

NUTRITION FOR CHILD AND ADOLESCENT ATHLETES

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KEY POINTS

- To facilitate growth and development, the daily protein requirements per unit body weight are higher for children than for adults, but it is unclear whether child athletes need more protein than their inactive counterparts for normal growth and development and for optimal performance.
- Children require more energy than do adolescents or adults during sports activities that include walking or running, and possibly in other activities.
- Compared with adults, children and adolescents use more fat and less carbohydrate during prolonged exercise.
- Special attention must be paid to prevent voluntary dehydration in children who exercise in hot/humid climates. To encourage further drinking, a beverage should be tasty and include glucose and small amounts of sodium chloride.

INTRODUCTION

Like adults, child athletes need adequate nutrition to maintain health and to optimize performance. Unlike adults, nutrition for youngsters must provide for physical growth and development. This review is not meant to examine the adequacy of current nutritional intake among young athletes nor their eating patterns. For more information on these issues see reviews by Nelson-Steen (1996) and by Loosli and Benson (1990) and articles regarding young gymnasts (Benardot et al., 1989; Ersoy, 1991), runners (Schemmel et al., 1988), figure skaters (Delistraty et al., 1992; Ziegler et al., 1998) and wrestlers (Schemmel et al., 1988). Our focus will be on several nutritional issues that are specific to the growing athlete: protein and energy needs, utilization of carbohydrate and fat for energy during exercise, and maintenance of adequate fluid and electrolyte balance.

RESEARCH REVIEW

Protein Needs in the Growing Athlete

For adults, adequate protein intake is defined as the minimal amount needed to maintain nitrogen balance. In contrast, children and adolescents must maintain a positive nitrogen balance (i.e., a higher intake than utilization) for the purpose of growth and development of body organs and tissues. As a result, while in adults the recommended intake is 0.8-1.0 g protein/kg body weight per day, protein requirements are higher during childhood and adolescence (National Research Council, 1989). For example, children aged 7-10 years must consume 1.1-1.2 g/kg per day, and children aged 11-14 need 1 g/kg per day (Ziegler et al., 1998).

Protein provides only a minor source of energy during aerobic exercise (Melby et al., 1998). Adults who engage consistently in strenuous training may benefit from protein intake that is higher than that recommended for the general population (Lemon et al., 1992), but there are no similar data for children.

From a practical point of view, it is not clear whether and to what extent the above age-related differences should be taken into account when planning a child athlete's diet. There is little information as to whether or not young athletes consume enough proteins. For example, surveys among

small groups of young figure skaters suggest that their protein intake is adequate or even exceeds the recommended amounts (Delistraty et al., 1992; Ziegler et al., 1998). One should realize, though, that protein intake sufficient to meet the Recommended Dietary Allowance (RDA) may not guarantee an adequate nutritional status. For example, a study of adolescent wrestlers showed that their protein status became less than optimal as the season progressed, even though their reported protein intakes seemed sufficient (Horswill et al., 1990). Such relative deficiency may have been secondary to "making weight" through restriction in energy intake. Moreover, such dietary restrictions among high school wrestlers may induce loss of fat-free mass (Roemmich et al., 1991), which reflects a negative nitrogen balance.

Energy Needs of Children During Exercise

Adult-based data have shown that differences in daily energy requirements among athletes depend on the volumes or total amounts of their training and the specific energy costs of their physical routines. For example, endurance athletes who have large training volumes may need twice or even three times as much energy intake (calories) per day as do sprinters or gymnasts. While the same rationale applies to athletes of all ages, there are no specific data for children who train regularly. Similarly, there is a lack of documentation of the energy a child athlete expends while performing a specific sports routine. Such scant information gives no indication of the daily energy demands in specific sports.

Still, there is reason to assume that energy requirements of child athletes are different from those of adults. The energy cost of walking or running at any given speed, when calculated per kg body mass, is considerably higher in children than in adolescents and adults, and the younger the child, the higher the relative cost (Åstrand, 1952; Daniels et al., 1978; MacDougall et al., 1983). A 7-year-old child, for example, would require as much as 25-30% more energy per kg body mass than would a young adult when they both walk or run at the same speed (Åstrand, 1952). The main reason for a relative "wastefulness" of energy in children is the lack of adequate coordination between their agonist and antagonist muscle groups. During walking and running, the antagonist muscles of children, particularly in their first decade of life, do not seem to relax sufficiently when the agonist muscles contract. This pattern, termed "co-contraction,"

requires extra metabolic energy, which makes children metabolically less economical than adolescents and adults (Frost et al., 1997). Another possible reason for a high metabolic cost is a greater biomechanical energy cost due to a faster stride frequency (Unnithan & Eston, 1990). It is likely, but not yet proven, that the same applies to other physical activities such as swimming, skiing, and skating.

One practical implication for the above differences in energy cost is that one should not use adult-based tables when attempting to calculate the energy cost of sports activities for children. Such tables, when corrected for body mass, are likely to underestimate the actual energy expenditures of children. Very few attempts have been made so far to construct tables of energy costs for children who vary in body mass (Bar-Or, 1983).

It is likely that the energy cost decreases as the proficiency of executing a specific exercise routine increases. However, experimental data yield inconsistent results about such an effect in child athletes. In a longitudinal study Daniels et al. (1978) tested the same teenage cross-country runners for several years. Their average energy cost of running at a fixed submaximal speed decreased at a faster rate than previously observed among non-athletes. Unfortunately, the lack of a proper control group in the study prevents the determination of whether the above decrease in cost represented a training effect or an aging effect. In a more recent study, Sjodin and Svedenhag (1992) tested a small group of male runners and controls periodically between ages 12 and 20 years. While the O₂ cost of running at a standard submaximal speed was lower in the athletes, there was no difference in the rate of decline over time between the two groups. To further confuse the issue, a 10-wk training program in another study was accompanied by a reduction in the energy cost of running in the exercising group, but not among the controls (Unnithan, 1993). In conclusion, the effect of training on the energy cost of activity is not yet clear, nor is it known whether the above considerations have direct implications for nutrition.

Use of Energy Sources During Exercise

Analysis of data on respiration (Martinez & Haymes, 1992), concentrations of potential fat and carbohydrate fuels in the blood (Berg & Keul, 1988), and activities of muscle enzymes (Haralambie, 1979) suggest that, during prolonged exercise, children use relatively more fat and less carbohydrate than do adolescents or adults. Unpublished data (Riddell, personal communications) also suggest that during adolescence, younger boys burn relatively more fat and less carbohydrates during prolonged exercise than do older boys. Likewise, during short, intense activities children seem to rely more on aerobic energy metabolism (in which fat is a major energy source) than on anaerobic energy metabolism (in which muscle glycogen is the predominant energy source) (Hebestreit et al., 1996). This may be one reason why children are usually less successful in high-power "anaerobic" activities such as sprinting and jumping. The cause for the above differences in the use of energy sources is not clear.

Whether children's preferential use of fat as an energy substrate has any implications for nutritional recommendations has yet to be determined. Still, it is clear that there is no evidence to suggest that children--athletes or non-athletes--should consume more than 30% of their total energy intake as fat.

Fluid and Electrolyte Requirements

One implication of the increase in energy expenditure during exercise is the production of more metabolic heat. Because of their higher energy cost of performing physical activities, children produce more metabolic heat per unit body mass than do adults (Bar-Or, 1989). Unless this extra heat is dissipated, core body temperature will increase; if extreme, this storage of heat in the body may induce heat-related illness.

Evaporation of sweat is the main avenue for heat dissipation in the exercising person, particularly in hot climates. While sweating is a very effective mechanism for body cooling, it may result in excessive losses of fluid and, to a lesser extent, electrolytes such as sodium and chloride. To prevent this, body fluids and electrolytes should be fully replenished. Unfortunately, our thirst mechanism, which determines our fluid consumption, almost invariably underestimates the actual fluid requirements during prolonged exercise. Such insufficient drinking may result in "voluntary dehydration," i.e., dehydration that occurs even when beverages are offered in abundance. The effects of dehydration have been studied mostly in adults, but it is clear that loss of body fluids is usually deleterious to performance and health. Single tests of muscle strength, power, and local muscle endurance are typically not dramatically affected by dehydration (Horswill, 1992). Still, one's ability to endure and to perform skills in "stop and go" sports (e.g., soccer, basketball, tennis) and in intermittent exercise routines that mimic such sports can be markedly improved if athletes drink carbohydrate-electrolyte beverages before and/or during such activities (Davis et al., 1997; Leatt & Jacobs, 1989; Vergauwen et al., 1998; Welsh et al., 1999). Also, as reviewed by Sawka & Pandolf (1990), it has been repeatedly shown that dehydration adversely affects the performance of prolonged exercise. Of special relevance to sports that require fine motor skills and precision (e.g., gymnastics, figure skating, basketball) is a decrease in mental acuity. For example, a dehydrated person may not notice certain visual cues (Leibowitz et al., 1972), and tests of mental performance are improved when sports drinks are consumed before and during intermittent activity that mimics basketball competition (Welsh et al., 1999). Deliberate fluid loss to "make weight" in sports such as wrestling or rowing may have negative psychological effects such as aggressiveness, anger and anxiety (Steen & Brownell, 1990). Most important, excessive dehydration may lead to, and aggravate, heat-related illness.

Voluntary dehydration occurs in children (Bar-Or et al., 1980; 1992; Rivera-Brown et al., 1999; Wilk & Bar-Or, 1996) as well as in adults. Importantly, in children, core body temperature during dehydration increases faster than in adults (Bar-Or et al., 1980). It is therefore essential to prevent or ameliorate voluntary dehydration in child athletes.

Inappropriate fluid replenishment patterns may also result in electrolyte insufficiency. In particular, a severe fall in the concentration of sodium in body fluids, a condition known as

hyponatremia, can cause serious illness. This decrease in sodium concentration will occur, for example, when the athlete replenishes sweat and urinary losses by drinking only water, which contains little or no sodium (Meyer & Bar-Or, 1994). One of the outcomes of hyponatremia is muscle cramps during or following exercise. Severe hyponatremia in children may induce apathy, nausea, vomiting, reduced consciousness, seizures, and occasionally even death.

How can one prevent voluntary dehydration in child athletes? The main strategy is to enhance thirst and to educate athletes (but also the coach, parents and team physician) to drink frequently, even when they are not thirsty. Children's thirst can be enhanced during exercise by flavouring the drink and by adding sodium chloride (NaCl) and carbohydrate in amounts typically found in sports drinks, e.g., 18 mmol NaCl/L (110 mg/8 oz) and 6% sugar (14 g/8 oz) (Rivera-Brown et al., 1999; Wilk & Bar-Or, 1996). In a study of 9- to 12-year-old untrained boys who exercised intermittently in a hot environment, voluntary consumption increased by 45% when grape flavouring was added to the water. Drinking was enhanced by a further 46% when the subjects drank a grape-flavoured sports drink (Gatorade) that contained carbohydrate and NaCl. The added intake when carbohydrate and NaCl were included was enough to prevent dehydration altogether (Wilk & Bar-Or, 1996). A similar benefit also occurred when the subjects were male athletes 11-14 years old and highly acclimatized to exercise in a hot climate (Rivera-Brown et al., 1999). The latter observation is important because trained athletes, particularly if acclimatized to the heat, produce much more sweat than do non-athletes, so their fluid requirements are considerably higher. The high consumption of a flavoured carbohydrate-electrolyte drink does not occur merely due to the novelty of the beverage. In boys aged 10-12, dehydration was prevented when the children were given Gatorade during several exercise sessions over a 2-wk period in a hot climate, even when the novelty of the drink had waned (Wilk et al., 1998).

Studies with adults have shown that cooling a drink to approximately 10° C (50° F) makes it more palatable than a drink at room temperature or at outdoor temperatures on hot days. This cooling will cause an increase in voluntary consumption of the beverage. Although there are no similar studies with children, it is reasonable to assume that they will derive the same benefit when the drink is chilled. The addition of salt tablets to a drink should be discouraged, because such tablets contain excessive amounts of salt, which may cause irritation to the stomach lining.

PRACTICAL APPLICATIONS

The limited research that has been performed with active children suggests the following recommendations:

- Even though young athletes usually have enough protein in their daily diets, special attention must be given to those who curtail their food intake to maintain or lose body weight. Such athletes may incur a net loss of body protein and lean body mass, which may compromise their health and their sport performance.

- During various athletic activities, children use more energy per kg body weight than do adults. Therefore, adult-based tables of estimated energy expenditure in any given sport might underestimate the actual needs of children. As a rule of thumb, for children 8-10 years old, one can add 20-25% to the adult values for energy expenditure; add 10-15% for children who are 11-14 years old.
- Like adults, children underestimate their fluid needs during exercise lasting more than 30 min. Because children respond to dehydration with an excessive increase in their core body temperatures, every effort should be made to prevent exercise-induced dehydration in child athletes.
- One should make certain that children arrive fully hydrated for a practice session or for competition and enforce drink pauses every 15-20 min during prolonged activities, even when the child does not feel thirsty. If necessary, rules of the sport should be modified to facilitate periodic drinking.
- Weighing an athlete before and after a training session or a competition is a simple yet effective means of determining whether fluid intake was adequate. Changes in body weight are caused almost entirely by changes in total body fluid content. Children who do not drink enough to restore their body weights to normal between practices or competitions should be required to drink adequate fluids before they are allowed to participate in a subsequent practice or competition.
- Cooling a drink to refrigerator temperature and, in particular, adding flavour to the drink will increase its palatability. Children will voluntarily drink more when the drink is tasty. Therefore, beverages flavoured to satisfy each athlete's taste preference should be readily available for the athlete to drink before, during, and after training sessions and competitions.
- Addition of sugar and a small amount of salt to a beverage will further stimulate the child's thirst and increase fluid consumption. Commercially available sport drinks contain these elements, and such drinks are consumed in greater quantities than are water, diluted fruit juice, or homemade beverages (Passe et al., 1999; Rivera-Brown et al., 1999).

SUMMARY

Most of the research on sports nutrition has been done with adults. While physiological responses of children to exercise are similar to those of adults, there are some differences in these responses that may have implications for the young athlete's nutritional requirements. Coaches, parents, team physicians, and athletic trainers should be sensitive to protein requirements of young athletes; age-related differences in energy expenditure during exercise; differences between children and adults in the utilization of fat and carbohydrates during prolonged exercise; and means of enhancing the amount of fluid intake during exercise to prevent exercise-induced dehydration, particularly in hot/humid climates.

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