

Food and Fluid Guidelines Before, During, and After Exercise

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Athletes who are properly fueled and hydrated before, during, and after exercise can improve training, increase performance, and decrease fatigue. Many commercial products are marketed to athletes and are designed to be consumed at specific periods: before, during, and after exercise. Are these products really necessary? This article reviews the research on nutrition support for the athlete surrounding exercise and discusses the different nutritional needs of the recreational athlete versus the elite athlete. Guidelines for macronutrient intake before, during, and after exercise are provided along with decision trees to help the practitioner guide the athlete to proper fueling strategies. *Nutr Today*. 2012;47(2):63–69

Do athletes need to eat before, during, and after exercise for peak performance? Many new products, from bars to gels to drinks, tout the benefits of special foods and fluids to get the most out of a workout or sports competition, but are they necessary for all active people? This article looks at the science behind the recommendations on fueling before the workout, during the workout, and after the workout for recovery. It is important to note that most of the research on food and fluid consumption around exercise was done with competitive athletes, usually highly trained endurance athletes, who are exercising at high intensity for a long duration. Sports nutrition recommendations for elite athletes are extrapolated to recreational athletes who often have very different reasons for exercising. The goal of a competitive athlete is to win and set personal best records. Recreational athletes want to get fit, look good, improve body composition by losing fat and gaining lean muscle mass, and stay healthy. This is not to say that recreational athletes are not competitive; many want to improve their performance, but they usually do not have the time to train for several hours each day (often twice a day) and engage in high-level competitions. Therefore, the nutrition needs of recreational athletes are different than for elite athletes, and nutrition recommendations made for one population may not be appropriate for the other.

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Sports nutrition research is conducted with highly trained elite athletes, and nutrition recommendations are different for recreational athletes.

Review of Fuels Used in Exercise

Muscles use adenosine triphosphate (ATP) as the energy currency to perform work. The macronutrients, carbohydrate, protein, and fat can all be used to produce ATP; however, all have unique ways of contributing to ATP production, and some are more readily available and more easily converted to ATP than others.

Carbohydrate is the preferred fuel used in exercise. Carbohydrate is stored in the liver and muscles as glycogen and a smaller amount of carbohydrate is available in the form of glucose as blood sugar. A workout that is of moderate intensity draws about half of the energy demand from muscle glycogen and blood glucose, and as exercise intensity increases, about two-thirds of needed energy comes from these 2 sources. Liver glycogen is used to maintain blood sugar levels. Carbohydrate is the only fuel that can be used anaerobically or without oxygen, so when exercise intensity is high (sprinting, jumping, or other explosive power moves), carbohydrate availability is important.¹ Current recommendations for daily carbohydrate intake for a wide range of athletic performance are found in Table 1.

Fats, stored as triglycerides in adipose tissue, are a great reserve of energy for working muscles, but to use this abundant energy source, several steps must occur. First, fats must be broken down (lipolysis) to fatty acids and glycerol and then must be carried through the bloodstream to the muscles. Once at the muscle, fatty acids get transported across the mitochondrial membrane for aerobic metabolism. Before fatty acids can be used to generate ATP, they undergo β -oxidation to produce acetyl CoA, which can then enter the Krebs cycle to produce ATP. So although fat is a good source of energy, using it to produce ATP is more complicated than using carbohydrate, and it must have oxygen for the many chemical reactions to proceed.

Protein is not a preferred fuel in exercise because protein is needed for more crucial functions (synthesizing enzymes, hormones, red and white blood cells, muscle and

TABLE 1 Daily Carbohydrate Recommendations³

Activity	Carbohydrate Intake Range, g/lb	Example of Daily Carbohydrate Recommendation for a 130-lb Athlete, g/d
Low-intensity or skill sports with light training (eg, baseball, softball, golf, recreational walking or cycling, weight training using machines or free weights)	1.35–2.25	175–292
Individuals who moderately train and have large body mass		
Individuals who moderately train and who are following calorie-reduction weight-loss diets		
Moderate exercise programs (moderate-intensity exercise that is continuous for about 60 min)	2.25–3.15	292–409
Individuals who train for about 60 min each day		
Endurance training	2.7–4.5	350–585
Athletes who train at moderate to high intensity for 1–3 h/d		
Ultraendurance exercise training at moderate to high intensity for >4–5 h/d	3.6–5.4	468–700

bone tissue, etc). However, amino acids can be oxidized for fuel, but rarely does protein contribute more than 10% of energy production, and this usually occurs in late-stage endurance or ultraendurance events when glycogen is depleted.

Preworkout Nutrition Recommendations

What should an athlete eat or drink before a workout or a competitive event? The answer is it depends. First, it is important to know when the exercise session is going to occur, as well as the intensity and duration of the workout. Nutrition needs for a brisk afternoon walk with the family dog are different than for an early-morning 10-mile run. Second, what are the environmental conditions? Exercising in hot, humid conditions requires a hydration plan, whereas playing a short game of pickup basketball in an air-conditioned gym may not increase fluid needs. Third, it helps to know the athlete's goals; an athlete who is trying to lose weight can easily sabotage the calories burned during a workout by eating too many calories before exercise. Lastly, when did the last meal occur, and what was eaten? If an athlete ate a healthy lunch with adequate carbohydrate and protein, there may be no need for a preworkout snack for a late afternoon workout. Figure 1 contains a decision tree for preworkout feeding.

When and What to Eat Before Exercise

If you exercise early in the morning, there is usually little time to digest a meal before exercise. However, depending on the type of exercise and its duration and intensity,

a light meal with easy-to-digest carbohydrate might help performance. Glycogen can be depleted after an overnight fast, so eating a carbohydrate-rich snack before exercise can help "top off" liver glycogen. The current recommendations for carbohydrate intake before exercise are designed for athletes with the assumption that individuals are eating a diet with sufficient carbohydrate to support exercise by maximizing glycogen stores and replacing glycogen after exercise. This is especially important for an individual who exercises strenuously every day for more than 90 minutes²; recreational athletes who workout 3 or 4 times a week and are eating carbohydrates with meals probably do not need to supplement with extra carbohydrate before a workout. Ideally, a mixed meal should be eaten 3 to 4 hours before exercise to allow enough time for digestion and absorption of nutrients. But, for those who exercise in the morning, this may not be possible. Recommendations for consuming carbohydrate based on the length of time before exercise are shown in Table 2. If an individual finds there is no time to eat before a morning event, eating just 30 g of carbohydrate 5 to 10 minutes before exercise may improve performance. Carbohydrate should be easy to digest such as liquid sources of carbohydrate found in sports drinks or foods such as a serving of plain grits, miniplain bagel, a small banana, or yogurt.³

Foods and fluids consumed before exercise should be easy to digest and relatively low in fiber, as shown in Table 3. Athletes are encouraged to try new food and fluid choices in

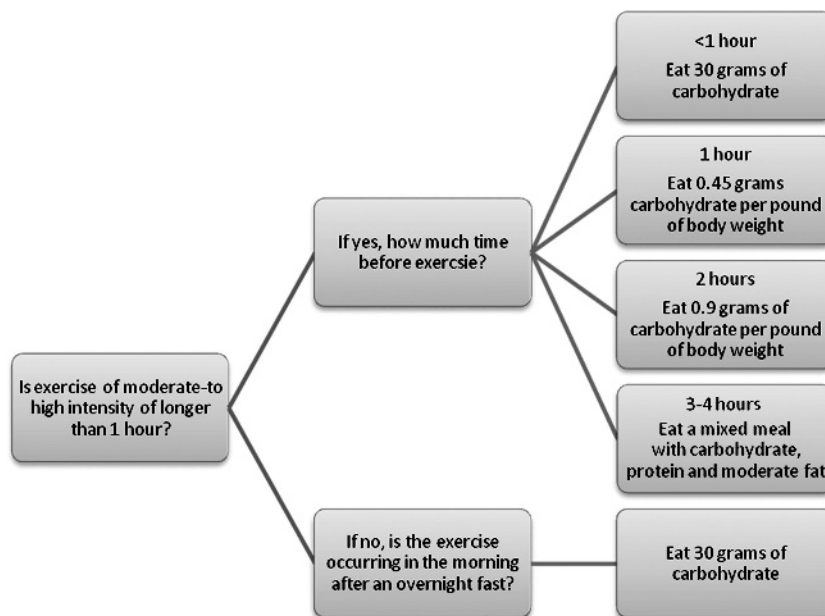


FIGURE 1. Decision tree for eating before exercise.

training so they know what works best for them during competition. For recreational athletes who workout but may not compete in sporting events, the principles found in Table 3 still hold true. To get the most out of a workout, choose foods or fluids that provide carbohydrate while minimizing fat and fiber.

Several popular exercise books have suggested that working out in the morning without eating will cause greater fat loss. Schoenfeld⁴ recently reviewed the evidence for this popular recommendation and gives 4 reasons why this practice is misinformed. Exercising while fasting does lead to an increase in fat oxidation. However, recent research on high-intensity interval training shows that this type of exercise is superior for losing body fat compared with lower-intensity exercise or what many exercise machines label as the “fat burning zone.” Most important is how many calories are burned in an exercise session and how that contributes to energy balance over the course of the day, not the course of minutes or an hour. A second consideration of exercising while fasting is that more muscle protein is broken down, suggesting that the goal of gaining muscle mass could be thwarted. Third,

eating before exercise increases the thermic effect of exercise, which would also increase the calorie-burning effect of the exercise. Lastly, and maybe most important, fasting before morning exercise makes it hard to work out at even a moderate level of intensity. So, even though exercising while fasting can increase fat oxidation, it can also lead to less work being performed during the exercise session and the perception that more effort is needed to complete the workout making exercise less enjoyable.⁵

Exercising while fasting is not beneficial to burning more calories during a workout and may make exercise more difficult to perform.

Glycemic Index and Glycemic Load of Food or Meals Before Exercise

The glycemic index (GI) of a food has been suggested as the most important factor in choosing pre-exercise foods, although the results of using the GI on exercise performance are mixed. In a recent review, O'Reilly and

TABLE 2 Carbohydrate Intake Before Exercise³

Time Before Exercise	Amount Carbohydrate, g/lb	Example for a 130-lb Athlete, g
1 hour	0.45	58
2 hours	0.90	117
3 hours	1.36	176
4 hours	1.80	234

TABLE 3 What to Eat and What to Avoid in Preworkout or Competition Meals

Do Try	Try to Avoid
Easy-to-digest foods such as low-fiber carbohydrates and low-fat protein foods, such as grilled chicken sandwich, sliced turkey on a plain bagel, hard-boiled eggs with lightly buttered toast, low-fiber cereal, and low-fat milk	High-fat, protein-rich foods such as hamburgers, cheeseburgers, ribs, sausage
Foods with a lower glycemic index such as milk, yogurt, peeled apple slices, banana, oatmeal, pasta	High-fiber and gas-forming foods such as cauliflower, onions, broccoli, Brussels sprouts, and garlic; high-fiber breakfast cereals and energy bars
Foods that are well tolerated by the individual athlete	Unfamiliar foods

colleagues.⁶ suggest there are some gains in performance and exercise capacity when low-GI foods are selected. The benefit may be from the decreased postmeal hyperglycemia and hyperinsulinemia, resulting in an increase in free fatty acid oxidation, which could sustain carbohydrate availability during endurance exercise.⁷ However, when looking at multiple meals and the way most athletes eat (ie, mixed meal of both high- and low-GI foods), there is no performance advantage. Athletes might want to experiment with consuming low-GI foods prior to exercise, but it may not always be practical.³

Fluids Before Exercise

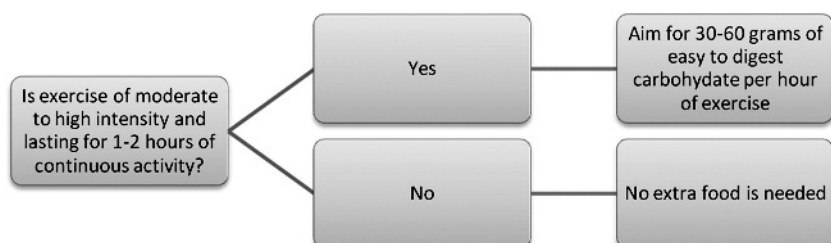
Starting a workout or training session well hydrated is important not only for exercise performance but also for health by preventing an unsafe rise in body temperature. The goal is to drink enough fluids to minimize dehydration while not overdrinking. Recommendations for fluid intake before exercise vary slightly, but in general, it is suggested that 2 to 3 hours before exercise an individual should drink 17 to 20 oz of water or sports drink and 7 to 10 oz 10 to 20 minutes before exercise.⁷ Recreational athletes should consider that most people drink fluids with meals, so if consuming water or other beverages while eating, a rigid preworkout hydration plan may be unnecessary. Water might be preferred for recreational athletes who are trying to reduce body fat and are working out for an hour or less, but sports drinks are not as high in

calories as many think they are. A sports drink with 6% to 8% carbohydrate (the recommended level of carbohydrate in any sports drink) contains only 60 to 75 calories per 8 oz or fewer calories than found in a glass of fruit juice. Another option for recreational athletes is “light” or lower-calorie versions of sports drinks that provide half (or less) of the carbohydrate and calories with the same amount of electrolytes as regular sports drinks.

Eating During Exercise

Consuming foods during exercise is recommended for those athletes who engage in exercise of long duration (marathon, triathlon, road cycling, or ultraendurance events) lasting more than 1 to 2½ hours. However, that advice is most important when an athlete has not eaten before exercise and is starting exercise in a depleted state.² For most recreational athletes, eating during a workout that lasts less than an hour is not necessary. Figure 2 shows a decision tree for providing food during exercise.

For those participating in endurance events, it is recommended that a range of 30 to 60 g of carbohydrate per hour be consumed. The maximum rate of glucose that can be oxidized is about 1 g/min, hence the recommendation to not exceed 60 g of carbohydrate per hour.⁸ Consuming more than 60 g of carbohydrate during exercise can lead to gastrointestinal discomfort. For ultraendurance athletes who are exercising for 4 hours or longer, new research shows that up to 90 g of carbohydrate per hour can be

**FIGURE 2.** Decision tree for eating during exercise.

consumed if multiple carbohydrate sources are used (sucrose, glucose, and fructose). The gut uses different transporters for different carbohydrates, so larger amounts of carbohydrates can be oxidized when consuming coming from multiple sources.⁹ However, using this strategy is not necessary for most recreational athletes who are exercising for fitness.

During exercise, staying hydrated is a key strategy for improving performance and reducing the perceived effort of exercise. Athletes should not lose more than 2% of body weight during exercise. The weight loss represents water loss, not fat loss. Recommendations for fluid intake during exercise are highly individualized and are based on environmental conditions, sweat rates, and the intensity and duration of the activity. Availability of fluids is another consideration for staying well hydrated; some sports limit access to fluids during competition. Sports drinks of 6% to 8% carbohydrate are recommended when exercise is longer than 1 hour.² Drinking sports drinks can be an easy way to meet both carbohydrate and fluid needs. Two cups (about 500 mL) of sports drink provide about 30 g of carbohydrate, as well as sodium and potassium lost in sweat. However, sports drinks are not just for the competitive or elite athlete. Peacock and colleagues¹⁰ have shown that hypohydration is common in adults who exercise at fitness centers, even though there is unlimited access to water. The researchers conducted urine osmolality screening on male and female fitness center members who participated in activities such as running, jogging, using weight machines, cycling, and cross-training. Thirty-seven percent began exercise without being sufficiently hydrated with a urine osmolality of more than 900 mOsm/kg of body weight, which is consistent with about a 2% body mass deficit.¹⁰ As a follow-up study, Peacock and colleagues¹¹ found that when recreational athletes were given sports drinks (a 2% carbohydrate sports was used in this study, similar to "light" sports drinks available in the United States), water, or no access to fluids during exercise, the group that drank sports drinks consumed more fluids and maintained

better hydration compared with the water or no access to fluids group. In other words, if you like the taste (and sweetness) of your hydration beverage, you are more likely to drink more of it during exercise.

Athletes need to experiment to find what foods and fluids work for them during exercise as digestion and absorption are altered during activity. Some athletes can tolerate fluids better than solid foods during exercise, but each individual has to find what works best for him/her through trial and error.

Many recreational athletes start exercise in a hypohydrated state.

Eating After Exercise

Recovery nutrition is one of the hottest topics among athletes and for good reason. Athletes who train hard for more than 90 minutes each day or those who compete in multiple events within a day or several events in a period of few days (track and field, swimming, tennis, tournament play in sports such as basketball, volleyball, and soccer) need to replace lost glycogen. Athletes who are trying to build muscle mass (football, body builders, fitness enthusiasts) could benefit from a protein-rich snack after a workout to stimulate muscle protein synthesis. And, most athletes do not drink enough fluids during exercise, so at the end of activity they are often hypohydrated if not outright dehydrated. Figure 3 contains a decision tree for postexercise feeding and recovery.

Recovery nutrition for endurance-type athletes or those who participate in high-intensity intermittent activities focuses on carbohydrate intake to restore muscle glycogen. Carbohydrate consumption also stimulates the hormone insulin, and both are needed to transport glucose into muscle to replace glycogen used in exercise. When there is a short amount of time between events (≤ 8 hours), glycogen resynthesis should start immediately at the end of an

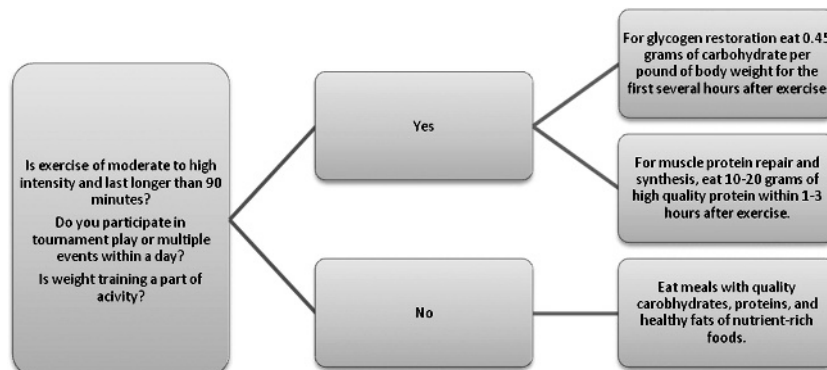


FIGURE 3. Decision tree for postexercise meals and recovery.

exercise session. The goal is to consume carbohydrate at the rate of 0.45 g/lb during the first 4 hours. For those athletes who have a full 24 hours before the next exercise session, it is not critical to eat immediately after exercise as long as carbohydrate is consumed in sufficient quantities in meals or snacks before the next workout or competition.³ Adding protein to the postexercise feeding may not enhance glycogen resynthesis as long as carbohydrate intake is adequate. However, many athletes do not meet carbohydrate goals, so combining carbohydrate with protein is a smart strategy to help restore glycogen and provide needed amino acids for muscle repair and synthesis.

Recovery nutrition for weight training focuses on providing high-quality protein (ie, one that provides all of the essential amino acids) along with some carbohydrate for insulin stimulation to aid in muscle repair and provide nutrients for muscle protein synthesis. Athletes are encouraged to consume about 10 to 20 g of protein within 2 to 3 hours after a weight-training session. More is not better; excess protein will be oxidized and used as a fuel, not building additional muscle.¹²

Much is made of the source of protein... is one superior to the others? Is whey protein better than milk protein, and is soy protein a good option for vegetarian athletes? Current research suggests that the crucial element in the protein-rich food or beverage is the amino acid leucine. One of the branched-chain amino acids, leucine, appears to trigger protein synthesis,¹³ and whey protein contains more leucine than other proteins (about 14% of the total amino acids). Milk protein may have the advantage by containing 2 proteins: whey (20% of milk protein) and casein (about 80% of milk protein). Whey is a fast-acting protein, meaning it appears rapidly in the blood, and casein is a slow-acting protein, so together the proteins can stimulate protein synthesis while buffering protein breakdown. Soy protein contains only 1 protein source, so the effect on muscle may not be as great; however, soy protein can promote muscle protein accretion but not as rapidly as whey or milk protein.¹⁴ Athletes should drink at least 16 to 20 oz of fluids for every pound lost during exercise to rapidly and completely replace fluid losses. This becomes especially important for the athlete who competes in multiple events over many days like a tennis tournament, track-and-field competitions, or conference basketball tournaments. Sports drinks are often recommended because the sodium in the beverage encourages fluid consumption and helps the body hold on the fluid by decreasing urine output.¹⁵ As Bob Murray succinctly puts it, "Plain water is a good thirst quencher, but not an effective rehydrator."¹⁶

CONCLUSIONS

All athletes, whether elite or recreational, benefit from consuming a diet containing carbohydrate to match the

demands of activity, protein timed to exercise, and healthy fats to support training and competition. To attain peak performance, all athletes should eat regular meals and snacks. Relying on a preworkout snack to provide enough energy if an athlete has not been eating well in the days leading up to a workout or competitive event will not be sufficient for maximizing performance.

Products designed to be consumed before, during, and after workout are not superior to ordinary foods that can be purchased in the grocery store, but they might have several advantages for the serious athlete. The products are portable and premeasured, and they are precise; that is, they are easy to pack and consume, there is no guess work as to the amount of carbohydrate or protein in the product, and they are formulated with the athlete's needs in mind. As with all commercial products, athletes are encouraged to try them during training to know how they will be tolerated. Recreational athletes might consider the calories in these products and determine if they are consistent with their goals for body composition and performance. Lastly, athletes might want to consider the cost: is an expensive protein recovery shake worth the extra cost when low-fat chocolate milk or a hard-boiled egg provides high-quality protein at a fraction of the cost.

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