required for proper nerve function, releasing neurotransmitters that facilitate the perpetuation and activation of nerve signals. Calcium is pumped into and out of muscle cells to initiate both muscle contraction and relaxation in smooth muscle, skeletal muscle, and the heart. These functions are all essential for endurance athletes to maintain the intensity and duration of training and competition. During exercise, heart rate, muscle contraction and relaxation, and nerve impulse activity are all increased at incredible rates for sustained

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periods of time. Calcium also activates several enzymes that affect the synthesis and breakdown of muscle and liver glycogen, which is the main energy source during endurance exercise. Although critical in many ways for peak performance, many athletes are consuming suboptimal amounts of calcium on a daily basis. By striving for three to four servings of milk/alternatives, or other calcium-rich sources every day, athletes can meet their calcium needs. Calcium intake is not required during training sessions or competitions. Calcium stored within the body and the small amounts consumed in preexercise meals will provide the calcium needed during activity for proper nerve function and muscle contraction. See Table 12.4 for examples of calcium-rich foods.

Why are vitamins C and E important for endurance athletes?

Vitamins C and E have recently been acknowledged as potent antioxidants, helping to combat the oxidative damage that can occur during intense endurance exercise. Some research has shown that vitamins C and E actually work in concert with one another, enhancing each other's antioxidant properties.

Megadose supplements of vitamins C and E are often marketed to endurance athletes, touting enhanced recovery from intense workouts. Although these vitamins can make an impact on the recovery process, there is a safe and acceptable limit to daily intake. Vitamin C intake of 250–500 mg per day is above the RDA of 90 mg for males and 75 mg for females, yet far below the tolerable upper limit (UL) of 2,000 mg daily for adults.[62] Intake of 250–500 mg will assure that endurance athletes are meeting minimum needs and also possible additional antioxidant needs from the added stress of physical activity. This level is easily obtained through a balanced diet including plenty of fruits and vegetables and meeting daily energy needs. Supplementation of vitamin E has become quite popular with endurance athletes due to recent studies touting its antioxidant abilities.[63] This research is conflicting (see Chapter 6); a prudent approach to vitamin E intake is to remain below the UL of 1,000 mg (1,500 IU) daily. Endurance athletes who may not meet daily energy needs or are restricting dietary intake for weight control may require vitamin E supplementation. Because large amounts of vitamin E are rarely toxic, supplementation at far higher than the 15 mg (23 IU) RDA is not a concern for most endurance athletes. However, it is also not clear if and at what level of supplementation vitamin E might benefit endurance athletes' performance. Combined dietary and supplemental vitamin E intakes of 100–270 mg daily (or approximately 150–400 IU) is appropriate and will assure adequate intake without concern for negative side effects. See Table 12.4 for examples of vitamin C- and vitamin E-rich foods.

Why are sodium and potassium important for endurance athletes?

Sodium and potassium are crowned as heroes for their critical roles during endurance exercise. Sodium, one of the extracellular **electrolytes**, acts in conjunction with potassium, one of the intracellular electrolytes, to maintain proper fluid balance throughout the body during long-duration exercise. The interchange and flow of these electrolytes into and out of cells is responsible for the transmission of nerve impulses and muscle contractions. Sodium and potassium are both lost in sweat; however, sodium losses are of greater magnitude and significance. If sodium loss during exercise is excessive, without replacement, a life-threatening condition called hyponatremia can result. Sodium also aids in the absorption of glucose, which makes it a key component to any sports beverage.

electrolytes Positively or negatively charged ions found throughout the body. The body uses the electrolytes to establish ionically charged gradients across membranes in excitable tissues such as muscle and nerves so that they can generate electrical activity. The most well-known electrolytes are sodium (Na^+), potassium (K^+), and chloride (Cl^-).

Most Americans, including athletes, consume plenty of sodium on a daily basis. For athletes participating in ultra-endurance events, adding a little more sodium to meals and snacks in the days leading up to an event can help to "stockpile" a little extra sodium for race day. Sodium consumption during endurance training and competitive events is important for health and performance. Refer to the following section, "Why are fluids critical to endurance performance?" for more information on calculating sodium needs for athletes during endurance events as well as guidelines for developing a nutrition plan that includes sports beverages, foods, and salt supplements. The replacement of salt after endurance exercise is easily accomplished by consuming salty foods and beverages.

On the other hand, most Americans, including athletes, are not doing a good job of consuming enough potassium on a daily basis. This suboptimal intake has been attributed to a low consumption of fruits, vegetables, and low-fat dairy products. En-

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Figure 12.5 Choose foods with potassium and sodium after long exercise bouts to replenish these lost electrolytes.

durance athletes should be encouraged to eat more of these foods every day. During exercise, potassium can be obtained from sports beverages, as well as commonly consumed endurance fare such as bananas and oranges. See Table 12.4 and Figure 12.5 for examples of sodium- and potassium-rich foods.

Why are fluids critical to endurance performance?

As discussed in Chapter 8, 60% of our body weight is water. Fluid intake and maintenance of body water levels are critical to the endurance athlete for several reasons, in particular for the regulation of body temperature and maintenance of blood plasma volume. During exercise, the body's primary means of cooling itself is through the evaporation of sweat. Failure to adequately rehydrate during and after training leads to dehydration, which in turn results in elevated body temperatures during exercise. Elevated body temperatures cause an increased strain on the cardiovascular system, which is already a weak link in the aerobic power of most athletes, and leads to overheating of the body, which has negative and sometimes deadly consequences.

Blood plasma volume is one of the most important determinants of aerobic capacity because the cardiovascular system's ability to deliver oxygen is rate limiting in regards to exercise intensity. The more blood that can be delivered to working muscles, the faster oxygen can be used for the aerobic production of ATP. The direct consequence of this is that the athlete can perform or maintain a faster race pace without the build-up of lactic acid, which ultimately can cause fatigue. If an athlete becomes dehydrated, the blood plasma volume decreases to support sweat formation for evaporative cooling purposes. The resulting decrease in blood plasma volume leads to a decrease in the cardiac output of the heart, which in turn decreases delivery of oxygen to the working muscles and slows aerobic performance. Obviously, maintenance of hydration is of utmost importance to the endurance athlete because of the direct negative consequences inadequate fluid intake can have on performance.

How are daily fluid needs calculated for endurance athletes?

An endurance athlete cannot rely on becoming well-hydrated during activity by drinking copious amounts of fluids if he or she is not well-hydrated at the onset of exercise. In order to be well-hydrated at the onset of exercise, endurance athletes should follow the daily hydration guidelines stated in Chapter 8 of this book. As a reminder, the AI of water for men and women over age 19 is 3.7 liters and 2.7 liters of water per day, respectively. Basic fluid needs can also be estimated based on an athlete's total daily calorie needs (see Chapter 8 for the estimation calculation). Remember, fluid losses during exercise are in addition to daily fluid recommendations. Due to the frequency and duration of endurance athletes' training and competition sessions, maintaining **euhydration** (i.e., a positive fluid balance) is of utmost importance and should be a dietary focus every day.

euhydration A state of positive fluid balance in which more fluids are being ingested than being lost.

How are fluid and electrolyte needs during endurance activities determined?

Maintaining euhydration during endurance activities is dependent on making accurate estimations of individual sweat rates and electrolyte losses, practicing the consumption of the estimated amounts of fluid while exercising, and overcoming any logistical barriers to fluid availability.

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Endurance athletes should make it a habit to carry a water bottle throughout the day. The physical reminder of holding a water bottle and the immediate availability of water will help athletes meet their daily fluid needs.

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How do endurance athletes determine their individual fluid needs?

If left to their own devices, endurance athletes will typically not drink enough fluid during exercise to maintain euhydration.[19,32] In a study conducted by Iuliano et al.,[24] female and male junior elite triathletes performed a simulated duathlon event consisting of either a 2-km run, 12-km bike ride, and 4-km run or a 1-km run, 8-km bike ride, and 2-km run based on age. All subjects were allowed to drink ad lib of their chosen beverage during all three segments of the simulated duathlon. All groups drank suboptimally, as revealed by a loss of body mass, both in absolute and relative terms. Many endurance athletes are not aware of how much fluid they are losing during exercise; therefore, the first step in promoting an athlete's awareness is to perform a sweat trial and then to practice their "ideal" fluid consumption frequently in training sessions. To review the sweat trial calculations presented in Chapter 8:

---

1. *Determine body weight (BW) lost during exercise:*

   BW before exercise – BW after exercise = pounds of water weight loss

2. *Determine the fluid equivalent, in ounces, of the total weight lost during exercise:*

   Pounds of water weight lost during exercise × 16–24 ounces = number of ounces of additional fluid that should have been consumed to maintain fluid balance during the exercise session

3. *Determine the actual fluid needs of the athlete during an identical workout:*

   Ounces of fluid consumed + ounces of additional fluid needed to establish fluid balance = total fluid needs

4. *Determine the number of fluid ounces needed per hour of exercise:*

   For practical purposes, total fluid needs ÷ duration of the sweat trial, in hours = number of fluid ounces needed per hour of exercise

---

For example, Jack is preparing for an ultra-endurance bike ride called the RAIN ride (Ride Across INdiana), which consists of riding 162 miles across the state of Indiana in one day. As part of his training, he participates in a 110-mile group bike ride. The ride takes 7.5 hours. During this time he drinks 224 fluid ounces of a sports drink. By the end of his workout, he had lost 8 pounds of body weight. What is the ideal amount of fluid he should be consuming per hour?

Using the steps stated above:

1. His body weight loss during the workout was 8 pounds.
2. The fluid equivalent of his loss was 128–192 ounces (8 × 16–24 oz).
3. His total fluid needs for the 7.5 hours of cycling are 352–416 ounces (224 oz + 128–192 oz).
4. Jack needs 47–55 ounces of fluid per hour to match his sweat losses (352–416 ÷ 7.5).

For practical purposes, 47–55 ounces of fluid per hour is equivalent to 2.3–2.75 bottles per hour (assuming 20-oz bottles). For Jack, it would be in his best interest to install at least four water bottle holders on his bike so he could carry enough fluid for several hours of riding. Because Jack was only drinking about 30 ounces per hour during the 110-mile training ride (224 oz ÷ 7.5 hours = 29.8 oz/hour), he will need to practice drinking 160%–180% more fluid per hour before participating in the RAIN ride. A change in drinking behavior of this magnitude should be incorporated over time and not made overnight, to allow the body to adjust.

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>
> Suggest endurance athletes start performing sweat trials months in advance of an importance athletic event or competition. Changing fluid (as well as food) intake while exercising should be incorporated over time. Gradual increases in fluid are perceived as less challenging and overwhelming.

It is ideal for an athlete to consume mainly—if not solely—sports beverages during endurance activities lasting longer than an hour. A sports beverage delivers not only fluids, but also carbohydrates, sodium, and other electrolytes to the body. Generally, liquids or semi-solid foods consumed while exercising settle better than solid food. Therefore, if calories, carbohydrates, and electrolytes can all be obtained while maintaining hydration, the athlete will minimize the gastrointestinal issues that often result from eating solid foods during exercise.

How do you determine fluid and electrolyte needs for "big sweaters"?

Athletes who lose excessively large quantities of fluid and/or sodium during endurance exercise are often classified as "big sweaters." Although sports beverages are critical for the health and performance of these athletes, plain water can also be added into the nutrition/hydration plan for during activity. Some individuals require 64 fluid ounces or more per hour—that is a lot! If an athlete was to consume solely sports drinks in quantities to match fluid needs, the total amount of carbohydrates con-

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sumed could potentially reach a level that exceeds the recommended range of 1.0–1.1 grams of carbohydrates per minute. For example, if an athlete requires 54 ounces of fluid (based on sweat trials), this quantity of most sports beverages would supply approximately 94–101 grams of carbohydrates in 1 hour—far exceeding the recommended range of 60–66 grams of carbohydrates per hour. In this example, the athlete should consume 36–40 fluid ounces of a sports beverage and then drink an additional 14–18 ounces of water to meet his or her total fluid needs, without exceeding carbohydrate recommendations.

Oftentimes, "big sweaters" will complain of muscle cramps during training sessions and competitions. Muscle cramping is mainly due to inadequate fluid consumption and dehydration. By performing a sweat trial and developing a hydration plan based on individual needs, cramping issues are often resolved. After an inquiry on the fluid choices of big sweaters, it is often revealed that they are drinking mainly water (versus a sports beverage) during training sessions. By switching from water to sports drinks, thereby supplying sodium, potassium, and other electrolytes lost in sweat, a second line of defense against muscle cramps is established. If these two approaches do not work, the athlete should seek professional help from a dietitian, physician, and athletic trainer. In some cases, athletes are not only "big sweaters," but also "big salt sweaters," meaning they are losing excessive amounts of sodium and other electrolytes due to higher concentrations in their sweat, which in turn causes muscle cramps. For big salt sweaters, an electrolyte supplement in addition to a sports beverage may be indicated. The provision of specific electrolyte supplements on a regular basis should be monitored by a physician to avoid any complications and to ensure supplements are taken safely. The excessive consumption of electrolyte supplements can disrupt the electrolyte balance in the body and ultimately alter heart function.

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Remember that each athlete is different. Some athletes can digest and tolerate more carbohydrates and fluid than the recommended ranges. Trial runs and practice will fine tune a nutrition plan in preparation for hard training days and competitions.

How do you determine electrolyte needs for ultra-endurance athletes?

Ultra-endurance athletes, even those who are not considered big salt sweaters, may require additional sodium during long-duration training sessions and competitive events. Sodium losses are estimated at 50 mmol per liter of sweat, or 1 gram per liter, during exercise, with a range of 20–80 mmol per liter. Therefore, sodium requirements for athletes participating in training sessions and competitions lasting longer than 4–6 hours require approximately 500–1,000 milligrams of sodium per hour of exercise, based on sweat rate.[60] If the sodium lost in sweat is not replaced in adequate amounts, blood levels of sodium begin to drop and hyponatremia can ensue.

As mentioned in Chapter 8, hyponatremia is defined as blood sodium levels below 130–135 mmol/L. As the duration of an endurance event increases, the risk for hyponatremia also increases. However, with proper nutrition and hydration planning, it can be avoided. Salt tablets are commonly used to boost sodium intake above what is supplied in a sports beverage for events lasting longer than 4 hours. The quantity of sodium in a salt tablet can range from as little as 150 milligrams up to 1,000 milligrams per tablet. Salt tablets are sold online and in local pharmacies. Salt tablets should be used in moderation and used only to supplement the sodium obtained from sports beverages during training sessions and competitive events lasting longer than 4 hours. Consuming sports drinks alone, in adequate amounts, is sufficient for endurance activity lasting less than 4 hours.

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Some sports beverage companies have recently developed formulas containing almost twice as much sodium as regular sports beverages. Endurance athletes regularly engaging in training and competitive sessions lasting longer than 4 hours should use the higher-sodium versions. Look for beverages containing approximately 175–200 mg of sodium per 8 fluid ounces of the beverage.

To reiterate the importance of monitoring intake, caution should be taken to ensure that excessive sodium is not ingested. Salt tablets are not required on a daily basis. The average American diet provides adequate sodium to replace losses through sweat. If necessary, additional salt can be consumed by using the salt shaker at the table in small amounts. Refer to the example in the following **Fortifying Your Nutrition Knowledge** section regarding Mark, a half-Ironman triathlete, which demonstrates

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Remember to use moderation with sodium intake. Replacing sodium losses is important for the prevention of hyponatremia; however, excessive amounts of sodium intake on a regular basis can contribute to high blood pressure. Use salt tablets discriminately and consume salty foods and table salt in moderation.

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Fortifying *Your Nutrition Knowledge*

Mark contacted a dietitian to help him determine how to prevent the cramping he was experiencing during long bike rides and runs while training for a half-Ironman triathlon (1.2-mile swim, 56-mile bike ride, 13.1-mile run). He was baffled regarding the source of the problem because he had been taking three salt tablets an hour (150 milligrams per tablet) during long workouts since a training partner had suggested that low sodium levels were most likely the culprit of his cramps. Mark also reported that he was drinking plenty of water—consuming a full 20-oz water bottle an hour during training.

The dietitian asked Mark to perform a sweat trial to determine the amount of fluid loss he was experiencing during training. After performing the trial and reporting the results, the dietitian informed Mark that he was only meeting a portion of his fluid needs. Mark was losing 32–36 ounces of fluid per hour and only replacing 20 ounces. In addition to not meeting his fluid needs, he was also falling short on his sodium intake. Even though he was taking salt tablets, he was consuming only 450 milligrams of sodium per hour because he was drinking solely water, which provides no sodium. The dietitian calculated his total fluid, carbohydrate, and sodium requirements and helped Mark develop a nutrition and hydration plan for the race using the following steps:

1. The first step was to determine his fluid needs. As stated above, the sweat trial results revealed a fluid loss of 32–36 ounces of fluid per hour.
2. The next step was to determine how much carbohydrate and sodium would be supplied if all of his fluid needs were met by a sports beverage. Thirty-two to thirty-six ounces of a sports beverage per hour supplies approximately 56–63 grams of carbohydrates and 440–495 milligrams of sodium per hour, depending on the brand used. A sports beverage is preferred over water because fluid, carbohydrates, and sodium can all be provided, versus only fluid supplied in water.
3. The quantity of carbohydrates supplied through the sports beverage was sufficient to meet his needs during exercise, although on the low end of the range. Mark can consume carbohydrate gels, energy bars, bananas, or other foods to supplement the carbohydrates supplied through the sports beverage.
4. Mark had been consuming approximately 450 milligrams of sodium through salt tablets. This quantity of sodium was just slightly below the minimal level of sodium recommended per hour, which may have been contributing to his muscle cramps in addition to dehydration. Preferably, sodium would be obtained by drinking a sports beverage that simultaneously supplies fluid, sodium, and carbohydrates for optimal performance and hydration. In Mark's case, basing his intake of a sports beverage solely on fluid needs, the quantity of sodium supplied by the sports beverage is slightly below the 500-milligram minimum level recommended per hour. If he consumes 440–495 milligrams of sodium in the sports beverage, an additional 150–500 milligrams needs to be obtained from other sources. If he chooses to use an energy gel, bar, or peanut butter/cheese crackers for food during the bike portion of the triathlon, then additional sodium will be supplied in small quantities from these foods. By also planning on taking 1–2 salt tablets per hour, 150 milligrams of sodium per tablet, Mark can easily reach the goal of 500–1,000 milligrams of sodium per hour.

See **Training Table 12.3** for an excerpt of Mark's half-Ironman plan focused on his needs during the race. The plan is designed to prevent muscle cramps by supplying adequate fluids and sodium while also providing the carbohydrates needed to keep him performing at his best.

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Training Table 12.3: Mark's Half-Ironman Nutrition/Hydration Plan

Swim 1.2 miles

Total Time = 45 minutes
no food or drink

Bike 56 miles

Total Time = 3:18 (~17 mph)

Hour Elapsed on the Bike	Food/Fluid	Fluid (oz)	Carbohydrates (g)	Sodium (mg)
1	32–36 oz sports beverage*	32–36	56–63	440–495
	1 salt tablet**			150
2	32–36 oz sports beverage	32–36	56–63	440–495
	½ energy gel***		14	25
	1 salt tablet			150
3	32–36 oz sports beverage	32–36	56–63	440–495
	1 salt tablet			150
18 minutes	10–12 oz sports beverage	10–12	18–21	138–165
Average intake on Bike		*32–36 oz/hour*	*60–67 g/hour*	*580–638 mg/hour*

Run 13.1 miles

Total Time = 1:51 (~8:30 min/mile pace)

Aid Stations on Course at Mile Markers	Food/Fluid	Fluid (oz)	Carbohydrates (g)	Sodium (mg)
1	5 oz sports beverage	5	9	69
2	5 oz sports beverage	5	9	69
	1 salt tablet			150
3	5 oz sports beverage	5	9	69
4	5 oz sports beverage	5	9	69
5	5 oz sports beverage	5	9	69
	1 salt tablet			150
	½ energy gel		14	25
6	5 oz sports beverage	5	9	69
7	5 oz sports beverage	5	9	69
	1 salt tablet			150
8	5 oz sports beverage	5	9	69
9	5 oz sports beverage	5	9	69
10	5 oz sports beverage	5	9	69
	1 salt tablet			150
11	5 oz sports beverage	5	9	69
12	5 oz sports beverage	5	9	69
13.1—strong to the finish!				
Average intake on Run		*32 oz/hour*	*66 g/hour*	*785 mg/hour*

*Using a sports beverage with 14 grams of carbohydrates and 110 milligrams of sodium per 8-oz serving
**Using a salt tablet with 150 milligrams of sodium per tablet
***Using an energy gel with 28 grams of carbohydrates and 50 milligrams of sodium per gel

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the development of a race-day nutrition plan including the appropriate use of salt tablets.

Are fluids needed for recovery from endurance exercise?

Absolutely! Endurance athletes can potentially lose huge quantities of fluid while exercising, which need to be replaced as quickly as possible after exercise. As highlighted in Chapter 8, endurance athletes should:

- Drink fluids to replace any weight loss during endurance exercise. For every pound lost, an athlete should consume 16–24 ounces of fluid.
- Consume fluids slowly and gradually, instead of through a large bolus of fluid in one sitting. Athletes should begin drinking immediately after exercise and then continue to drink throughout the day.
- Ideally consume fluids containing carbohydrates, sodium, and potassium, which help to maximize not only fluid replenishment, but also glycogen stores and lost electrolytes. Sports drinks, vegetable and fruit juices, milk, and smoothies are examples of fluids containing more than just water.

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>
> Euhydration is not a static state; therefore, maintaining euhydration should be a daily focus for endurance athletes. Optimal performance hinges on an athlete's correct estimation of fluid needs before, during, and after training and competitions. It is critical for athletes to know their individual sweat rates and daily fluid requirements and follow through with diligent and appropriate fluid consumption.

Fluid replenishment ranks as high as carbohydrate replenishment on the recovery importance list for endurance athletes. Athletes should strive for consuming individually optimal amounts of fluids in a timely manner.

What meal planning/event logistics need to be considered during endurance events?

The nature of the sport will be a major factor in determining a specific nutrition plan for an endurance athlete. Endurance training prepares athletes for events that can last minutes, hours, or days. Training may occur in a controlled environment or can be held in a remote area with limited access to facilities. When developing a nutrition plan for endurance athletes, the feasibility of consuming foods or fluids, length of the event, availability of refrigeration/heating equipment, and space for carrying supplies must be considered.

How can a nutrition plan be developed for sports that are not conducive to consuming foods or fluids while exercising?

Long distance swimming, mountain biking, and rowing events are examples of sports that do not lend themselves to easily consuming foods and fluids during an event. Swimming and rowing involve both upper and lower body movement, requiring an athlete to come to a complete stop in order to eat or drink. In a competitive environment, coming to a halt will translate into the loss of precious seconds or minutes to competitors. In rowing, carrying any food or fluid will add weight to the boat, thus potentially slowing the athlete and negatively affecting performance. Mountain biking requires concentration and attention to the course, with legs needed for pedaling while arms and hands are steering the bike and keeping it upright and on course. In these situations, proper nutrition before and after the event will be critical in supplying nutrients and fluids to the athlete, because minimal consumption will occur during exercise.

Several factors should be considered in the days prior to and immediately before training or competition. Consuming higher levels of carbohydrates in the 3–4 days prior to an endurance competition can supercompensate muscle and liver glycogen stores. This allows additional energy stores to be available during long events where carbohydrate consumption is logistically impossible. The nutrients and fluid supplied in the hours leading up to the event will be the fuel used during exercise. If an athlete runs short on calories, carbohydrates, or fluids, performance will suffer because additional nutrients will not be consumed during the activity. Athletes should consider eating a larger preactivity meal, which might also mean planning additional time before a training session or event to allow for the digestion of the meal. Athletes should continue to sip on fluids between the preactivity meal and the beginning of a training session or competition to ensure proper hydration. Athletes also need to plan ahead and pack food and beverages to be consumed immediately following the activity to replenish lost nutrients and fluids.

> ***gaining the performance edge***
>
> If the sport is not conducive to eating and drinking while moving, athletes must place a strong emphasis on consuming nutrients and fluids before and after the event. Encourage athletes to plan ahead and pack coolers of food and drinks to have nutrition easily accessible when eating/drinking is feasible.

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There are some exceptions to the rule. For example, several ultra-endurance open water swimming events allow support boats to follow swimmers, giving the athletes a chance to stop, drink or eat, and then continue swimming. The following is an example of a swimmer, Amy Krauss, who is a four-time competitor in the Key West Open Water Swim—a 12.5-mile event circling the island of Key West in 1 day.

Key West 12.5-Mile Open Water Swim. Most open water swims consist of a 1-, 2-, or 6-mile course. The Key West Open Water Swim is an incredible 12.5-mile swim completed in one session. During the event, each swimmer must have a kayaker following alongside for safety reasons (see Figure 12.6). The accompanying kayak also provides the opportunity for the competitors to have access to fluids and food during the event. On average, it will take a swimmer 4–6 hours to complete the race. By maintaining proper hydration and supplying a steady stream of energy to the body, the swimmer can perform at his or her best.

Over the years Amy has experimented with various hydration/fueling schedules, including different fluids, food, and nutrition products, to determine which options taste appealing and digest easily while swimming. Her hydration goal has been to drink 24 ounces of fluid per hour, which is achieved by stopping to drink every 15–20 minutes. Amy alternates between water, sports drinks, and more concentrated recovery-type nutrition drinks to supply fluids, carbohydrates, and electrolytes. In addition to fluids, Amy consumes sports gels and small pieces of energy bars to supply more calories and carbohydrates to her muscles.

Although the kayaker makes it easy to have fluids and food available at any time, it is not always easy to eat and drink. Depending on the roughness of the water, actual ingestion of fluid and food can be challenging. The constant bobbing of the body in the waves can lead to seasickness and vomiting, which is obviously detrimental to athletic performance. Amy experienced this scenario in the 2000 race when she had to stop to tread water for 90 minutes while vomiting. She now takes medication several days before the race to prevent the seasickness, allowing her to consume fluids and food comfortably, which has led to several great race performances.

Figure 12.6 Swimmer Amy Krauss during the Key West Open Water Swim. Having support staff carry fluids and foods in long distance endurance races makes adequate replenishment of needed nutrients more likely.

How can a nutrition plan be developed for sports lasting 24 hours or longer?

Ultra-endurance events once reserved for really "crazy" people are now becoming more mainstream. Ultra-marathons and adventure races have exploded in popularity, drawing recreational and elite athletes into events lasting 8–24 or more hours. When events are spanning the majority of one day, energy expenditure increases dramatically while simultaneously making it challenging to consume enough fuel because regular meals are essentially skipped.

Fortunately, these ultra-endurance sports are conducive to eating and drinking while moving, though only in small quantities at a time. In some cases, aid stations with supplies may be available on the race course, whereas other events are self-sustaining.

In cases when an athlete is planning on relying on aid stations for food and fluids, planning and practicing before an event is paramount. Athletes should contact the race director or consult the race information packet or Web site to discover what type of food and fluids will be available on the course. Athletes should then consume the same type of food and fluid throughout their training. For example, Barbara, an ultra-marathoner, typically uses All-Sport, oranges, and PowerBars during her training. She registers for a race and discovers that Gatorade, bananas, and fig bars are going to be supplied on the course. Barbara should immediately switch to using these products and foods during her training. Even though All-Sport, oranges, and PowerBars are nutritionally similar to Gatorade, bananas, and fig bars they are not identical and can potentially cause taste aversions and gastrointestinal problems if an athlete is not accustomed to the products. As the length of an endurance event increases, nutrition becomes even more critical to performance. As with any sport, there should be no surprises on race day! Athletes should

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find out what products are going to be supplied during their scheduled races and then practice, practice, practice during training.

Another issue to address during 8–24+ hour events is the variety of flavors and textures of food consumed. A common compliant of ultra-endurance athletes is flavor fatigue for sweet products. Sports drinks, bars, and gels are made of carbohydrates that taste sweet—some more intensely than others. When an athlete is consuming these foods over 1–4 hours, flavor fatigue is not typically a concern. However, when athletes are consuming large quantities of food in order to meet the energy needs of events lasting more than 8 hours, flavor fatigue is a reality that must be addressed during training. If an athlete gets "tired" of the sweet taste, and all he or she has practiced consuming during training is sports drinks, fruits, and bars, then a switch to different foods or fluids during a race can be disastrous. Athletes should practice consuming foods and fluids with salty or bland flavors to balance with sweet items. Examples of salty items that are commonly used in races are pretzels, peanut butter crackers, chicken broth, sesame sticks, and even lunchmeat sandwiches. Continuing the ingestion of calories will ensure an athlete keeps moving forward on pace, and feeling good.

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Encourage athletes to research what products will be supplied on the race course so the identical products can be used during training. Be creative when developing a nutrition plan for events lasting 8–24 or more hours—include different flavors, textures, and types of food and fluids.

In an adventure race, when many different sports are involved in one event and athletes are typically self-supporting, the timing of food and fluid intake as well as the reliance on nonperishable items makes the nutrition plan unique. Keep in mind that nutrition plans need to include an athlete's favorite training foods and fluids, while maintaining the feasibility of transporting the items while moving and ensuring food safety. For example, an adventure racer might really enjoy eating a turkey and cheese sandwich 10 hours into a race. However, if the race is self-sufficient and without access to refrigeration, keeping a lunchmeat and cheese sandwich outside refrigeration for more than 2 hours will increase the risk for a foodborne illness. A peanut butter and jelly sandwich or turkey jerky might be better options.

How can a nutrition plan be developed for a multi-day event that will be fully supported?

Multi-day endurance events, or stage events, may be fully supported with team vehicles and overnight accommodations supplying refrigeration and cooking capabilities. These types of events are logistically much easier to plan for because athletes can in some cases stay on a "normal" schedule of eating meals and snacks. The variables to consider in this type of scenario are the refrigeration, preparation, and storage space for supplies as well as the length and frequency of exercise during the multi-day event.

An example of this type of event is the Race Across America (RAAM). RAAM, first held in 1982, is a nonstop cycling event across the United States. The 2,900–3,000 mile race begins on the west coast and travels across the mountains and plains to the east coast. Racers can enter the event as a solo rider or as a 2-, 4-, or 8-person team. Individuals and teams are allowed to have multiple support vehicles throughout the race and along the course. Most competitors will have a motor home to allow for meal preparation and vans to fetch additional supplies while the cyclists continue to progress en route. **Training Table 12.4** gives an example day of meals, snacks, and fluids consumed by a rider on the 4-man Team 70+ in 1996.

How can a meal plan be developed for a sport such as a long distance triathlon that includes a nonconducive eating environment, a length of time spanning several meals, and race course support?

The sport of triathlon has exploded in popularity in the past decade. Triathlons can be categorized into four distances: Sprint (500-meter swim, 10-mile bike ride, 5-kilometer run), Olympic (1.5-kilometer swim, 40-kilometer bike ride, 10-kilometer run), half-Ironman (1.2-mile swim, 56-mile bike ride, 13.1-mile run), and Ironman (2.4-mile swim, 112-mile bike ride, 26.2-mile run). Sprint and Olympic distance races can be completed within 1–3 hours for a majority of competitors, requiring a proper prerace meal, a strong focus on hydration, and minimal amounts of sports bars, gels, and other foods during the race. However, the half and full Ironman distance races can last 4–17 hours, making nutrition a critical component of race day success. Triathlon is unique due to the three sports included, each providing a different environment and plan for hydration and fuel consumption. No food or drink is

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Training Table 12.4: Jack's Meal Plan during RAAM

Jack Boyer was a 70-year-old member of Team 70+. He was 5′8″ and weighed 158 pounds. His daily energy and carbohydrate needs, accounting for 4–8 hours of cycling per day, were estimated at 5,422 calories and 990 grams of carbohydrates. In order to meet this goal, he was instructed to consume the following each day:

- 6 liters of Cytomax sports beverage, supplying 1,278 calories and 360 grams of carbohydrates
- 1 "Meal A," supplying 1,100 calories and 150 grams of carbohydrates
- 2 "Meal Bs," each supplying 800 calories and 120 grams of carbohydrates
- 12 snacks, each supplying 120 calories and 20 grams of carbohydrates

Meal options included, but were not limited to: oatmeal, dry cereal, spinach lasagna, turkey chili, stuffed potatoes, bagel sandwiches, and pasta dishes. Snacks were eaten during breaks from cycling. Snacks included, but were not limited to: PowerBars, granola bars, GatorPro, Gatorlode, pretzels, bagels with jelly, dry cereal, trail mix, peanut butter crackers, and Ritz snack crackers. The four-man team was split into two subteams. The subteams alternated 8-hour shifts—8 hours in the motor home resting, eating, and getting massages, alternating with 8 hours of cycling. The 8 hours of cycling by each subteam of two men was then split into alternating 1-hour time blocks of riding and then resting in the van following directly behind the cyclist on the road. All meals were eaten in the motor home while sports beverages and snacks were consumed during the 8-hour shift of cycling.

Because the motor home had a refrigerator and a microwave, foods could be prepared for the team on-site. However, most of the food was prepared before leaving on the adventure and frozen, minimizing the time and effort of meal preparation during the race. Therefore, the menu was planned around foods that could be reheated well, made from scratch in a microwave, or prepared with no cooking. A small cooler was taken during the 8-hour shift of cycling allowing for drinks and other foods to stay cold.

Jack, as well as the other three riders, was monitored daily through a food record and by obtaining body weights before and after 8-hour riding shifts. The riders stayed on plan for the entire race, feeling good and riding strong. Tastes changed during the ride, requiring the menu to be flexible, allowing for foods from restaurants and "interesting" requested combinations such as baked potatoes with raisins, milk, and salt. The nutrition plan fueled Jack and the rest of the 70+ Team to a successful RAAM finish of 9 days, 2 hours, and 27 minutes.

available during the swim portion of a triathlon, making prerace nutrition and hydration a top priority. The bike segment of the race is most conducive to drinking and eating. Bikes can carry fluids in bottles attached to the bike frame, behind the seat, and in specialized bottles that fit within the aerobars placed on the front of the bike. Athletes can pack their own food to be carried in the back pockets of a bike jersey or in a variety of bike bags, pouches, or "boxes" that attach to the bike frame or seat. This allows an athlete to drink and eat gradually throughout the bike segment of the race, playing a little "catch-up" from the swim and "stocking up" before the run. Because biking is nonimpact, athletes experience fewer gastrointestinal issues with eating and drinking while cycling as opposed to running, and therefore the second segment of a triathlon is an ideal time for fueling. The nutrition plan for the run is typically developed around what is available on the course at aid stations. Some athletes choose to rely mainly on their own fluid and food choices by wearing belts with bottle holders and pouches for food. However, for the Ironman distance races, the amount of fluid and fuel needed during the marathon will exceed the carrying capacity of the belt. Therefore, a combination plan of self-support and race course support may work best. One other opportunity for food and fluid consumption occurs during the two transitions during a triathlon—one after the swim and the second after the bike segment. During shorter triathlons, athletes aim to keep transition time to a minimum, often choosing not to take time to consume anything during transition. In longer distance triathlons, during transition is an ideal time for changing clothes, taking a minute to rest before the next segment of the race, and consuming small amounts of food or fluids.

The Ironman distance is by far the most taxing and most reliant on proper nutrition and hydration. **Training Table 12.5** provides an example of the Ironman plan followed by Heather Fink when she completed Ironman Coeur d'Alene in 2003. Her race and nutrition plan progressed flawlessly, allowing her to qualify for the Hawaii Ironman in the fall of 2003.

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Training Table 12.5: Heather's Ironman Nutrition/Hydration Plan

After 5 years of competing in sprint through half-Ironman distance triathlons, in 2003 Heather decided to participate in an Ironman distance race. Ironman Coeur d'Alene, held in late June and located in northern Idaho, involved a cold swim in Lake Coeur d'Alene; a challenging bike course with several tough, steep hills; and a relatively flat run course. Heather, being a dietitian, knew the importance of practicing her race day nutrition throughout her training, and therefore developed a proposed plan by January and spent the next 4–5 months refining the plan for race day. From past experience in triathlons, she knew sports beverages, gels, and bars worked well and settled well for her during races. However, she knew she would need to intake more energy and sodium during Ironman and therefore began experimenting with other foods, drinks, and products. The schedule below was the result of using tried-and-true products, newly discovered products, and beverages/foods known to be available on the race course:

Breakfast (4 hours prior to race start)
- 1½ cups dry cereal with one scoop of protein powder and 1 cup soy milk
- 1 banana and 8 ounces of orange juice
- Sips of Gatorade between breakfast and race start

2.4-Mile Swim (Total time = 1:05:00)

- No food or drink

Transition #1 (after swim, before bike; Total time = 3:36)
- ½–1 can of Ensure

112-Mile Bike Ride (Total time = 6:02:00)

Nutrition Goals During the Bike Ride: 32 ounces of fluid per hour (specifically, Gatorade), 70–75 grams of carbohydrates per hour, and 500–750 mg sodium per hour. Plan was broken down into 10-mile increments because aid stations were located every 10 miles on the bike course. Three 24-ounce bottles of Gatorade were placed on the bike at the beginning of the race and replaced throughout the course. A Bento Box was attached to the bike frame holding salt tablets, Baker's Breakfast Cookies, peanut butter crackers, and one gel. The specific nutrition plan for the bike ride progressed as follows:
- 10 miles—Bottle pick-up
- 20 miles—¾ of a Baker's Breakfast Cookie
- 30 miles—Bottle pick-up
- 40 miles—3 peanut butter crackers
- 50 miles—Bottle pick-up + one sodium tablet (1,000 mg)
- 60 miles—1 gel
- 70 miles—Bottle pick-up
- 80 miles—¾ Baker's Breakfast Cookie
- 90 miles—Bottle pick-up
- 100 miles—3 peanut butter crackers + one sodium tablet
- 110 miles—Bottle pick-up

Transition #2 (after bike, before run; Total time = 2:51)
- ½–1 can of Ensure

26.2-Mile Run (Total time = 3:43:00)

Nutrition Goals During the Run: 28 ounces of fluid per hour, 60–65 grams of carbohydrates per hour, and 500–750 mg sodium per hour. The plan was broken down into 1-mile increments because aid stations were located every mile on the run course. A gel flask filled with four gels was carried during the run with a small plastic pouch attached to the flask to hold several sodium tablets.
- 4–6 ounces of fluid were consumed every mile on the course, mainly Gatorade, with a little water, cola (for a flavor change), and ice cubes.
- Half of a gel was originally planned to be consumed every 3 miles during the race for a total of four gels over the 26.2 miles. However, only 1–2 gels were actually consumed. The temperatures on race day climbed to 97 degrees, increasing the need for fluids during the race. Due to an increased ingestion of fluids, which contained calories, fewer gels were consumed in order to stay on track with the planned quantity of carbohydrates needed per hour.

Total Ironman race time = 10:58
Second female in 30–34 age group, qualifying Heather for the Hawaii Ironman in October 2003.

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The Box Score

Key Points of Chapter:

- Endurance athletes expend a tremendous number of calories not only during competition, but also in the preparatory training. Energy expenditures of 6,000–8,000 kcals/day are not out of the ordinary for ultra-endurance athletes. This puts a huge drain on energy reserves that must be replenished after daily training bouts and thus makes diet a key factor in athletic success.
- Of the three energy systems, endurance athletes rely most heavily on the aerobic energy system. Appropriately designed training programs challenge the aerobic system and increase the athlete's aerobic power so that he or she can maintain a faster race pace.
- It is critical for endurance athletes to consume sufficient calories on a daily basis to supply the energy for daily training and competition, ensure the delivery of nutrients needed for complete recovery from workouts, and stay healthy and injury-free. Daily energy needs can be estimated using the following formula: Resting energy expenditure × Activity factor.
- Often it is not physically or logistically possible for an endurance athlete to fully match his or her energy expenditure with intake during actual training or competition. As a consequence, the event nutrition plan should be based on meeting the performance requirements of providing carbohydrates, fluids, and sodium.
- The main difference between diets of endurance athletes and those of other sports is in the quantity of food consumed, not necessarily the macronutrient composition of the diet.
- Carbohydrate intakes of 5 to 10 grams per kilogram of body weight are recommended for endurance athletes. When expressed as a percentage of their total daily caloric intake, carbohydrates should be approximately 50% to 65% for daily training and approximately 65% to 70% during carbohydrate loading.
- Research has demonstrated that consuming carbohydrates in the hours leading up to an endurance training session or competition is critical for optimal performance, especially during activities lasting longer than 2 hours. Endurance athletes should be encouraged to consume a carbohydrate-rich preactivity meal 2–3 hours prior to a training session or event and then continue consuming carbohydrates throughout exercise in order to optimize performance.
- Carbohydrate needs during exercise are estimated at 1.0–1.1 grams of carbohydrates per minute of activity, or 60–66 grams carbohydrates per hour for endurance athletes. Some athletes can easily consume and digest upwards of 75–85 grams of carbohydrates per hour, whereas others can barely stomach 45–55 grams. Athletes need to experiment with varying quantities of carbohydrates surrounding the 60–66 gram range to determine the best estimate for them individually.
- Carbohydrate intake is also important after competition to help replenish glycogen stores. Consuming 1 gram of carbohydrates per kilogram of body weight within 15 to 30 minutes after the cessation of exercise provides glucose to muscles at a time when they are most receptive to absorbing and storing glucose as glycogen.
- Although protein is not typically used by the body to provide energy, the extreme energy demands of endurance training and competition do result in the metabolizing of some protein for energy. As a result, the protein intake recommendation for endurance athletes is higher than the current RDA and falls in the range of 1.1 to 2.0 grams per kilogram of body weight.
- The effect of protein intake during competition and its impact on performance requires more research; however, for ultra-endurance athletes, the consumption of protein seems prudent.
- Despite the fact that fats are a major energy source during endurance sports, high-fat diets have not been shown to improve endurance performance. The diet of endurance athletes should include enough fat to account for approximately 20% to 35% of total daily calories consumed. Immediately prior to training, during exercise, and immediately after training, fat intake should be kept to a minimum while focusing primarily on carbohydrates and secondarily on protein.
- Vitamin and mineral needs of endurance athletes are similar to those of other athletes. However, there are a few vitamins and minerals that should be given particular attention. These include the B vitamins, iron, calcium, vitamin C, vitamin E, sodium, and potassium.
- Adequate fluid intake is important for maintaining the hydration status of endurance athletes during their prolonged training bouts and during competition. Failure to do so can have deadly consequences.
- An excellent way to monitor hydration status is to weigh athletes before and after training or competition. For every pound of body weight lost the athlete should drink 2–3 cups of fluid.
- The risk for hyponatremia increases as the duration of an endurance event lengthens. As a result, the sodium

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intake of ultra-endurance athletes should be considered when developing a nutrition plan. Sports beverages can provide both fluid and sodium; however, pre-event experimentation is critical for successful use.

- Each endurance athlete requires an individualized nutrition plan. Sport-specific logistics must be considered in order to plan food and fluid intake appropriately and to implement the plan successfully.

Study Questions

1. Can endurance athletes adopt an "eat-as-you-like attitude"? Defend your answer.
2. Of the three energy systems, which one do endurance athletes rely upon most for energy? Under what circumstances would the other two energy systems play a bigger role during endurance competition?
3. What pieces of information would you need as a dietitian in order to estimate an endurance athlete's daily caloric needs?
4. What is the reasoning behind the statement, "An athlete who cuts back on carbohydrate intake is committing performance suicide"?
5. What should the percent composition of carbohydrates, proteins, and fats be for an endurance athlete's diet?
6. How does the combination of tapering and carbohydrate loading affect endurance performance?
7. What role do proteins play in regard to the needs of the endurance athlete? What is the current recommendation for protein intake in endurance athletes?
8. For ultra-endurance athletes, is there a training or performance benefit to eating a high-fat diet? Should you recommend eating higher-fat foods during and after training or competition? Discuss why or why not.
9. What are BCAAs and MCTs? What role, if any, do they play in meeting the needs of the endurance athlete?
10. What is hyponatremia? Which athletes are at greatest risk for developing it (be very specific)? What nutritional strategies would you use to prevent it?
11. Which vitamins and minerals are of special concern to endurance athletes?
12. What strategies could be employed to help ensure the hydration status of endurance athletes?
13. What is a "sweat trial," and why is it important to the endurance athlete?
14. What are some of the logistical and nutritional issues that must be dealt with when working with ultra-endurance athletes who are competing in 8+ hour events?

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