Position of Dietitians of Canada, the American Dietetic Association, and the American College of Sports Medicine:

endorsed by the Coaching Association of Canada

Nutrition and Athletic Performance

Abstract

It is the position of Dietitians of Canada, the American Dietetic Association, 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 athletes' energy needs, assessment of body composition, strategies for weight change, athletes' nutrient and fluid needs, special nutrient needs during training, the use of supplements and nutritional ergogenic aids, and 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 repairing tissue. Fat intake should be adequate to provide 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 (20-25% of energy); 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 levels during exercise, maximize exercise performance, and improve recovery time. Athletes should be well hydrated before beginning exercise; they 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 levels 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, have 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, for efficacy, for potency, and to determine whether or not it is a banned or illegal substance. Nutrition advice, by a qualified nutrition expert, should be provided only after the athlete's health, diet, supplement and drug use, and energy requirements have been carefully reviewed.

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Résumé

Les Diététistes du Canada, l'American Dietetic Association et l'American College of Sports Medicine soutiennent qu'une nutrition optimale améliore l'activité physique, la performance sportive et la récupération après l'exercice. Ces organismes recommandent de bien choisir les aliments et les liquides, le moment de l'ingestion et les suppléments, afin de maintenir une santé et une performance physique optimales. Cet énoncé de position, passe en revue les données scientifiques actuelles relatives aux besoins énergétiques des sportifs et sportives, à l'évaluation de la composition corporelle, aux stratégies de changement de poids, aux besoins en nutriments et en liquides, aux besoins nutritifs spéciaux pendant les périodes d'entraînement, à l'usage de suppléments et de produits ergogènes et aux recommandations nutritionnelles pour les sportifs végétariens. Au cours des périodes d'activité physique intense, les besoins en énergie et en macronutriments – en particulier l'apport en glucides et en protéines – doivent être comblés pour assurer la stabilité du poids, restaurer les réserves de glycogène et fournir les protéines nécessaires à la formation et à la réparation des tissus. L'apport en matières grasses doit être suffisant pour fournir les acides gras essentiels, les vitamines liposolubles et l'énergie nécessaire au maintien du poids. Dans l'ensemble, l'alimentation doit renfermer des quantités modérées d'énergie sous forme de matières grasses (20 à 25% de l'énergie); cependant, une alimentation comportant moins de 15% de l'énergie provenant des matières grasses ne semble pas présenter d'avantages pour la santé ou la performance. Le poids et la composition corporelle peuvent influer sur la performance physique, mais ils ne doivent pas en être le seul critère; on décourage d'ailleurs la pesée quotidienne. La consommation d'aliments et de liquides appropriés avant, pendant et après l'exercice peut aider à maintenir les concentrations de glucose sanguin pendant l'exercice, à atteindre une performance physique maximale et à réduire le temps de récupération. Les sportifs et sportives doivent bien s'hydrater avant de commencer leurs activités physiques; ils doivent également boire suffisamment pendant et après l'exercice pour contrebalancer les pertes liquidiennes. Pendant l'exercice, la consommation de boissons pour sportifs renfermant des glucides et des électrolytes, fournit le combustible nécessaire aux muscles, aide à maintenir les concentrations de glucose sanguin et le mécanisme de la soif et diminue le risque de déshydratation ou d'hyponatrémie. Les sportifs et sportives n'ont pas besoin de suppléments de vitamines et de minéraux s'ils consomment une variété d'aliments qui leur procurent la quantité d'énergie adéquate pour maintenir leur poids. Cependant, certains peuvent en avoir besoin s'ils restreignent leur apport en énergie, adoptent des stratégies d'amaigrissement draconiennes, éliminent un ou plusieurs groupes d'aliments ou consomment une alimentation à forte teneur en glucides et à faible densité en micronutriments. Les produits nutritionnels ergogènes doivent être utilisés avec prudence, et uniquement après une évaluation rigoureuse de leur innocuité, de leur efficacité et de leur puissance; il faut également vérifier s'il ne s'agit pas d'une substance interdite ou illégale. Les conseils nutritionnels ne doivent être dispensés aux sportifs et sportives que par une personne spécialisée en nutrition suite à l'évaluation minutieuse de la santé, de l'alimentation, des besoins en énergie et de l'usage de suppléments ou de médicaments. (Rev can prat rech diétét 2000; 61:176-192)

INTRODUCTION

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 have 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 paper is focused on adult athletes, rather than on children or adolescents, and does not focus on any particular type of athlete or athletic event. The position is intended to provide guidance to dietetic and health professionals working with athletes, and is not directed at individual athletes themselves.

POSITION STATEMENT

It is the position of Dietitians of Canada, the American Dietetic Association, 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.

KEY POINTS

The following key points summarize the current energy, nutrient, and fluid recommendations for active adults and competitive athletes discussed in this position paper. Sport nutrition experts can further adjust these general recommendations to accommodate individual athletes' unique concerns about 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 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 athlete's sex, age, and heredity, 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 of body weight a day. The amount required depends upon the athlete's total daily energy expenditure, type of sport performed, the athlete's sex, 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 of body weight a day, whereas those for resistance and strength-trained athletes may be as high as 1.6 to 1.7 g/kg of body weight a 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 20-25% of energy from fat. Fat is important in athletes' diets because it provides energy, fat-soluble vitamins, and essential fatty acids. However, there is no scientific basis for recommending 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 recommended dietary allowances (RDAs)/dietary reference intakes (DRIs) for all micronutrients from food.

Dehydration decreases exercise performance; thus, adequate fluid intake 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 minutes, 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 a snack should provide sufficient fluid to maintain hydration, be relatively low in fat and fiber to facilitate gastric emptying and minimize gastrointestinal (GI) distress, be relatively high in carbohydrate to maximize maintenance of blood glucose levels, be moderate in protein, and be composed of foods familiar to and well tolerated by the athlete.

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

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

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 child-bearing potential – should be followed. If an athlete is dieting, is eliminating foods or food groups, is sick or recovering from injury, or has a specific micronutrient deficiency, a multivitamin-and-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 counselled on 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 products from the diet. Consultation with a registered dietitian will help prevent 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 optimal athletic performance. Energy balance is defined as a state in which 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) (1). Inadequate energy intake relative to energy expenditure compromises performance and the benefits associated with training. With limited energy intake, the body will use fat and lean tissue mass 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 RDAs (2), mean energy requirements for women and men who are slightly to moderately active and aged 19-50 were established as 2200 and 2900 kcal a day, respectively. When expressed alternatively, these energy requirements mean that normally active people are counselled to have an energy intake of 1.5 to 1.7 times resting energy expenditure or at a rate of 37 to 41 kcal/kg of body weight a day (2).

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 (3,4,5). For example, a 70-kg male runner who runs ten miles a day at a six-minute pace would require approximately 1063 kcal a day to cover the energy expenditure of running (0.253 kcal/min/kg) (6) plus the energy cost of normal daily activities (70 kg x 37 to 41 kcal/kg of body weight) for normal activity. Thus, this athlete would need approximately 3653 to 3933 kcal a day to cover the total cost of energy expenditure.

Ultimately, however, numeric guidelines for energy intake, such as those cited above, can provide only a crude approximation of an individual athlete’s average energy needs. 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 3000 to 5000 kcal a day (7). 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 1800 to 2000 kcal a day (6-11).

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 of body weight a day, and those in serious training may have even higher energy requirements (more than 50 kcal/kg of body weight a day) (12,13).

Weight Change

Often an athlete wants 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 incorporating additional energy into the diet (500 to 1000 kcal a day) and increasing 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 a 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 (14,15). 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 one to two pounds a week or 0.5 to 1 kg/week). 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 maintained, allows positive advances in exercise performance, minimizes the risk of injury or illness, and reduces risk factors for chronic disease. Appendix 1 shows strategies to help health professionals work with athletes to identify and maintain healthful body weights.

Failure to meet weight-loss goals may have severe consequences, such as being cut from the team, restricted participation, or elimination from competition. This may lead many athletes to adopt chronic dieting 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 (16-19).

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 do 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]) (10,20). These alterations result in changes in ovarian hormone secretions, which lead to amenorrhea and loss of (or failure to gain) bone mass in young female athletes (21).

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 to maintain all vital functions (8,10,22). Thus, a negative energy balance, due to chronic dieting or under-eating in conjunction with heavy exercise, may alter the energy flux and create a negative "energy drain," which compromises reproductive function and bone health. Incorporating additional energy into these women's diets has resulted in the return of menstrual function and improved overall nutritional status (8,23). Although failure of reproductive function in male athletes has not been investigated extensively, Loucks (24) 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 two of the many factors that contribute to optimal exercise performance. Taken together, these two 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 emphasized in many sports (25). However, too little body fat results in deteriorating health and performance (22,26). Athletic performance cannot be accurately predicted solely on the basis of body weight and composition (27).

The primary reason for determining an athlete's body composition is to obtain information that may help improve athletic performance (28). The determination of an athlete's optimal body weight and composition for health and competition should therefore be done individually, because these factors are strongly influenced by age, sex, genetics, and the requirements of the sport. However, 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 aesthetic 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 influence an athlete's performance adversely. Thus, an athlete's optimal competitive body weight and relative body fat should be determined when an athlete is healthy and performing at his or her best (29).

Body Composition and Sport Performance
Percentage of body-fat values for athletes varies depending on the athlete's sex 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% and 15% body fat (26,30). Male athletes involved in power sports such as football, rugby, and ice and field hockey have slightly more variable body-fat levels (6-19%). Female athletes with the lowest estimates of body fat (6-15%) participate in bodybuilding, cycling, triathlons, and running events; higher fat levels (10-20%) are found in female athletes participating in racquetball, skiing, soccer, swimming, tennis, and volleyball (26,30).

The estimated minimal level of body fat compatible with health is 5% for males and 12% for females (31); however, optimal body fat percentages for an individual athlete may be much higher than these minimums and should be determined individually. Athletes who strive to maintain inappropriate body weight or body-fat levels, or who 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 (8,11,18,22,23,32-34).

Assessment of Body Composition
Methods for assessing body composition are based on either a two-component or a multi-component model and involve several measurement techniques. Two-component models divide the body into either fat mass (all lipids within the body) or fat-free mass (the remainder of tissue after fat is subtracted). The multi-component model divides the body into three or more components. For example, the three-component model divides the body into fat mass and two 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 two-component or a multi-component model. Although a multi-component 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 two-component criterion model typically uses hydrodensitometry (hydrostatic weighing) or plethysmography (BODPOD) measurement techniques, and a three-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 (skinfold measurements), bioelectrical impedance analysis (BIA), and near-infrared interactance. These field methods are validated using either two-component or multi-component criterion models (35). When these field methods are used, care should be taken to choose the appropriate validated prediction equation for estimating body composition; if accurate estimates are to be obtained, this equation should be based on an athlete's demographics (age, sex, level of adiposity, ethnicity, and physical activity)(36).

The relative validity of any body composition field method depends on its accuracy compared with the criterion method and its reliability (reproducibility) (31). Hydrostatic weighing (hydrodensitometry) and DEXA are two widely used criterion methods from which field methods of body-composition assessment for athletes are developed (37-42). Regardless of the method used, athletes and coaches should know the errors associated with the body-composition assessment method being used. With carefully applied skinfold or BIA methods, it is possible to estimate relative body-fat percentage with an error of 3-4%, and to estimate fat-free mass within 2.5 to 3.5 kg (27,31,35). Thus, if the actual body-fat percentage is 15%, then predicted values could range from 12-18% (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, if poor measurement techniques are 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, setting a specific body-fat percentage goal for an individual athlete is inappropriate. Instead, a range of target percentages 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, the athlete's sex, 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 (43,44). As 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 levels cannot be maintained, the intensity of the exercise performed will decrease (45).

Fat contributes to the energy pool over a wide range of exercise intensities, being metabolized at approximately 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 (46).

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 (47,48). As the duration of exercise increases, protein may contribute to the maintenance of blood glucose levels 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 post-prandially when the exercise performed is moderate (approximately 50% of maximal oxygen uptake [VO_2max]) (49). With exercise of higher intensity (greater than 65% of VO_2 max), neither prior feeding nor training markedly affects the fuel used (49). Data are not currently available, however, to suggest that athletes need a diet substantially different from that recommended in the Dietary Guidelines for Americans (50) or the Nutrition Recommendations for Canadians (51) (55-58% of energy from carbohydrate, 12-15% of energy from protein, and 25-30% 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 dietary recommendations may actually be misleading in terms of optimal nutrition. When energy intake is 4000 to 5000 kcal a 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 (52,53). Similarly, if protein intake in such a diet were even as low as 10% of energy intake, absolute protein intake (100-125 g a day) would exceed the recommendations for athletes' protein intake (1.2-1.7 g a day or 84-119 g in a 70-kg athlete; see the following discussion on nitrogen balance in men). Conversely, when energy intake is less than 2000 kcal a day, even a diet providing 60% of 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 when 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 the athlete's sex.

Athletes' protein needs have received considerable investigation, not only in regard to whether athletes' protein requirements are increased, but also in relation to whether individual amino acids benefit performance. Mechanisms suggested to increase athletes' protein requirements include the need to repair exercise-induced micro-damage 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 (54,55). 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 participant's sex.

For endurance athletes, nitrogen balance studies in men suggest a protein recommendation of 1.2 g/kg a day (56). Little information is available on requirements for women endurance athletes. 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 of body weight a day to allow for the accumulation and maintenance of lean tissue (55,57). 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 (54), although some sources have suggested an intake of 1.2 to 1.4 g/kg a day (55). Energy intake must be adequate; otherwise, protein will be used as an energy source, which falsely elevates 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 (7).

The use of individual amino acids to enhance performance has also been studied. One proposal is that administration of branched-chain amino acids (BCAAs) may enhance endurance performance by delaying the onset of central nervous system fatigue (58). It has also been proposed that BCAAs may extend performance by serving as substrates for energy expenditure (59). The results of human studies, however, have been inconsistent (60-63). Because the safety and efficacy of these mixtures have not been established, their use cannot be advocated.

Some investigators (64,65) have proposed a positive effect of relatively high-fat diets (more than 70% of energy intake) on athletic performance. Careful evaluation of these studies reveals little evidence to support this concept (66). 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 the Nutrition Recommendations for Canadians state that the proportion of energy from fatty acids should be 10% from saturated, 10% from polyunsaturated, and 10% from monounsaturated fat (50,51). Athletes should follow these general recommendations, and should also ensure that their fat intake is not excessively low. Dreon and colleagues' 1999 study (67) 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 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, and exercise training thus 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 lean tissue mass in athletes. The current RDAs and DRIs may be assumed to be appropriate for athletes unless otherwise stated (2,68,69).

Athletes at the greatest risk of poor micronutrient status are those who restrict energy intake or have severe weight-loss practices; who eliminate one or more of the food groups from their diet; or who consume high-carbohydrate, low micronutrient-dense diets. Athletes with these types of behaviours may need 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 iron deficiency anemia requiring iron supplementation or the need to prevent birth defects with folic acid.

The B-complex vitamins have two major functions directly related to exercise. Thiamin, riboflavin, vitamin B-6, niacin, pantothenic acid, and biotin are involved in energy production during exercise (4,70-74), whereas folate and vitamin B-12 are required for the production of red blood cells, for protein synthesis, and in tissue repair and maintenance (75). Limited research has been conducted to examine whether exercise increases the need for some of the B-complex vitamins, especially vitamin B-6, riboflavin, and thiamin (70,71,73,75,76). Available data are not sufficiently precise to make separate recommendations for athletes or to link recommendations to energy expenditure quantitatively (69). Nevertheless, the available data suggest that exercise may increase the need for these vitamins slightly, perhaps up to twice the current recommended amount (72). These increased needs can generally be met by the higher energy intakes that athletes need 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 ten- to 15-fold, it has been hypothesized that chronic exercise produces a constant "oxidative stress" on the muscles and other cells (77,78). In addition, muscle-tissue damage caused by intense exercise can lead to lipid peroxidation of membranes. However, although there is some evidence that acute exercise may increase levels of lipid peroxide by-products (79), habitual exercise has been shown to result in an augmented antioxidant system and reduced lipid peroxidation (77). Thus, a well-trained athlete may have a more developed endogenous antioxidant system than a sedentary person (80). Results of research examining whether exercise increases the need for antioxidant nutrients are equivocal and controversial; thus, there is no clear consensus on whether supplementation of antioxidant nutrients is necessary (77,79,80). The lack of consensus especially pertains to the athlete with adequate or above-adequate blood levels of the antioxidant vitamins (77). Athletes at greatest risk for poor antioxidant intakes are those following a low-fat diet, those who restrict energy intakes, or those with limited dietary intake of fruits and vegetables.

The primary minerals low in the diets of athletes – especially female athletes – are calcium, iron, and zinc (11,81). 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 and stress fractures. Female athletes are at greatest risk for low bone-mineral density if energy intakes are low, dairy products are eliminated from the diet, and menstrual dysfunction is present (8,22).
Vitamin D is also required for adequate calcium absorption, regulation of serum calcium levels, and promotion of bone health. The two primary sources of vitamin D are fortified foods, such as milk, and ultraviolet conversion in the skin, which produces the vitamin. 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 they do not consume foods fortified with vitamin D (82). These athletes would benefit from vitamin D supplementation at the DRI level (5 μg/day or 200 IU) (68). Iron plays an important role in exercise because it is required for the formation of hemoglobin 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 hemoglobin levels), exercise performance can be affected negatively (4,81).

The high incidence of iron depletion in athletes is usually attributed to poor energy intake due to 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 women, 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 hemoglobin and hematocrit concentrations). Because reversing iron deficiency anemia can require three to six 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 9-11% found in the general female population (81,83).

Some athletes may experience a transient decrease in ferritin and hemoglobin at the initiation of training. These decreases result from an increase in plasma volume, which causes hemodilution and appears to have no negative effect on performance (81). If an athlete appears to have iron deficiency anemia but does not respond to nutrition intervention, then low hemoglobin values may be the result of changes in plasma volume, rather than poor nutritional status (4). Chronic iron deficiency anemia resulting from poor iron intake can seriously affect health and exercise performance, and needs medical and nutritional intervention.

In the United States, the zinc content of the food supply is estimated to be approximately 12.3 mg of zinc per person, with 70% of the zinc coming from animal products (84). Survey data indicate that approximately 90% of men and 81% of women have zinc intakes below the 1989 RDAs (15 mg and 12 mg, respectively) (85). This nutritional shortfall is also seen in athletes, particularly females (11). 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 (86). Because of the role that zinc plays in growth, building, and repair of muscle tissue, and in energy production, assessing the diets of active women for adequate zinc intake is prudent.

HYDRATION

Exercise performance is optimal when athletes maintain fluid balance during exercise; conversely, exercise performance is impaired with progressive dehydration (87-91). Moreover, dehydration increases the risk of potentially life-threatening heat injury, such as heat stroke (92). Accordingly, athletes should attempt to remain well hydrated before and during exercise.

The American College of Sports Medicine (ACSM) “Position Stand on Exercise and Fluid Replacement” (93) and the “National Athletic Trainers’ Association Position Statement on Fluid Replacement for Athletes” (94) provide comprehensive overviews of the research and recommendations on maintaining hydration during exercise. The following information summarizes the key points from these position statements 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 vaporization of water. In hot, dry environments, evaporation accounts for over 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 1800 mL) an hour (93). In addition to water, sweat also contains substantial amounts of sodium (an average of approximately 50 mmol/L, or about 1 g/L, 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 physiologic 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 limits fluid absorption. In most cases, however, athletes' rates of fluid ingestion 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 an hour during competition (93), whereas gastric emptying rates of more than 1 L per hour are possible (93).

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 4-8% carbohydrate can generally be emptied by more than 1 L an hour in most people when gastric volume is maintained at or above 600 mL (93,94).

Dehydration, hypohydration, and hyponatremia: Disturbances of fluid and electrolyte balance that can occur in athletes include dehydration, hypohydration, and hyponatremia (95). 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 rowing, weight lifting, and judo). Hyponatremia (blood sodium concentrations of less than 130 mmol/L) can develop as a result of prolonged, heavy sweating with failure to replace sodium, or when excess water is retained in the body (96).

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 Ironman New Zealand Triathlon developed severe hyponatremia, and eight of these athletes were likely overhydrated, as they had either maintained or gained up to 5% of body weight during the race (97).

Fluid and Electrolyte Recommendations

Before exercise: Athletes should be well hydrated when they begin to exercise. In addition to advising that athletes drink generous amounts of fluid in the 24 hours before an exercise session, the ACSM and the National Athletic Trainers' Association recommend 400-600 mL of fluid two to three hours before exercise (93,94). Such a practice should optimize hydration while allowing enough time for any excess fluid to be excreted as urine before exercise is started.

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-minute intervals, beginning at the start of exercise (93).

Beverages containing carbohydrate in concentrations of 4-8% are recommended for intense exercise events lasting longer than one hour (93). These beverages are also suitable for hydration during exercise events lasting less than one hour, 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 three to four hours), particularly if sodium was present in the previous meal. However, including sodium in amounts between 0.5 and 0.7 g/L is recommended during exercise lasting longer than one hour because it may enhance palatability and the drive to drink, thereby increasing the amount of fluid consumed (93). Note that this amount of sodium exceeds that typically available in commercial beverages. Including sodium in fluid-replacement beverages may also help prevent hyponatremia in people susceptible to it (93,98).

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 (97). 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 the 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 (99). Including sodium either in or with fluids consumed after exercise reduces the diuresis that occurs when only plain water is ingested (94,100). Sodium also helps the rehydration process by maintaining plasma osmolality and therefore the desire to drink.

Because most commercial sport drinks do not contain enough sodium to optimize post-exercise fluid replacement, athletes can rehydrate in conjunction with a sodium-containing meal (101). 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 increases sodium intake.

Special Environmental Conditions

Hot and humid environments: The risks of dehydration and heat injury increase dramatically in hot, humid environments (102). 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, which leads to non-functional fluid loss. When temperature and humidity are high, there is a very high risk of heat illness, and competitive events should be postponed, rescheduled, or cancelled (94,102). 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 (94).

Cold environments: Although the risk of dehydration is greater in hot environments, dehydration is not uncommon in cool or cold weather (103). Factors that can 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 can 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 clearly is reduced. Finally, the difficulty of removing multiple layers of clothing to urinate may cause some athletes, especially women, to limit their fluid intake voluntarily (104).

High altitude: Exposure to altitudes higher than 2500 m (8200 ft) may result in fluid losses beyond those associated with any exercise that might be performed. These losses result from mandatory diuresis and high respiratory water losses, accompanied by decreased appetite, which lead to an increased need for fluid. Some consider the diuresis an indication of successful acclimatization (105), although others (106) 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 seven days (106). Respiratory water losses may be as high as 1900 mL a day in men (107) and 850 mL in women (108). Thus, to assure optimal kidney function, fluid intake should be increased to as much as 3-4 L a day at high altitudes.

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 of carbohydrate/kg of body weight) and must be translated into food choices consistent with athletes' food preferences and training schedules (109). The foundation (proportion of energy from protein, fat, and carbohydrate) for athletes' training diets, however, does 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 (50) and Canada's Guidelines for Healthy Eating (110), and be based on the 1992 US Food Guide Pyramid: A Guide to Daily Food Choices (111) or the 1992 Canada's Food Guide to Healthy Eating (112).

The fundamental difference between an athlete's diet and that of the general population is that the athlete requires 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. Although in some cases needs for other nutrients (e.g., protein, B-complex vitamins) also increase, the proportional increase in energy requirements appears 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 for the carbohydrate-based food groups (breads, cereals and grains, vegetables, and fruits).

For many athletes, however, energy needs will exceed the amount of energy (kilocalories a day) from the upper range of servings suggested for these food groups in 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 athletes' diet is the timing of meals and snacks. Common sense dictates that food and fluid intake around workouts needs to be determined individually and will depend, in part, on an athlete's GI characteristics as well as the intensity of the workout. For example, an athlete might tolerate a snack consisting of milk and a sandwich one hour before a low-intensity workout, but be uncomfortable if the same meal is consumed before very intense exercise. In any case, athletes in heavy training or doing multiple daily workouts may need to eat more than three meals and three snacks a day, and should consider every possible eating occasion (113). For example, they should consider eating shortly after a workout, having more than one afternoon snack, or eating a substantial snack before bed.

Pre-exercise Meal

Eating before exercise, as opposed to exercising in the fasting state, has been shown to improve performance (114-116). 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: they should contain sufficient fluid to maintain hydration, be low in fat and fiber to facilitate gastric emptying and minimize GI distress, be high in carbohydrate to maintain blood glucose levels and maximize glycogen stores, contain a moderate amount of protein, and be composed of foods familiar to the athlete. The size and the timing of the pre-exercise 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; 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 for meals consumed three to four hours before exercise (114-117). The recommendations on carbohydrate consumption within one hour before activity have been controversial. Early research suggested that this practice leads to hypoglycemia and premature fatigue (118); however, more recent studies report either no effect or beneficial effects of pre-event feeding on performance (53,114,119-121). Current data are mixed on whether the glycemic index of carbohydrate in the pre-exercise meal affects performance (122,123).

Although the above guidelines are sound and work well on average, the athlete's individual needs must be emphasized. For example, some athletes consume and enjoy a substantial meal (e.g., pancakes, juice, and scrambled eggs) two to four hours before exercise or competition; however, others may suffer severe GI distress following such a meal and need to rely on liquid meals. Athletes should always ensure that they know what works best for them 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

There is controversy over whether consuming carbohydrate in amounts typically provided by sport drinks (4% to 8%) improves performance in events lasting one hour or less. Current research indicates that this practice is beneficial (88,124,125,126-129), especially in athletes who exercise in the morning after an overnight fast, when liver glycogen levels are low. Providing exogenous carbohydrate under these conditions can help maintain blood glucose levels and improve performance. Performance advantages in short-duration activities may not be apparent when exercise is done in the non-fasting state.

For longer events, consuming 0.7 g carbohydrate/kg of body weight an hour (approximately 30 to 60 g an hour) has been shown unequivocally to extend endurance performance (52). Consuming carbohydrates during exercise is even more important in situations where athletes have not carbohydrate-loaded, have not consumed pre-exercise meals, or have 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 two hours of exercise is not as effective as consuming the same amount at 15- to 20-minute intervals during the first two hours of activity (130). The carbohydrate consumed should yield glucose primarily; fructose alone is not as effective and may lead to diarrhea, although mixtures of glucose and fructose seem to be effective (52). If the same total amounts of carbohydrate and fluid are 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.

Post-exercise Meal

The timing and composition of the post-competition or post-exercise meal or snack depend on the length and intensity of the exercise session (i.e., whether glycogen depletion occurred), and on when the next intense workout will occur. For example, most athletes finish a marathon with depleted glycogen stores, whereas glycogen depletion is much less marked following a 90-minute 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 post-exercise meal are thus less critical for these athletes. Conversely, a triathlete participating in a 90-minute run in the morning and a three-hour cycling workout in the afternoon needs to maximize recovery between training sessions, and the post-workout meal assumes considerable importance in meeting this goal.

Timing of post-exercise carbohydrate intake affects glycogen synthesis over the short term. Consumption of carbohydrates beginning immediately after exercise (1.5 g carbohydrate/kg at two-hour intervals is often recommended) results in higher glycogen levels six hours post-exercise than does carbohydrate ingestion that has been delayed for two hours (131,132). The highest reported rates of post-exercise glycogen synthesis occurred in individuals fed 0.4 g carbohydrate/kg every 15 minutes for four hours after glycogen-depleting exercise (133). Note, however, that this represents a very high energy load (almost 2000 kcal for a 75-kg athlete), which may exceed the energy expended during the exercise session itself.

Athletes who take one or more days between intense training sessions need not adhere to the timing of ingestion above; when sufficient carbohydrate is provided over a 24-hour period, the timing of intake does not appear to affect the amount of glycogen stored (134). Nevertheless, consuming a meal or a snack in close proximity to the end of exercise may be important if athletes are to meet daily carbohydrate and energy goals.

The type of carbohydrate consumed can also affect post-exercise glycogen synthesis. When simple sugars are compared, glucose and sucrose appear equally effective when consumed at a rate of 1.5 g/kg of body weight for two hours; fructose alone is less effective (135). With regard to whole foods, consuming carbohydrates with a high glycemic index results in higher muscle glycogen levels 24 hours after exercise than does consuming the same amount of carbohydrates provided as foods with a low glycemic index (136). These findings must, however, be considered in conjunction with the athlete’s overall diet; consumption of high glycemic-index carbohydrates should likely be reserved for occasions when maximizing post-exercise glycogen synthesis is critical.

When isocaloric amounts of carbohydrates or carbohydrates plus protein and fat are provided following endurance (137) or resistance (138) exercise, glycogen synthesis rates are similar. Accordingly, in contrast to what was suggested in earlier research (139), adding protein does not enhance glycogen repletion appreciably. Nevertheless, including protein in a post-exercise meal may provide amino acids needed for muscle protein repair and promote a more anabolic hormonal profile (140).

SUPPLEMENTS AND ERGOGENIC AIDS

The marketing of ergogenic aids (items claiming to increase work output or performance) is an international, multi-million dollar business that preys on athletes’ desires to be the best. 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 Supplements Health and Education Act of 1994 (141) allows supplement manufacturers to make claims about the effect of products on body structure or function, provided they are not claimed 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 – 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 experts to keep up-to-date on both the science of and the claims about ergogenic aids (142). 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 (143) (see Appendix 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 that are dangerous, banned, or illegal, and consequently should not be used.

With regard to legality of use by competing athletes, both national (National Collegiate Athletic Association, United States Olympic Committee, Canadian Olympic Association) and international (International Olympic Committee) sports organizations 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 (144-146). Currently, the recommendation of ergogenic aids and their use by athletes is controversial. Some health care professionals discourage the use of all ergogenic aids, although others suggest that they be used cautiously and only after careful examination 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.

THE VEGETARIAN ATHLETE

Some athletes choose to follow vegetarian diets. Nutrition recommendations for these athletes should be formulated with consideration to the effects of both vegetarianism and exercise. The American Dietetic Association's position on vegetarian diets (147) provides appropriate dietary guidance that should be considered in conjunction with the information provided herein.

Vegetarianism does not necessarily affect energy needs, although energy availability could be reduced slightly in a vegetarian with 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 (148). Because of this association, coaches and trainers should be alert when an athlete becomes vegetarian, and ensure that appropriate weight is maintained.

Studies consistently indicate that vegetarians have lower protein intakes than do omnivores. Although the protein quality of a vegetarian diet is adequate for adults (2,51,149), plant proteins are not as well digested as animal proteins (2). Thus, to adjust for incomplete digestion, an increase of about 10% in the amount consumed may be made (2). Accordingly, recommended protein intakes for vegetarian athletes would be about 1.3 to 1.8 g/kg of body weight, when recommendations for athletes are used as a baseline (53,54,57). 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 animal products are high in many of these nutrients. Iron is a nutrient that may be of particular concern to vegetarian athletes. Because of the lower bioavailability of iron in plant-based diets, vegetarians' iron stores are generally lower than omnivores', despite total iron intakes that are similar or even higher (150). This fact, along with data indicating that exercise may increase iron requirements, means that vegetarian athletes, especially women, may be at greater risk for developing poor iron status. Accordingly, routine iron status monitoring is prudent 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 his or her best. The sports nutrition expert's role is to advise athletes about 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 do the following to help athletes and other active people:
Educate athletes about energy requirements for their sport and the role of food in fuelling the body.
Discourage unrealistic weight and body-composition goals and emphasize the importance of adequate energy intake for good health, injury prevention, and exercise performance.

Assess an athlete's body size and composition to determine 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 behaviours, and in extreme cases may 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 travelling and eating away from home.

Assess the athlete's fluid intake and weight loss during exercise and make appropriate recommendations about total fluid intake and fluid intake before, during, and after exercise. Help athletes determine appropriate types and amounts of beverages to use during exercise, especially if the athlete is exercising in extreme environments.

For athletes with special nutrition concerns, such as the vegetarian athlete, provide appropriate nutrition guidelines to ensure adequate intakes of energy, protein, and micronutrients.

Carefully evaluate any vitamin-and-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 on the product label. These products should not be recommended until the athlete's health, diet, nutrition needs, current supplement and drug use, and energy requirements have been evaluated.

All nutrition recommendations for athletes should be based on current scientific data and athletes' individual needs. 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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Appendix 1
Weight-management strategies for athletes (31)

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 overall well-being.
- Help athletes develop lifestyle changes to 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 10-20% of normal intake will lead to weight loss without the athlete feeling deprived or overly hungry. Strategies such as substituting lower-fat foods for whole-fat foods, reducing intake of energy-dense snacks, and doing activities other than eating when not hungry can be useful.
- Athletes can reduce fat intake, if this is appropriate, but they need to know that a lower-fat diet will not guarantee weight loss if they do not also achieve a negative energy balance (reduced energy intake and increased energy expenditure). 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 legumes.
- Five or more daily servings of fruits and vegetables provide nutrients and fiber.
- Dieting athletes should not skimp on protein, and need to maintain an adequate calcium intake. Accordingly, use of low-fat dairy products and lean meats, fish, and poultry is suggested.
- Fluids – especially water – should be consumed throughout the day, including before, during, and after exercise workouts. Dehydration is contraindicated as a means of reaching a body-weight goal.

Other weight-management strategies

- Encourage athletes not to skip meals (including breakfast) and not to let themselves get too hungry. They should be prepared for times when they might get hungry, and keep 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” foods 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 go off someday.

Appendix 2
Guidelines for evaluating the claims of ergogenic aids
(31,137,145,146,147)

Evaluate the scientific validity of an ergogenic claim:

- Do the amount and the form of the active ingredient claimed to be present in the supplement match those used in scientific studies on this ergogenic aid?
- Is the manufacturer's claim about the product in keeping with 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 (e.g. 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
    - Appropriate dose of the ergogenic substance/placebo used
- What research methods were used, and does the study answer the questions asked? Are the methods clearly presented so the study could be repeated?
- Are the results clearly presented in an unbiased manner, and are appropriate statistical procedures, limitations, 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 a person's health? 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 practices important to performance? For example, does the manufacturer claim that the product replaces food or good training practices?
- Is the product illegal or banned by any athletic organizations?