AMERICAN COLLEGE of SPORTS MEDICINE®

AMERICAN DIETETIC ASSOCIATION

and

DIETITIANS OF CANADA

JOINT POSITION STATEMENT

Nutrition and Athletic Performance

ABSTRACT

It is the position of the American Dietetic Association, Dietitians of Canada, and the American College of Sports Medicine that physical activity, athletic performance, and recovery from exercise are enhanced by optimal nutrition. These organizations recommend appropriate selection of food and fluids, timing of intake, and supplement choices for optimal health and exercise performance. This position paper reviews the current scientific data related to the energy needs of athletes, assessment of body composition, strategies for weight change, the nutrient and fluid needs of athletes, special nutrient needs during training, the use of supplements and nutritional ergogenic aids, and the nutrition recommendations for vegetarian athletes. During times of high physical activity, energy and macronutrient needs—especially carbohydrate and protein intake—must be met in order to maintain body weight, replenish glycogen stores, and provide adequate protein for building and repair of tissue. Fat intake should be adequate to provide the essential fatty acids and fat-soluble vitamins, as well as to help provide adequate energy for weight maintenance. Overall, diets should provide moderate amounts of energy from fat (20% to 25% of energy); however, there appears to be no health or performance benefit to consuming a diet containing less than 15% of energy from fat. Body weight and composition can affect exercise performance, but should not be used as the sole criterion for sports performance; daily weigh-ins are discouraged. Consuming adequate food and fluid before, during, and after exercise can help maintain blood glucose during exercise, maximize exercise performance, and improve recovery time. Athletes should be well-hydrated before beginning to exercise; athletes should also drink enough fluid during and after exercise to balance fluid losses. Consumption of sport drinks containing carbohydrates and electrolytes during exercise will provide fuel for the muscles, help maintain blood glucose and the thirst mechanism, and decrease the risk of dehydration or hyponatremia. Athletes will not need vitamin and mineral supplements if adequate energy to maintain body weight is consumed from a variety of foods. However, supplements may be required by athletes who restrict energy intake, use severe weight-loss practices, eliminate one or more food groups from their diet, or consume high-carbohydrate diets with low micronutrient density. Nutritional ergogenic aids should be used with caution, and only after careful evaluation of the product for safety, efficacy, potency, and whether or not it is a banned or illegal substance. Nutrition advice, by a qualified nutrition expert, should only be provided after carefully reviewing the athlete's health, diet, supplement and drug use, and energy requirements. *Med. Sci. Sports Exerc.* Vol. 32, No. 12, pp. 2130–2145; *J. Am. Diet. Assoc.* Vol. 12, pp. 1543–1556. 2000; *Diet of Canada* Vol. 61, pp. 176-192.

Over the past 20 years, research has clearly documented the beneficial effects of nutrition on exercise performance. There is no doubt that what an athlete eats and drinks can affect health, body weight and composition, substrate availability during exercise, recovery time after exercise, and, ultimately, exercise performance. As the research and interest in sport nutrition has increased, so has the sale of ergogenic aids, supplements, herbal preparations, and diet aids, all aimed at improving sports performance. The manufacturers of these products frequently make unsubstantiated claims to entice the athlete to use their products. The athlete who wants to optimize exercise performance needs to follow good nutrition and hydration practices, use supplements and ergogenic aids carefully, minimize severe weight loss practices, and eat a variety of foods in adequate amounts.

This position is focused on adult athletes, rather than children or adolescents, and does not focus on any particular type of athlete or athletic event. Moreover, the position is intended to provide guidance to dietetics and health professionals working with athletes, and is not directed to individual athletes themselves.

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This joint position statement was authored by the American College of Sports Medicine, the American Dietetic Association, and the Dietitians of Canada, and content appears in ADA style (e.g. skin-fold). Individual name recognition is reflected in the acknowledgments at the end of the statement.

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KEY POINTS

The following key points summarize the current energy, nutrient, and fluid recommendations for active adults and competitive athletes noted in this position paper. Sport nutrition experts can further adjust these general recommendations to accommodate the unique concerns of individual athletes regarding health, sports, nutrient needs, food preferences, and body weight and body composition goals.

● During times of high-intensity training, adequate energy needs to be consumed to maintain body weight, maximize the training effects, and maintain health. Low-energy intakes can result in loss of muscle mass, menstrual dysfunction, loss or failure to gain bone density, and increased risk of fatigue, injury, and illness.

● Body weight and composition can affect exercise performance but should not be used as the sole criterion for participation in sports; daily weigh-ins are discouraged. Optimal body-fat levels vary depending upon the sex, age, and heredity of the athlete, as well as the sport itself. Body-fat assessment techniques have inherent variability, thus limiting the precision with which they can be interpreted. If weight loss (fat loss) is desired, it should start early—before the competitive season—and involve a trained health and nutrition professional.

● Carbohydrates are important to maintain blood-glucose levels during exercise and to replace muscle glycogen. Recommendations for athletes range from 6 to 10 g/kg body weight per day. The amount required depends upon the athlete's total daily energy expenditure, type of sport performed, sex of the athlete, and environmental conditions.

● Protein requirements are slightly increased in highly active people. Protein recommendations for endurance athletes are 1.2 to 1.4 g/kg body weight per day, whereas those for resistance and strength-trained athletes may be as high as 1.6 to 1.7 g/kg body weight per day. These recommended protein intakes can generally be met through diet alone, without the use of protein or amino acid supplements, if energy intake is adequate to maintain body weight.

● Fat intake should not be restricted, because there is no performance benefit in consuming a diet with less than 15% of energy from fat, compared with 20% to 25% of energy from fat. Fat is important in the diets of athletes as it provides energy, fat-soluble vitamins, and essential fatty acids. Additionally, there is no scientific basis on which to recommend high-fat diets to athletes.

● The athletes at greatest risk of micronutrient deficiencies are those who restrict energy intake or use severe weight-loss practices, eliminate one or more food groups from their diet, or consume high-carbohydrate diets with low micronutrient density. Athletes should strive to consume diets that provide at least the RDAs/DRIs for all micronutrients from food.

● Dehydration decreases exercise performance; thus, adequate fluid before, during, and after exercise is necessary for health and optimal performance. Athletes should drink enough fluid to balance their fluid losses. Two hours before exercise 400 to 600 mL (14 to 22 oz) of fluid should be consumed, and during exercise 150 to 350 mL (6 to 12 oz) of fluid should be consumed every 15 to 20 min depending on tolerance. After exercise the athlete should drink adequate fluids to replace sweat losses during exercise. The athlete needs to drink at least 450 to 675 mL (16 to 24 oz) of fluid for every pound (0.5 kg) of body weight lost during exercise.

● Before exercise, a meal or snack should provide sufficient fluid to maintain hydration, be relatively low in fat and fiber to facilitate gastric emptying and minimize gastrointestinal distress, be relatively high in carbohydrate to maximize maintenance of blood glucose, be moderate in protein, and be composed of foods familiar and well tolerated by the athlete.

● During exercise, the primary goals for nutrient consumption are to replace fluid losses and provide carbohydrate (approximately 30 to 60 g per h) for the maintenance of blood glucose levels. These nutrition guidelines are especially important for endurance events lasting longer than an h, when the athlete has not consumed adequate food or fluid before exercise, or if the athlete is exercising in an extreme environment (heat, cold, or altitude).

● After exercise, the dietary goal is to provide adequate energy and carbohydrates to replace muscle glycogen and to ensure rapid recovery. If an athlete is glycogen-depleted after exercise, a carbohydrate intake of 1.5 g/kg body weight during the first 30 min and again every 2 h for 4 to 6 h will be adequate to replace glycogen stores. Protein consumed after exercise will provide amino acids for the building and repair of muscle tissue. Therefore, athletes should consume a mixed meal providing carbohydrates, protein, and fat soon after a strenuous competition or training session.

● In general, no vitamin and mineral supplements should be required if an athlete is consuming adequate energy from a variety of foods to maintain body weight. Supplementation recommendations unrelated to exercise—such as folic acid in women of childbearing potential—should be followed. If an athlete is dieting, eliminating foods or food groups, is sick or recovering from injury, or has a specific micronutrient deficiency, a multivitamin/mineral supplement may be appropriate. No single nutrient supplements should be used without a specific medical or nutritional reason (e.g., iron supplements to reverse iron deficiency anemia).

● Athletes should be counseled regarding the use of ergogenic aids, which should be used with caution and only after careful evaluation of the product for safety, efficacy, potency, and legality.

● Vegetarian athletes may be at risk for low energy, protein, and micronutrient intakes because of high intakes of low- energy–dense foods and the elimination of meat and dairy from the diet. Consultation with a registered dietitian will help to avoid these nutrition problems.

ENERGY REQUIREMENTS

Meeting energy needs is the first nutrition priority for athletes. Achieving energy balance is essential for the maintenance of lean tissue mass, immune and reproductive function, and optimum athletic performance. Energy balance is defined as a state when energy intake (the sum of energy from food, fluids, and supplement products) equals energy expenditure (the sum of energy expended as basal metabolism, the thermic effect of food, and any voluntary physical activity) (139). Inadequate energy intake relative to energy expenditure compromises performance and the benefits associated with training. With limited energy intake, fat and lean tissue mass will be used by the body for fuel. Loss of muscle results in the loss of strength and endurance. In addition, chronically low energy intake often results in poor nutrient intake, particularly of the micronutrients.

In the 1989 Recommended Dietary Allowances (RDAs) (112), mean energy requirements for women and men who are slightly to moderately active and between 19 to 50 yr of age were established as 2,200 and 2,900 kcal per day, respectively. Expressed alternatively, normally active people are counseled to consume an energy intake of 1.5 to 1.7 times resting energy expenditure or at a rate of 37 to 41 kcal/kg body weight per day (112). Energy expenditure is influenced by heredity, age, sex, body size, fat-free mass, and the intensity, frequency, and duration of exercise. For athletes, the recommendation is made to evaluate the kind of exercise performed for its intensity, frequency, and duration, and then to add this increment to the energy needed for normal daily activity (109,97,59). For example, a 70 kg male runner who runs 10 miles per day at a 6-min pace would require approximately 1,063 kcal per day to cover the energy expenditure of running (0.253 $kcal \cdot min^{-1}/kg$) (78), plus the energy cost of normal daily activities (70 kg $\times$ 37 to 41 kcal/kg body weight) for normal activity. Thus, this athlete would need approximately 3,653 to 3,933 kcal per day to cover the total cost of energy expenditure. Ultimately, however, numeric guidelines for energy intake, such as those cited above, can only provide a crude approximation of the average energy needs of an individual athlete. Any athlete needs to consume enough energy to maintain appropriate weight and body composition while training for a sport. Usual energy intakes for male endurance athletes range from 3,000 to 5,000 kcal per day (56). Although usual energy intakes for many intensely training female athletes may match those of male athletes per kg of body weight, some consume less energy than they expend. This low-energy intake can lead to weight loss and disruption of reproductive function, and is often seen with energy intakes of less than 1,800 to 2,000 kcal per day (78, 56, 48, 75, 90, 93).

Although resistance exercise usually requires less energy than endurance exercise, the total energy needs of athletes participating in strength training and bodybuilding may be as high as those of endurance athletes because of their increased body size and high levels of fat-free mass. In circumstances in which an increase in lean body mass is the goal, energy intake must be sufficient to meet the needs for muscle growth. Thus, many strength athletes may need 44 to 50 kcal/kg body weight/d, and those in serious training may have even higher energy requirements (more than 50 kcal/kg body weight/d) (79, 98).

Weight Change

It is often the case that an athlete will want to increase or decrease body weight to meet the demands of a sport. In either case, weight change should be accomplished slowly during the off-season, or at the beginning of the season, before competition begins. Weight gain can be accomplished by the incorporation of additional energy into the diet (500 to 1,000 kcal per day) in conjunction with increased strength training to promote the accretion of the tissue desired. How quickly weight gain occurs will depend on the athlete's genetic makeup, degree of positive energy balance, number of rest and recovery days per week, and type of exercise training program. Weight loss is somewhat more problematic, as diminished energy intake can compromise nutrient intake and exercise performance while decreasing both body fat and muscle mass (141,95).

Consultation with a registered dietitian trained in sport nutrition can help athletes maintain a healthful diet while reducing total energy intake to allow gradual weight loss (approximately 1 to 2 lbs/wk or 0.5 to 1.0 kg/wk). The process begins with the identification of what constitutes a realistic, healthful body weight based on genetic, physiologic, social, sport, and psychological factors. A healthful weight is one that can be realistically maintained, allows for positive advances in exercise performance, minimizes the risk of injury or illness, and reduces the risk factors for chronic disease. Table 1 shows strategies to help health professionals work with athletes to identify and maintain healthful body weights.

Failure to meet weight-loss goals may result in severe consequences, such as being cut from the team, restricted participation, or elimination from competition. This may result in chronic dieting by many athletes to maintain lower-than-healthful body weights, which in turn can lead to disordered eating and, in severe cases, clinical eating disorders. Nutrition strategies for identification, intervention, and treatment of eating disorders in athletes have been presented elsewhere (152, 22, 138, 142).

When pressure to achieve a weight goal is high, athletes are likely to attempt any weight-loss method to achieve success, regardless of the health consequences. Weight loss can be especially problematic for female athletes who generally are smaller, and thus may have lower energy needs than male athletes. In women, low-energy intake, in conjunction with high-energy output, has been associated with alterations in the secretion of the pituitary gonadotropins (luteinizing hormone [LH] and follicle-stimulating hormone [FSH]) (90,58). This, in turn, results in changes in ovarian hormone secretions leading to amenorrhea and loss of (or failure to gain) bone mass in young female athletes (5). It has been proposed that energy availability (amount of energy intake unused after energy for activity has been provided) determines the health of the body, and that curtailing energy intake to attain some body weight or fat standard may result in insufficient energy being available to maintain all vital functions (48, 90, 47). Thus, a negative energy balance, due to chronic dieting or undereating in conjunc-

TABLE 1. Weight management strategies for athletes.[a]

Setting and monitoring goals

- Set realistic weight and body composition goals. Ask the athlete:
  - –What is the maximum weight that you would find acceptable?
  - –What was the last weight you maintained without constantly dieting?
  - –How did you derive your goal weight?
  - –At what weight and body composition do you perform best?
- Encourage less focus on the scale and more on healthful habits such as stress management and making good food choices.
- Monitor progress by measuring changes in exercise performance and energy level, the prevention of injuries, normal menstrual function, and general overall well-being.
- Help athletes to develop lifestyle changes that maintain a healthful weight for themselves—not for their sport, for their coach, for their friends, for their parents, or to prove a point.

Suggestions for food intake

- Low-energy diets will not sustain athletic training. Instead, decreases in energy intake of 10% to 20% of normal intake will lead to weight loss without the athlete feeling deprived or overly hunger. Strategies such as substituting lower-fat foods for whole-fat fodds, reducing intake of energy-dense snacks, and doing activities other than eating when not hungry can be useful.
- If appropriate, athletes can reduce fat intake but need to know that a lower-fat diet will not guarantee weight loss if a negative energy balance (reduced energy intake and increased energy expenditure) is not achieved. Fat intake should not be decreased below 15% of total energy intake, because some fat is essential for good health.
- Emphasize increased intake of whole grains and cereals, beans, and legumens.
- Five or more daily servings of fruits and vegetables provide nutrients and fiber.
- Dieting athletes should not skimp on protein and need to maintain adequate calcium intakes. Accordingly, use of low-fat dairy products and lean meats, fish, and poultry is suggested.
- A variety of fluids—especially water—should be consumed throughout the day, including before, during, and after exercise workouts. Dehydration as a means of reaching a body-weight goal is contraindicated.

Other weight management strategies

- Encourage athletes not to skip meals, especially breakfast, and not to let themselves get too hungry. They should be prepared for times when they might get hungry, including keeping nutritious snacks available for those times.
- Athletes should not deprive themselves of favorite foods or set unrealistic dietary rules or guidelines. Instead, dietary goals should be flexible and achievable. Athletes should remember that all foods can fit into a healthful lifestyle; however, some foods are chosen less frequently. Developing lists of "good" and "bad" food is discouraged.
- Help athletes identify their own dietary weaknesses and plan strategies for dealing with them.
- Remind athletes that they are making lifelong dietary changes to sustain a healthful weight and optimal nutritional status rather than going on a short-term "diet" that they will someday go off.

[a] Source: reference 92.

tion with heavy exercise may alter the energy flux and create a negative "energy drain," which compromises reproductive function and bone health. Incorporation of additional energy into the diets of these women has resulted in the return of menstrual function and the improvement in overall nutritional status (48, 80). Although failure of reproductive function in male athletes has not been extensively investigated, Loucks (89) has identified changes in LH and FSH secretion in men that mimic those of women in response to changes in energy availability.

BODY COMPOSITION

Body composition and weight are 2 of the many factors that contribute to optimal exercise performance. Taken together, these 2 factors may affect an athlete's potential for success within a given sport. Body weight can influence an athlete's speed, endurance, and power, whereas body composition can affect an athlete's strength, agility, and appearance. Most athletes require a high strength-to-weight ratio to achieve optimal athletic performance, and because body fat adds to weight without adding to strength, low body fat percentages are often emphasized within many sports (123). However, too little body fat results in deterioration of health and performance (47, 65). Athletic performance cannot be accurately predicted based solely on body weight and composition (64).

The primary reason for determining an athlete's body composition is to obtain information that may be beneficial in improving athletic performance (10). Therefore, the determination of an athlete's optimal body weight and composition for health and competition should be done individually, because these factors are strongly influenced by age, sex, genetics, and the requirements of the sport. Yet, some sports dictate that athletes make changes in body weight and composition that may not be optimal for the athlete. For example, weight-class sports—such as wrestling or lightweight rowing—may require athletes to lose or gain weight to qualify for a specific weight category. Sports with an esthetic component—such as dance, gymnastics, and figure skating—may pressure athletes to lose weight and body fat to have a lean physique, although their current weight for health and performance may be optimal. With extreme energy restrictions, both muscle and fat mass are lost, which may adversely influence an athlete's performance. Thus, an athlete's optimal competitive body weight and relative body fatness should be determined when an athlete is healthy and performing at his or her best (147).

Body Composition and Sport Performance

Percentage of body fat values for athletes varies depending on the sex of the athlete and the sport itself. Male athletes with the lowest estimates of body fat (less than 6%) include middle-distance and long-distance runners and bodybuilders, whereas male basketball players, cyclists, gymnasts, sprinters, jumpers, triathletes, and wrestlers average between 6% to 15% body fat (65, 135). Male athletes involved in power sports such as football, rugby, and ice and field hockey have slightly more variable body fat levels (6% to 19%). Female athletes with the lowest estimates of body fat (6% to 15%) participate in bodybuilding, cycling, triathlons, and running events; higher fat levels are found in female athletes participating in racquetball, skiing, soccer, swimming, tennis, and volleyball (10% to 20%) (65, 135). The estimated minimal level of body fat compatible with health is 5% for males and 12% for females (84); however, optimal body fat percentages for an individual athlete may be much higher than these minimums and should be determined on an individual basis. Athletes who strive to maintain body weight or body fat levels that are inappropriate, or have body-fat percentages below these minimal levels, may be at risk for an eating disorder or other health problems related to poor energy and nutrient intakes (48, 93, 138, 47, 80, 11, 12, 92).

Assessment of Body Composition

Methods for assessment of body composition are based on either a 2-component or a multicomponent model and use several different measurement techniques. Two-component models divide the body into either fat mass (all lipids within the body) or fat-free mass (the remainder of lipids after fat is subtracted). The multicomponent model divides the body into 3 or more components. For example, the 3-component model divides the body into fat mass and 2 components of fat-free mass (bone mineral and lean tissue). The criterion methods most commonly used to assess components of body composition in athletes are based on a 2-component or a multicomponent model. Though a multicomponent criterion model is preferred for assessing body composition because it provides more accurate estimates, measurement techniques required for this model are not readily available to most athletes. A 2-component criterion model typically uses hydrodensitometry (hydrostatic weighing) or plethysmography (BODPOD) measurement techniques, and a 3-component model uses dual-energy x-ray absorptiometry (DEXA) measurements. The most common methods used to measure body composition in field or clinical settings include anthropometry (skinfolds), bioelectrical impedance analysis (BIA), and near-infrared interactance. These field methods are validated using either 2-component or multicomponent criterion models (86). When using these field methods, care should be taken in choosing the appropriate validated prediction equation for estimating body composition based on an athlete's demographics (age, sex, level of adiposity, ethnicity, and physical activity) in order to obtain accurate estimates (62).

The relative validity of any body composition field method depends on its accuracy compared with the criterion method and its reliability (reproducibility) (84). DEXA and hydrostatic weighing (hydrodensitometry) are 2 widely used criterion methods from which field methods of body composition assessment for athletes are developed (55, 85, 107, 130, 50, 66). Regardless of the method used, athletes and coaches should know the errors associated with the body composition assessment method being used. With carefully applied skin-fold or BIA methods, it is possible to estimate relative body fat percentage with an error of 3% to 4%, and to estimate fat-free mass within 2.5 to 3.5 kg (64, 84, 86). Thus, if the actual body fat percentage is 15%, then predicted values could range from 12% to 18% (assuming a 3% error). If the actual fat-free mass is 50 kg, then predicted values could range from 47.5 to 52.5 kg, assuming an error of 2.5 kg. If inappropriate prediction equations for a method are used, poor measurement techniques applied or if the measurement equipment is poorly maintained and calibrated, the errors associated with the body composition estimate will be much larger. Because of the errors associated with body composition assessment methods, it is inappropriate to set a specific body-fat percentage goal for an individual athlete. Instead, a range of target percentage of body-fat values should be recommended.

MACRONUTRIENT REQUIREMENTS FOR EXERCISE

The fuel burned during exercise depends on the intensity and duration of the exercise performed, the sex of the athlete, and prior nutritional status. All other conditions being equal, an increase in the intensity of an exercise will increase the contribution of carbohydrate to the energy pool (20, 21). As the length of the exercise continues, the source of this carbohydrate may shift from the muscle glycogen pool to circulating blood glucose, but in all circumstances, if blood glucose cannot be maintained, the intensity of the exercise performed will decrease (39). Fat contributes to the energy pool over a wide range of exercise intensities, being metabolized at somewhat the same absolute rate throughout the range; however, the proportion of energy contributed by fat decreases as exercise intensity increases because the contribution of carbohydrate increases (17). Protein contributes to the energy pool at rest and during exercise, but in fed individuals it probably provides less than 5% of the energy expended (49,121). As the duration of exercise increases, protein may contribute to the maintenance of blood glucose through gluconeogenesis in the liver. In experiments in which subjects are tested in a fasting state, the contribution of fat to the energy pool will be greater than in people who are tested postprandially when exercise performed is moderate (approximately 50% of maximal oxygen uptake [$\dot{V}O_{2max}$]) (16). With exercise of higher intensity (greater than 65% of $\dot{V}O_{2max}$), neither prior feeding nor training markedly affects the fuel used (16).

Data are not presently available, however, to suggest that athletes need a diet substantially different from that recommended in the Dietary Guidelines for Americans (116) or the Nutrition Recommendations for Canadians (16) (55% to 58% of energy from carbohydrate, 12% to 15% of energy from protein and 25% to 30% of energy from fat). Although high-carbohydrate diets (more than 60% of energy intake) have been advocated in the past, the use of proportions in making dietary recommendations may actually be misleading in terms of providing optimum nutrition. When energy intake is 4,000 to 5,000 kcal per day, even a diet containing 50% of the energy from carbohydrate will provide 500 to 600 g of carbohydrate (or approximately 7 to 8 g/kg for a 70 kg athlete), which is sufficient to maintain muscle glycogen stores from day to day (36,38). Similarly, if protein intake in such a diet was even as low as 10% of energy intake, absolute protein intake (100 to 125 g per day) would exceed the recommendations for protein intake for athletes (1.2 to

1.7 g per day or 84 to 119 g in a 70 kg athlete, see the following discussion on nitrogen balance in men). Conversely, when energy intake is less than 2,000 kcal per day, even a diet providing 60% of the energy from carbohydrate may not provide sufficient carbohydrate to maintain optimal carbohydrate stores (4 to 5 g/kg in a 60 kg athlete). Typically, diets containing 20–25% energy from fat have been recommended to facilitate adequate carbohydrate intake and to assist in weight management where necessary. Thus, specific recommendations for individual energy components may be more useful when they are based on body size, weight and body composition goals, the sport being performed, and sex of the athlete.

Protein needs of athletes have received considerable investigation, not only in regard to whether athletes' protein requirements are increased, but also in relation to whether individual amino acids are a benefit to performance. Mechanisms suggested to increase athletes' protein requirements include the need to repair exercise-induced microdamage to muscle fibers, use of small amounts of protein as an energy source for exercise, and the need for additional protein to support gains in lean tissue mass (28,82). If protein needs are increased, the magnitude of the increase may depend on the type of exercise performed (endurance vs resistance), the intensity and duration of the activity, and possibly the sex of the participants.

For endurance athletes, nitrogen balance studies in men suggest a protein recommendation of 1.2 g/kg per day (105). Little information is available regarding requirements of endurance athletes who are women. Resistance exercise is thought to increase protein requirements even more than endurance exercise, and it has been recommended that experienced male bodybuilders and strength athletes consume 1.6 to 1.7 g/kg body weight per day to allow for the accumulation and maintenance of lean tissue (82, 140). Again, data on female strength athletes are not available. Athletes should be aware that increasing protein intake beyond the recommended level is unlikely to result in additional increases in lean tissue because there is a limit to the rate at which protein tissue can be accrued (28), whereas other sources have suggested an intake of 1.2 to 1.4 g/kg per day (82). It must be ensured that energy intake is adequate—otherwise, protein will be used as an energy source, falsely elevating estimates of the requirements under conditions of energy balance. It is worth noting that the customary diets of most athletes provide sufficient protein to cover even the increased amounts that may be needed (56).

The use of individual amino acids to enhance performance has also been studied. One proposal is that administration of branched chain amino acids (BCAA) may enhance endurance performance by delaying the onset of central nervous system fatigue (41). It has also been proposed that BCAA may extend performance by serving as substrates for energy expenditure (30). The results of human studies, however, have been inconsistent (19, 106, 143, 91). Because the safety and efficacy of these mixtures has not been established, their use cannot be advocated.

Some studies (111, 81) have proposed a positive effect of relatively high-fat diets (more than 70% of energy intake) on athletic performance. Careful evaluation of these studies show little evidence supporting this concept (73). Fat is a necessary component of a normal diet, providing energy and essential elements of cell membranes and associated nutrients such as vitamins E, A, and D. However, the long-term negative effects of high-fat diets on health are well known. The Dietary Guidelines for Americans and Nutrition Recommendations for Canadians make recommendations for the proportion of energy from fatty acids (10% saturated, 10% polyunsaturated, 10% monounsaturated) (116, 61). Athletes should follow these general recommendations, and should also ensure that their fat intakes are not excessively low. The 1999 study by Dreon and colleagues (46) suggests that there are negative effects on blood lipid profiles in some people when total dietary fat intake is less than 15% of energy.

VITAMINS AND MINERALS

Micronutrients play an important role in energy production, hemoglobin (Hb) synthesis, maintenance of bone health, adequate immune function, and the protection of body tissues from oxidative damage. They are also required to help build and repair muscle tissue following exercise. Theoretically, exercise may increase or alter the need for vitamins and minerals in a number of ways. Exercise stresses many of the metabolic pathways in which these micronutrients are required, thus exercise training may result in muscle biochemical adaptations that increase micronutrient needs. Exercise may also increase the turnover of these micronutrients, thus increasing loss of micronutrients from the body. Finally, higher intakes of micronutrients may be required to cover increased needs for the repair and maintenance of the lean tissue mass in athletes. It is assumed that the current RDAs and Dietary Reference Intakes (DRIs) are appropriate for athletes unless otherwise stated (112,67,68). Athletes at the greatest risk of poor micronutrient status are those who restrict energy intake or use severe weight-loss practices, eliminate one or more of the food groups from their diet, or consume high-carbohydrate, low-micronutrient–dense diets. Athletes participating in these types of behaviors may need to use a multivitamin and mineral supplement to improve overall micronutrient status. Supplementation with single micronutrients is discouraged unless clear medical, nutritional, or public health reasons are present, such as the supplementation of iron to treat iron deficiency anemia or folic acid to prevent birth defects.

The B-complex vitamins have 2 major functions directly related to exercise. Thiamin, riboflavin, vitamin B-6, niacin, pantothenic acid, and biotin are involved in energy production during exercise (97,35,83,94,120,129,104), whereas folate and vitamin B-12 are required for the production of red cells, protein synthesis, and in tissue repair and maintenance (104). Limited research has examined whether exercise increases the need for some of the B-complex vitamins, especially vitamin B-6, riboflavin, and thiamin (35,83,120,104,96). Available data were not sufficiently precise to set separate recommendations for athletes or to quantitatively link recommendations to energy expenditure (68). Nevertheless, the data available suggest that exercise may slightly increase the need for these vitamins perhaps up to twice the current recommended amount (94). These increased needs can generally be met by the higher energy intakes required of athletes to maintain body weight.

The antioxidant nutrients—such as vitamins A, E, and C, beta carotene, and selenium—play an important role in protecting the cell membranes from oxidative damage. Because exercise can increase oxygen consumption by 10- to 15-fold, it has been hypothesized that chronic exercise produces a constant “oxidative stress” on the muscles and other cells (34,74). In addition, muscle-tissue damage caused by intense exercise can lead to lipid peroxidation of membranes. Although there is some evidence that acute exercise may increase levels of lipid peroxide by-products (76), habitual exercise has been shown to result in an augmented antioxidant system and a reduction of lipid peroxidation (34). Thus, a well-trained athlete may have a more developed endogenous antioxidant system than a sedentary person (77). Research examining whether exercise increases the need for the antioxidant nutrients is equivocal and controversial; thus, there is no clear consensus on whether supplementation of antioxidant nutrients is necessary (34, 76,77). The lack of consensus is especially true for the athlete with adequate or above-adequate blood levels of the antioxidant vitamins (34). Those athletes at greatest risk for poor antioxidant intakes are athletes following a low-fat diet, those who restrict energy intakes, or those with limited dietary intakes of fruits and vegetables.

The primary minerals low in the diets of athletes—especially female athletes—are calcium, iron, and zinc (93,60). Low intakes of these minerals can usually be attributed to energy restriction or avoidance of animal products such as meat, fish, poultry, and dairy products. Calcium is especially important for the building and repair of bone tissue and the maintenance of blood calcium levels. Inadequate dietary calcium increases the risk of low bone mineral density (BMD) and stress fractures. Female athletes are at greatest risk for low BMD if energy intakes are low, dairy products are eliminated from the diet, and menstrual dysfunction is present (48,47). Vitamin D is also required for adequate calcium absorption, regulation of serum calcium levels, and promotion of bone health. The 2 primary sources of vitamin D are fortified foods, such as milk, and the production of vitamin D by ultraviolet conversion in the skin. Athletes who live at northern latitudes or who train primarily indoors throughout the year—such as gymnasts and figure skaters—may be at risk for poor vitamin D status, especially if foods fortified with vitamin D are not consumed (14). These athletes would benefit from vitamin D supplementation at the level of the DRI (5 μg/d or 200 international units [IU] vitamin D) (67).

Iron plays an important role in exercise as it is required for the formation of Hb and myoglobin, which bind oxygen in the body, and for enzymes involved in energy production. Iron depletion (low iron stores) is one of the most prevalent nutrient deficiencies observed in athletes, especially female athletes. The impact of iron depletion on exercise performance is limited, but if this condition progresses to iron deficiency anemia (low Hb levels), exercise performance can be negatively affected (97,60).

The high incidence of iron depletion in athletes is usually attributed to poor energy intakes; avoidance of meat, fish, and poultry that contain iron in the readily available heme form; vegetarian diets that have poor iron bioavailability; or increased iron losses in sweat, feces, urine, or menstrual blood. Athletes—especially females, long-distance runners, and vegetarians—should be screened periodically to assess iron status. Changes in iron storage (low-serum ferritin concentrations) will occur first, followed by low-iron transport (low-serum iron concentrations), and eventually iron deficiency anemia (low Hb and hematocrit (Hct) concentrations). Because reversal of iron deficiency anemia can require 3 to 6 months, it is advantageous to begin nutrition interventions before iron deficiency anemia can develop. Although depleted iron stores are more prevalent in female athletes, the incidence of iron deficiency anemia in female athletes is similar to the 9% to 11% found in the general female population (60,87).

A transient decrease in ferritin and Hb may be experienced by some athletes at the initiation of training. These decreases are the result of an increase in plasma volume, which causes hemodilution and appears to have no negative effect on performance (60). If an athlete appears to have iron deficiency anemia but does not respond to nutrition intervention, then low Hb values may be the result of changes in plasma volume, and not poor nutritional status (97). Chronic iron deficiency anemia resulting from poor iron intake can seriously affect health and exercise performance and needs medical and nutrition intervention.

In the United States, it is estimated that the zinc content of the food supply is approximately 12.3 mg of zinc per person, with 70% of the zinc coming from animal products (37). Based on survey data, approximately 90% of men and 81% of women have zinc intakes that are below the 1989 RDAs (15 mg and 12 mg, respectively) (110). This nutritional shortfall is also seen in athletes, particularly females (93). The impact of these low zinc intakes on zinc status is difficult to measure, because clear assessment criteria have not been established and plasma zinc concentrations may not reflect changes in whole-body zinc status (88). Because of the role zinc plays in growth, building and repair of muscle tissue, and energy production, it is prudent to assess the diets of active females for adequate zinc intake.

HYDRATION

Exercise performance is optimal when athletes maintain fluid balance during exercise; conversely, exercise performance is impaired with progressive dehydration (8,13,102,108,146). Moreover, dehydration increases the risk of potentially life-threatening heat injury such as heat stroke (115). Accordingly, athletes should attempt to remain well-hydrated before and during exercise.

The American College of Sports Medicine Position Stand on Exercise and Fluid Replacement (4) and the National Athletic Trainers' Association (NATA) Position Statement on Fluid Replacement for Athletes (32) provide comprehensive overviews of the research and recommendations on maintaining hydration during exercise. The following information summarizes the key points from these position stands and provides recommendations for special environmental conditions.

Water and Electrolyte Balance

● **Losses during exercise** Athletes dissipate the metabolic heat produced during physical activity by radiation, conduction, convection, and by vaporization of water. In hot, dry environments, evaporation accounts for more than 80% of metabolic heat loss. Sweat rates will vary depending on variables such as body size, exercise intensity, ambient temperature, humidity, and acclimation, but can exceed 1.8 kg (approximately 1,800 mL) per h (4). In addition to water, sweat also contains substantial amounts of sodium (an average of approximately 50 $mmol \cdot L^{-1}$, or about 1 $g \cdot L^{-1}$, although concentrations vary widely), modest amounts of potassium, and small amounts of minerals such as iron and calcium.

● **Gastric emptying and intestinal absorption of fluids during exercise** Euhydration (and the associated maintenance of physiological function and performance) can be accomplished during exercise only if the rate of fluid ingestion and absorption equals the rate of fluid loss through sweating (and, in events of longer duration, urination). Fluid balance during exercise is not always possible because maximal sweat rates exceed maximal gastric emptying rates, which in turn limit fluid absorption. In most cases, however, rates of fluid ingestion by athletes during exercise fall short of amounts that could be emptied from the stomach and absorbed by the gut. For example, athletes often consume less than 500 mL per h during competition (4), whereas gastric emptying rates of more than 1 L per h are possible (4).

Gastric emptying is maximized when the amount of fluid in the stomach is high. It is reduced with hypertonic fluids or when carbohydrate concentration is greater than or equal to 8%; however, fluids containing 4% to 8% carbohydrate can generally be emptied at over 1 L per h in most people when gastric volume is maintained at or above 600 mL (4,32).

● **Dehydration, hypohydration, and hyponatremia** Disturbances of fluid and electrolyte balance that can occur in athletes include dehydration, hypohydration, and hyponatremia (7). In their most severe forms, all can be life-threatening. Exercise-induced dehydration develops as a consequence of fluid losses that exceed fluid intake. In contrast, hypohydration occurs when athletes dehydrate themselves before beginning a competitive event, and can be induced by prior fluid restriction, exercise practices, diuretic use, or sauna exposure. In most cases, hypohydration is practiced by athletes competing in sports with weight categories (e.g., wrestling, boxing, lightweight crew, weight lifting, and judo). Hyponatremia (low blood-sodium concentrations of less than 130 $mmol \cdot L^{-1}$) can develop either as a result of prolonged, heavy sweating with failure to replace sodium, or when excess water is retained in the body (9). Although endurance athletes are more likely to suffer from dehydration than from overhydration, the latter is not uncommon. For example, 11 of 605 athletes entered in the New Zealand Ironman triathlon developed severe hyponatremia, and 8 of these athletes were likely overhydrated, as they had either maintained or gained up to 5% of body weight during the race (136).

Fluid and Electrolyte Recommendations

● **Before exercise** Athletes should be well-hydrated when beginning to exercise. In addition to drinking generous amounts of fluid in the 24 h before an exercise session, the ACSM and the NATA recommend drinking 400 to 600 mL of fluid 2–3 h before exercise (4,32). Such a practice should optimize hydration status while allowing enough time for any excess fluid to be excreted as urine before beginning to exercise.

● **During exercise** Athletes should attempt to drink enough fluid to maintain fluid balance, as even partial dehydration can compromise performance. If fluid balance cannot be maintained, the maximal amounts that can be tolerated should be ingested. Optimal hydration can be facilitated by drinking 150 to 350 mL (6 to 12 oz) of fluid at 15- to 20-min intervals, beginning at the start of exercise (4).

Beverages containing carbohydrate in concentrations of 4% to 8% are recommended for intense exercise events lasting longer than 1 h (4). These beverages are also suitable for hydration during exercise events lasting less than 1 h, although plain water is appropriate under these conditions.

There appears to be little physiologic need to replace electrolytes during a single exercise session of moderate duration (e.g., less than 3 to 4 h), particularly if sodium was present in the previous meal. However, including sodium in amounts between 0.5 and 0.7 $g \cdot L^{-1}$ is recommended during exercise lasting longer than 1 h because it may enhance palatability and the drive to drink, therefore increasing the amount of fluid consumed (4). It should be noted that this amount of sodium exceeds that typically available in commercial beverages. Including sodium in fluid replacement beverages may also help prevent hyponatremia in susceptible people (4,145). Although most athletes who drink more fluid than they lose as sweat simply excrete the excess fluid as urine, in some people it is retained (136). If the fluid contains sodium, it could help prevent the dilution of serum sodium levels, thereby decreasing the risk of hyponatremia. Limiting fluid intake so that it does not exceed sweat rate can also decrease risk of hyponatremia.

● **After exercise** In most cases, athletes do not consume enough fluids during exercise to balance fluid losses, and thus complete their exercise sessions dehydrated to some extent. Consuming up to 150% of the weight lost during an exercise session may be necessary to cover losses in sweat plus obligatory urine production (134). Including sodium either in or with fluids consumed postexercise reduces the diuresis that occurs when only plain water is ingested (32,99). Sodium also helps the rehydration process by maintaining plasma osmolality and thereby the desire to drink. Because most commercial sport drinks do not contain enough sodium to optimize postexercise fluid replacement, athletes can rehydrate in conjunction with a sodium-containing meal (100). High-sodium items include soups, pickles, cheeses, processed meats, pizza, pretzels, and popcorn. Use of condiments such as soy sauce and ketchup, as well as salting food at the table, also increase sodium intake.

Special Environmental Conditions

• **Hot and humid environments** The risks of dehydration and heat injury increase dramatically in hot, humid environments (3). If the ambient temperature exceeds body temperature, heat cannot be dissipated by radiation. Moreover, if the relative humidity is high, the potential to dissipate heat by evaporation of sweat is substantially reduced—at a relative humidity of 100%, vaporization of sweat does not occur. Instead, in humid environments, sweat drips from the body, leading to nonfunctional fluid loss. When temperature and humidity are both high, there is a very high risk of heat illness, and competitive events should be postponed, rescheduled, or canceled (34,3). If competitive events do occur under these conditions, every precaution should be taken to assure that athletes are well hydrated, have ample access to fluids, and are monitored for heat-related illness (32).

• **Cold environments** Although the risk of dehydration is greater in hot environments, dehydration is not uncommon in cool or cold weather (1). Factors that could contribute to dehydration under these conditions include respiratory fluid losses in cold dry environments, as well as sweat losses that may be high if insulated clothing is worn during intense exercise. Dehydration could also occur as a result of low rates of fluid ingestion: if an athlete is chilled and available fluids are cold, the incentive to drink would clearly be reduced. Finally, the difficulty of removing multiple layers of clothing to urinate may cause some athletes, especially women, to voluntarily limit their fluid intake (54).

• **Altitude** Exposure to altitudes higher than 2,500 m (8,200 ft) may result in fluid losses beyond those associated with any exercise that might be performed. These losses are the result of mandatory diuresis and high respiratory water losses, accompanied by decreased appetite, which lead to an increased need for fluid intake. The diuresis is considered by some to be an indication of successful acclimatization (57), although others (27) have suggested that at least part of the diuresis can be minimized by adequate energy intake and maintenance of body weight. Under circumstances of weight maintenance, this diuresis is of a magnitude of about 500 mL per day and lasts for about 7 d (27). Respiratory water losses may be as high as 1,900 mL per day in men (29) and 850 mL in women (101). Thus, fluid intake at high altitude should be increased to as much as 3 to 4 L per day to assure optimal kidney function.

THE TRAINING DIET

Recommendations for athletes' intakes of energy, macronutrients, vitamins, and minerals are described elsewhere in this document. These recommendations are often presented in terms of milligram or gram amounts of nutrients (e.g., 6 to 10 g carbohydrate/kg body weight) and must be translated into food choices consistent with food preferences and training schedules of athletes (125). The foundations (proportion of energy from protein, fat, and carbohydrate) for the training diets of athletes, however, do not differ substantively from current recommendations for the general population. Thus, the training diet should incorporate the principles outlined in the Dietary Guidelines for Americans (116) and Canada's Guidelines for Healthy Eating (117), and be based on the 1992 U.S. food guide (U.S. Food Guide Pyramid) (52) or the 1992 Canadian food guide (Canada's Food Guide to Healthy Eating (31)).

The fundamental differences between an athlete's diet and that of the general population are that athletes require additional fluid to cover sweat losses and additional energy to fuel physical activity. As discussed earlier, it is appropriate for much of the additional energy to be supplied as carbohydrate. Though in some cases needs for other nutrients also increase (e.g., protein, B-complex vitamins), the proportional increase in energy requirements appear to exceed the proportional increase in needs for other nutrients. Accordingly, as energy requirements increase, athletes should first aim to consume the maximum number of servings specified in both food guides from carbohydrate-based food groups (breads, cereals and grains, vegetables, and fruits). For many athletes, however, energy needs will exceed the amount of energy (kcal per day) in the upper range of servings for these food groups as provided by both food guides. To maintain dietary variety, these athletes may also increase the number and/or size of servings of dairy products and protein foods, but should aim to keep the proportions of energy provided by different food groups consistent with those identified in both food guides. Conversely, athletes who are small and/or have lower energy needs will need to pay greater attention to making nutrient-dense food choices to obtain adequate carbohydrate, protein, and micronutrients.

The other issue that arises in a discussion of the diet of athletes relates to the timing of meals and snacks. Common sense dictates that food and fluid intake around workouts needs to be determined on an individual basis and will depend, in part, on an athlete's gastrointestinal characteristics as well as the intensity of the workout. For example, an athlete might tolerate a snack consisting of milk and a sandwich 1 h before a low-intensity workout, but would be uncomfortable if the same meal was consumed before a very hard effort. In any case, athletes in heavy training or doing multiple daily workouts may need to eat more than 3 meals and 3 snacks per day and should consider every possible eating occasion (15). For example, they should consider eating in close proximity to the end of a workout, having more than one afternoon snack, or eating a substantial snack before bed.

Preexercise Meal

Eating before exercise, as opposed to exercising in the fasting state, has been shown to improve performance (113,133,152). The meal or snack consumed before competition or an intense workout should prepare athletes for the upcoming activity, and leave him or her neither hungry nor with undigested food in the stomach. Accordingly, the following general guidelines for meals and snacks should be used: sufficient in fluid to maintain hydration, low in fat and fiber to facilitate gastric emptying and minimize gastrointestinal distress, high in carbohydrate to maintain blood glucose and maximize glycogen stores, moderate in protein, and composed of foods familiar to the athlete.

The size and timing of the preexercise meal are interrelated. Because most athletes do not like to compete on a full stomach, smaller meals should be consumed in closer proximity to the event to allow for gastric emptying, whereas larger meals can be consumed if more time is available before exercise or competition. Amounts of carbohydrate used in studies in which performance was enhanced have ranged from approximately 200 to 300 g carbohydrate for meals consumed 3 to 4 h before exercise (113,133,152,132). The recommendations on carbohydrate consumption within 1 h before activity have been controversial. Early research suggested that this practice leads to hypoglycemia and premature fatigue (53); however, more recent studies report either no effect or beneficial effects of preevent feeding on performance (38,113,2,44,63). Current data are mixed concerning whether the glycemic index of carbohydrate in the preexercise meal affects performance (143,148).

Although the above guidelines are sound and work well on average, the individual needs of the athlete must be emphasized. For example, some athletes consume and enjoy a substantial meal (e.g., pancakes, juice, and scrambled eggs) 2 to 4 h before exercise or competition; however, others may suffer severe gastrointestinal distress following such a meal and need to rely on liquid meals. Athletes should always ensure that they know what works best for themselves by experimenting with new foods and beverages during practice sessions and planning ahead to ensure they will have access to these foods at the appropriate time.

During Exercise

Whether or not carbohydrate consumption in amounts typically provided in sport drinks (4% to 8%) improves performance in events lasting 1 h or less has been controversial. Current research now supports the benefit of this practice (13,137,6,72,71,42,114), especially in athletes who exercise in the morning after an overnight fast when liver glycogen levels are low. Thus, providing exogenous carbohydrate under these conditions would help maintain blood glucose levels and improve performance. Accordingly, performance advantages in short-duration activities may not be apparent when exercise is done in the nonfasting state.

For longer events, consuming 0.7 g carbohydrate/kg body weight per h (approximately 30 to 60 g per h) has been shown unequivocally to extend endurance performance (36). Consuming carbohydrates during exercise is even more important in situations when athletes have not carbohydrate-loaded, consumed preexercise meals, or restricted energy intake for weight loss. Carbohydrate intake should begin shortly after the onset of activity; consuming a given amount of carbohydrate as a bolus after 2 h of exercise is not as effective as consuming the same amount at 15- to 20-min intervals during the first 2 h of activity (103). The carbohydrate consumed should yield primarily glucose; fructose alone is not as effective and may lead to diarrhea, although mixtures of glucose and fructose seem to be effective (36). If the same total amount of carbohydrate and fluid is ingested, the form of carbohydrate does not seem to matter—some athletes may prefer to use a sport drink whereas others may prefer to eat a solid or gel and consume water. As described elsewhere in this document, adequate fluid intake is also essential for maintaining endurance performance.

Postexercise Meal

The timing and composition of the postcompetition or postexercise meal or snack depend on the length and intensity of the exercise session (i.e., whether glycogen depletion occurred), and when the next intense workout will occur. For example, most athletes will finish a marathon with depleted glycogen stores, whereas glycogen depletion would be much less marked following a 90-min training run. However, most athletes competing in a marathon in the morning will not be doing another race or hard workout in the afternoon. Timing and composition of the postexercise meal are thus less critical for these athletes. Conversely, a triathlete participating in a 90-min run in the morning and a 3-h cycling workout in the afternoon needs to maximize recovery between training sessions, and the postworkout meal assumes considerable importance in meeting this goal.

Timing of postexercise carbohydrate intake affects glycogen synthesis over the short term. Consumption of carbohydrates beginning immediately after exercise (1.5 g carbohydrate/kg at 2-h intervals is often recommended) results in higher glycogen levels at 6 h postexercise than when ingestion is delayed for 2 h (69,70). The highest reported rates of postexercise glycogen synthesis occurred in individuals fed 0.4 g carbohydrate/kg every 15 min for 4 h after glycogen-depleting exercise (45). It should be noted that this represents a very high-energy load (almost 2,000 kcal for a 75-kg athlete) that may exceed the energy expended during the exercise session itself.

The above practices regarding timing of ingestion do not need to be adhered to by athletes who take one or more days between intense training sessions, because when sufficient carbohydrate is provided over a 24-h period, the timing of intake does not appear to affect the amount of glycogen stored (23). Nevertheless, consuming a meal or snack in close proximity to the end of exercise may be important for athletes to meet daily carbohydrate and energy goals.

The type of carbohydrate consumed can also affect postexercise glycogen synthesis. When comparing simple sugars, glucose and sucrose appear equally effective when consumed at a rate of 1.5 g/kg body weight for 2 h; fructose alone is less effective (18). With regard to whole foods, consumption of carbohydrates with a high glycemic index results in higher muscle glycogen levels 24 h after exercise as compared with the same amount of carbohydrates provided as foods with a low glycemic index (25). The usefulness of these findings, however, must be considered in conjunction with the athlete's overall diet, and should likely be reserved for occasions when maximizing postexercise glycogen synthesis is critical.

When isocaloric amounts of carbohydrates or carbohydrates plus protein and fat are provided following endurance (24) or resistance (127) exercise, glycogen synthesis rates are similar. Accordingly, in contrast to what was suggested in earlier research (154), adding protein does not appreciably enhance glycogen repletion. Nevertheless, including protein in a postexercise meal may provide needed amino acids for muscle protein repair and promote a more anabolic hormonal profile (128).

SUPPLEMENTS AND ERGOGENIC AIDS

The marketing of ergogenic aids (items claiming to increase work output or performance) is an international, multimillion dollar business that preys on the desires of athletes to be the best, and when one item does not work or is discredited by research, another comes along to take its place. Nutrition-related ergogenic aids are particularly problematic. In the United States, the Dietary Supplement Health and Education Act of 1994 (119) allows supplement manufacturers to make claims regarding the effect of products on the structure/function of the body, as long as they do not claim to "diagnose, mitigate, treat, cure, or prevent" a specific disease. As long as a special supplement label indicates the active ingredients and the entire ingredient list is provided, claims for enhanced performance—be they valid or not—can be made. The advent of the Internet means that a greater variety of products are more readily available, increasing the pressure on the experts to keep up-to-date on both the science and the claims of ergogenic aids (144).

Evaluating nutrition-related ergogenic aids requires attention to the following factors: validity of the claim relative to the science of nutrition and exercise; quality of the supportive evidence provided (placebo-controlled scientific studies vs testimonials); and health and legal consequences of the claim (26) (see Table 2). In general, most ergogenic aids can be classified into one of the following categories: those that perform as claimed, those that may perform as claimed but for which there is insufficient evidence of efficacy at this time, those that do not perform as claimed, and those which are dangerous, banned, or illegal, and consequently should not be used. With regard to legality in terms of use by competing athletes, both national (National Collegiate Athletic Association, United States Olympic Committee, Canadian Olympic Association) and international sports organizations (International Olympic Committee) limit the use of certain ergogenic aids and require random urine testing of athletes to ensure that these products are not consumed. However, the ethical issue of using performance-enhancing substances that are not banned has not been resolved (150,151,149). Currently, the use and recommendation of ergogenic aids to athletes is controversial. Some health care professionals discourage the use of all ergogenic aids, though others suggest they be used with caution and only after careful examination of the product for safety, efficacy, potency, and legality. Athletes should not use nutritional ergogenic aids until they have carefully evaluated the product, as indicated above, and discussed the use of the product with a qualified nutrition or health professional.

TABLE 2. Guidelines for evaluating the claims of ergogenic aids.[a]

Evaluate the scientific validity of an ergogenic claim
- ■ Does the amount and form of the active ingredient claimed to be present in the supplement match that used in the scientific studies on this ergogenic aid?
- ■ Does the claim made by the manufacturer of the product match the science of nutrition and exercise as you know it?
- ■ Does the ergogenic claim make sense for the sport for which the claim is made?

Evaluate the quality of the supportive evidence for using the ergogenic aid
- ■ What evidence is given for using the ergogenic aid (testimonial vs scientific study)?
- ■ What is the quality of the science? What is the reputation of the author and the journal in which the research is published? Was the research sponsored by the manufacturer?
- ■ Does the experimental design meet the following criteria?
  - –hypothesis driven;
  - –double-blind placebo controlled;
  - –adequate and appropriate controls used; and
  - –appropriate dose of the ergogenic substance/placebo used.
- ■ What research methods were used and do they answer the questions asked? Are the mehtods clearly presented so the study results could be reproduced?
- ■ Are the results clearly presented in an unbiased manner, with appropriate statistical procedures, limitations addressed, and adverse events noted? Are the results physiologically feasible and do the conclusions follow from the data?

Evaluate the safety and legality of the ergogenic aid
- ■ Is the product safe? Will its use compromise the health of a person? Does the product contain toxic or unknown substances or substances that alter nutrient metabolism? Is the substance contraindicated in people with a particular health problem?
- ■ Will use of the product preclude other important elements in performance? For example, does the product claim to replace food or good training practices?
- ■ Is the product illegal or banned by any athletic organizations?

[a] Adapted from the following references 92, 26, 33, 51, 126, 131, 36.

THE VEGETARIAN ATHLETE

Some athletes choose to follow vegetarian diets. Nutrition recommendations for these athletes should be formulated with consideration of the effects of both vegetarianism and exercise. The position of the American Dietetic Association on vegetarian diets (124) provides appropriate dietary guidance that should be considered in conjunction with the information provided herein.

Vegetarianism does not necessarily affect energy needs, though energy availability could be reduced slightly if a vegetarian has an extremely high fiber intake. As with all athletes, monitoring body weight and composition is the preferred means of determining if energy needs are satisfied. Some people—especially women—may switch to vegetarianism as a means of restricting energy intake to attain the lean body habitus favored in some sports. Occasionally, this may be a step toward development of an eating disorder (118). Because of this association, coaches and trainers should be alert when an athlete becomes vegetarian, and ensure that appropriate weight is maintained.

Studies consistently report that vegetarians have lower protein intakes than omnivores. Although the protein quality of a vegetarian diet is adequate for adults (112,61,153), plant proteins are not as well-digested as animal proteins (112). Thus, to adjust for incomplete digestion, an increase of about 10% in the amount consumed may be made (112). Accordingly, recommended protein intakes for vegetarian athletes would be about 1.3 to 1.8 g/kg body weight, using recommendations for athletes as a baseline (38,28,140). Vegetarian athletes with relatively low energy intakes may need to choose foods carefully to ensure that their protein intakes are consistent with these recommendations.

Vegetarian athletes may be at risk for low intakes of vitamins B-12 and D, riboflavin, iron, calcium, and zinc, because many of these nutrients are high in animal products. Iron is a nutrient that may be of particular concern to vegetarian athletes. Because of the lower bioavailability of iron in plant-based diets, the iron stores in vegetarians are generally lower than those of omnivores, despite total iron intakes that are similar or even higher (40). When combined with data indicating that exercise may increase iron requirements, it is possible that vegetarian athletes, especially women, may be at greater risk of developing poor iron status. Accordingly, it would be prudent for iron status to be monitored routinely in female vegetarian athletes.

ROLES AND RESPONSIBILITIES OF HEALTH CARE PROFESSIONALS

Every competitive and recreational athlete needs adequate fuel, fluids, and nutrients to perform at their best. It is the role of the sports nutrition expert to advise athletes regarding appropriate nutrition needs before, during, and after exercise, and for the maintenance of good health and optimal body weight and composition. Qualified health and nutrition professionals can help athletes and active people in the following ways:

- Educate athletes about energy requirements for their sport and the role of food in fueling the body. Discourage unrealistic weight and body composition goals and emphasize the importance of adequate energy intake for good health, prevention of injury, and exercise performance.
- Assess the body size and composition of an athlete for the determination of an appropriate weight and composition for the sports in which he or she participates. Provide the athlete with nutritionally sound techniques for maintaining an appropriate body weight and composition without the use of fad or severe diets. Undue pressure on athletes for weight loss or the maintenance of a lean body build can increase the risk of restrictive eating behaviors, and in extreme cases lead to a clinical eating disorder.
- Assess the athlete's typical dietary and supplement intake during training, competition, and the off-season. Use this assessment to provide appropriate recommendations for energy and nutrient intakes for the maintenance of good health, appropriate body weight and composition, and optimal sport performance throughout the year. Give specific guidelines for making good food and fluid selections while traveling and eating away from home.
- Assess the fluid intake and weight loss of athletes during exercise and make appropriate recommendations regarding total fluid intake and fluid intake before, during, and after exercise. Help athletes to determine appropriate types and amounts of beverages to use during exercise, especially if the athlete is exercising in extreme environments.
- For athletes such as the vegetarian athlete with special nutrition concerns, provide appropriate nutrition guidelines to assure adequate intakes of energy, protein, and micronutrients.
- Carefully evaluate any vitamin/mineral or herbal supplements, ergogenic aids, or performance-enhancing drugs an athlete wants to use. These products should be used with caution and only after a careful review of their legality and the current literature pertaining to the ingredients listed on the product label; these products should not be recommended until after evaluating the athlete's health, diet, nutrition needs, current supplement and drug use, and energy requirements.

All nutrition recommendations for athletes should be based on current scientific data and the needs of athletes as individuals. Health care professionals should work with athletes, coaches, and family members to build rapport and to provide athletes with the best-possible environment for meeting sports-related nutrition goals.

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