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Nutrition for the young athlete

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Abstract

Athletics is a popular sport among young people. To maintain health and optimize growth and athletic performance, young athletes need to consume an appropriate diet. Unfortunately, the dietary intake of many young athletes follows population trends rather than public health or sports nutrition recommendations. To optimize performance in some disciplines, young athletes may strive to achieve a lower body weight or body fat content and this may increase their risk for delayed growth and maturation, amenorrhoea, reduced bone density, and eating disorders. Although many of the sports nutrition principles identified for adults are similar to those for young athletes, there are some important differences. These include a higher metabolic cost of locomotion and preferential fat oxidation in young athletes during exercise. Young athletes, particularity children, are at a thermoregulatory disadvantage due to a higher surface area to weight ratio, a slower acclimatization, and lower sweating rate. An appropriate dietary intake rather than use of supplements (except when clinically indicated) is recommended to ensure young athletes participate fully and safely in athletics.

Keywords: *Energy, carbohydrate, fat, protein, calcium, iron, hydration, young athletes*

Introduction

Adequate dietary intake is important to maintain health, growth, and maturation as well as to minimize injury and optimize sports performance. An appropriate diet will help to develop sound dietary habits that follow through to adulthood and, together with physical activity, reduce the risk for many lifestyle diseases (Bass & Inge, 2006). Optimum diet and exercise in childhood and adolescence will promote an enjoyable, health-promoting, and rewarding experience with athletic participation throughout life. However, when young athletes are exposed to diet or training regimens that are too rigorous for their age, level of maturation or individual limits, the benefits of sports participation may be reduced or even deleterious (American Academy of Pediatrics, 2001).

Young athletes differ from adults and their non-athletic peers in important physiological, metabolic, and biomechanical aspects (Bar-Or, 2001). These differences have implications for their nutritional needs (Table I). Due to ethical considerations involving invasive or potentially harmful experimental research methods, limited information is available on the physiological and nutritional requirements of young athletes, and even less information is available on each of the specific disciplines of athletics. This review focuses on the most important and unique features of young athletes in general and where possible uses information from athletics disciplines.

Nutrition needs for the young athlete

Energy requirements, growth, and maturation

Adequate energy is required to meet the needs for growth, health, body mass maintenance, daily physical activity, and training. Chronic inadequate energy intake may result in short stature, delayed puberty, menstrual irregularities, poor bone health, and increased risk of injuries (Bass & Inge, 2006). Female adolescents in particular who participate in distance running, walking, and jumping events may be at an increased risk of inadequate energy intake and disordered eating as a result of their pursuit of a lighter and leaner physique (Manore, Kam, & Loucks, 2007).

Some estimates for energy expenditure in young athletes have been derived from adult data; however,

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Table I. Nutritional considerations of young athletes (adapted from Bar-Or, 2001).

1. Greater protein needs per kilogram of body weight to satisfy their growth requirements
2. Greater calcium needs to support bone accretion
3. Higher metabolic cost of movement per kilogram of body mass
4. Relatively more fat use during exercise
5. Sweat electrolyte losses differ between children, adolescents, and adults
6. Dehydration is more detrimental to children than to adults

this approach is flawed as children are less metabolically efficient (Bar-Or, 2001). Children's energy requirements per kilogram of body mass during walking and running can be as much as 30% higher than in adults (Krahenbuhl & Williams, 1992; MacDougall, Roche, Bar-Or, & Moroz, 1983). This may be due to a higher resting energy expenditure (Rowland, 2004), greater stride frequency (Unnithan & Eston, 1990), differences in kinematic variables due to knee joint range of motion, variation in total body mechanical work and power (Unnithan, Dowling, Frost, & Bar-Or, 1999), and more co-contraction of antagonist leg muscles (Frost, Bar-Or, Dowling, & Dyson, 2002). The above studies were performed in non-athletic children and it is likely that the energy cost of locomotion decreases in trained children and adolescent athletes. Regular training may also increase energy expenditure through mechanisms other than increased training demands. In a study of obese boys, daily energy expenditure increased by 12% more than estimated from training alone (Blaak, Westerterp, Bar-Or, Wouters, & Saris, 1992). This has not been systematically studied in young non-obese athletes but there is some evidence that energy expenditure may be more than expected (Bolster, Pikosky, McCarthy, & Rodriguez, 2001). When undergoing heavy training, it is likely that young athletes adapt by conserving energy through increasing sedentary behaviours during the day (Petrie, Stover, & Horswill, 2004).

Based on these considerations, it is difficult to establish a dietary reference intake (DRI) for energy in young athletes. Most countries provide guidance to accommodate sedentary through to very active or heavy activity for age and gender categories, but these activity categories are vague and do not consider the mismatch often observed between chronological age and maturational development. These reference values can be considered to be no more than a guide. Monitoring growth, body mass, and other anthropometric variables can help health professionals to assess if energy intake is adequate for a given young athlete to maintain growth, health, and performance.

Because children are beginning to train and compete at earlier ages, there is increasing concern about whether the energetic demand of athletic training can have negative effects on growth and maturation. Theintz and colleagues (Theintz, Howald, Weiss, & Sizonenko, 1993) suggested that linear growth in young female gymnasts might be delayed by the intense training. They followed a cohort of adolescent gymnasts ($\sim$22 h training per week) and swimmers ($\sim$8 h training per week) over 2–3 years. The gymnasts had a lower growth rate ($\sim 5.5\ \text{cm} \cdot \text{year}^{-1}$) than swimmers ($\sim 8.0\ \text{cm} \cdot \text{year}^{-1}$). A subsequent study (Theintz, 1994) reported "catch-up" growth in the gymnasts when their training was temporarily decreased or stopped. Such delayed growth, however, is more likely to result from inadequate nutritional practices than from excessive training, as increased physical activity and musculoskeletal stress are, in fact, necessary for optimal growth (Borer, 1995). Prospective studies of children and adolescents involved in recreational exercise lasting more than 15 h per week (Bonen, 1992), strength training twice a week with light to moderate loads (Sandres, Eliakim, Constantini, Lidor, & Falk, 2001), or club-level sports (Fogelholm, Rankinen, Isokääntä, Kujala, & Uusitupa, 2000) show no growth or maturation impairment. Even competitive sports did not impair pre-pubertal growth, but individual genetic responses may be important (Damsgaard, Bencke, Matthiesen, Petersen, & Müller, 2000). Indeed, an important variable to consider is selection bias. Certain sports show advantages for early maturing individuals, especially males, and other sports, especially gymnastics and dance, favour the late-developing female. Gymnasts are shorter, lighter, and have a lower percentage of body fat than their peers from a very young age (Malina, 1994a).

On average, boys who participate in sports have normal growth rates and maturation (Malina, 1994a). Some are even advanced in maturation, since their increased muscle mass favours power and performance (Malina *et al.*, 2000). Malina (1994b) reviewed the growth and maturation of young athletes in various sports, including track and field. The height of male distance runners (10–18 years) is close to the 50th percentile but their body mass is below this. Sprinters tend to be at or above the 50th percentile, while throwers are substantially taller and heavier (both around the 90th percentile) than all other track and field athletes, including jumpers (around the 50th percentile). Track athletes did not differ in skeletal maturity from their non-athletic peers. The stature of distance runners and female sprinters tends to be above the 50th percentile, while the mass of female distance runners is below this percentile.

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Possibly one of the greatest threats to energy intake is the practice of weight control in young athletes. If a reduction in body mass is required, it should be gradual and not more than 1.5% of body mass each week (American Academy of Paediatrics, 2005). Mass loss to achieve a light and lean physique may be the goal of some athletes, particularly female distance runners, as this is clearly a benefit to performance (O'Connor, Olds, & Maughan, 2007). However, this also increases the risk for energy deficiency, menstrual irregularity, poor bone health, and eating disorders. These issues are reviewed elsewhere in this issue (Manore *et al.*, 2007).

Macronutrient intake

Carbohydrate. Glycogen stores are lower in children than in adults (Boisseau & Delamarche, 2000), and enzymes involved in glycolytic capacity may not be fully developed. A lower lactate dehydrogenase activity has been observed in children and may explain their decreased anaerobic capacity and lactate production (Berg, Kim, & Keul, 1986; Kaczor, Ziolkowski, Popinigis, & Tarnopolsky, 2005). Glycolytic enzyme deficits may disappear during adolescence, as little to no difference has been observed in muscle glycolytic enzymes in adolescent age groups (Haralambie, 1982). Due to lack of research, it is unclear whether young athletes need carbohydrate intakes (per kilogram of body mass per day) comparable to those of adults (Burke, Millet, & Tarnopolsky, 2007). One study that used magnetic resonance spectroscopy to assess muscle glycogen utilization in adolescent athletes reported a depletion of 35% in glycogen stores after a simulated soccer match (~42 min). An association between glycogen utilized and time to exhaustion was also observed (Rico-Sanz, Zehnder, Buchli, Dambach, & Boutellier, 1999). In a subsequent study (Zehnder, Rico-Sanz, Kühne, & Boutellier, 2001), a carbohydrate intake of $4.8\ g \cdot kg \cdot day^{-1}$ almost restored glycogen levels to pre-simulation values. These studies suggest that carbohydrate is an important fuel to optimize athletic performance and recovery in young athletes. However, examples from other sports are required to develop specific guidelines on carbohydrate consumption.

There are no studies of glycogen or carbohydrate loading in children or adolescents. Due to the risk of fatigue, irritability, and inadequate nutrient intake, together with no performance benefit compared with a modified version (Burke *et al.*, 2007) of the classical method, glycogen loading would not be recommended to young athletes. In any case, the only events requiring this preparation would be the walk and the marathon and these are not usual competition events for athletes under the age of 18 years.

Carbohydrate-containing foods are generally important in the diet of young athletes to maintain health. Whole grains, fruits, vegetables, and milk/yoghurt are nutritious sources of carbohydrate and other key nutrients, including, vitamins, minerals, and dietary fibre. An adequate intake of these foods is recommended by public health agencies worldwide due to their association with a reduced risk of disease. Use of refined carbohydrates (e.g. sports drinks, gels, and bars) to support energy intake during training and competition can be useful for young athletes as well as adults (Burke *et al.*, 2007); however, there is a concern that their overuse may increase the risk for childhood obesity and dental caries/erosion. Active children or adolescents using sports drinks or foods appropriately to manage energy needs in conjunction with training/competition are at low risk for unwanted fat accumulation or obesity (Mundt *et al.*, 2006). Little research has been conducted on dental health, but preventative advice to young athletes is prudent. The potential cariogenicity of fermentable carbohydrate-containing foods and drinks is reduced by water rinsing, eating casein-containing foods or using chewing gum (preferably sugar-free) immediately after carbohydrate consumption (Sank, 1999). Dental erosion can also be minimized by reducing contact time with the teeth by consuming fluids through a straw or a squeeze bottle (Milesovic, 1997; Murray & Drummond, 1996). Good dental hygiene (brushing and flossing) and regular dental check-ups are also recommended.

The effect of carbohydrate drinks consumed during exercise is not as well studied in children as in adults. During heavy exercise, total carbohydrate utilization in adolescents may be as great as 1.0–$1.5\ g \cdot kg^{-1} \cdot h^{-1}$ (Riddell, Bar-Or, Schwarcz, & Heigenhauser, 2000). Only when the duration of exercise is increased is there a greater reliance on blood glucose, which can lead to a gradual decrease in glycaemia (Riddell & Iscoe, 2006). Using a ^{13}C isotopic label, Riddell *et al.* (2000) found that the addition of glucose induced a sparing of endogenous glucose utilization in boys (from 68% to 59% of total energy utilization). Ingestion of a glucose solution equal to the amount of carbohydrate that the boys were expending during 60 min cycling at 60% maximal oxygen uptake ($\dot{V}O_{2max}$) decreased fat utilization from 32% to 18% of total energy expended. During 1 h cycling at ~70% $\dot{V}O_{2peak}$, ingestion of a 6% carbohydrate–electrolyte solution had no effect on rating of perceived exertion in boys (Timmons & Bar-Or, 2003). Ingestion of carbohydrate during exercise improved performance time by 40% when boys aged 10–14 years cycled at 90% of their $\dot{V}O_{2max}$ (Riddell, Bar-Or, Wilk, Parolin, & Heigenhauser, 2001). In these studies, however, the participants were not athletes.

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For adults, the recommended concentration of carbohydrate for a drink to be ingested during exercise is about 6% (American College of Sports Medicine, 2007). Increased carbohydrate, energy content, and osmolality may decrease the gastric emptying rate (Murray, Bartoli, Stofan, Horn, & Eddy, 1999) and cause gastrointestinal discomfort. When 18 adolescents performed intermittent high-intensity exercise for 48 min (treadmill sprinting, lateral hops, and shuttle run), ingestion of an 8% carbohydrate drink caused a higher rating of gastro-intestinal discomfort (stomach upset and side ache) than ingestion of a 6% drink (Shi *et al*., 2004). Therefore, a 6% carbohydrate drink may be better tolerated by young athletes during exercise but more studies are required.

Fat. Children appear to oxidize relatively more fat than carbohydrate compared with adults during exercise at a given relative intensity (Duncan & Howley, 1999). This is based on studies that used the respiratory exchange ratio (RER) during (Martinez & Haymes, 1992; Riddell *et al*., 2001, Timmons, Bar-Or, & Riddell, 2003) and after exercise (Hebestreit, Mimura, & Bar-Or, 1993). Preferential fat oxidation is also indicated by a greater increase in plasma free glycerol (Macek & Vavra, 1981) and free fatty acid (Delamarche, Monnier, Gratas-Delamarche, Koubi, & Favier, 1992) concentrations during prolonged exercise. Lactate, the by-product of carbohydrate metabolism and an inhibitor of fatty acid mobilization and uptake (Brooks & Mercier, 1994), has been consistently found to be lower in children than in adults after sub-maximal, maximal, and supra-maximal exercise (Hebestreit, Meyer, Htay-Htay, Heigenhauser, & Bar-Or, 1996; Mahon, Duncan, Howe, & Del Corrall, 1997; Martinez & Haymes, 1992). Compared with late-pubertal and young adults, early-pubertal and mid-pubertal males had a lower RER and lactate concentration at most sub-maximal exercise intensities (Stephens, Cole, & Mahon, 2006). Therefore, the development of an adult-like metabolic pattern seems to occur between mid- to late-puberty and it is completed by the end of puberty.

Hormonal responses to exercise could contribute to maturity-related differences in fuel metabolism (Boisseau & Delamarche, 2000). Younger children show lower sympathetic activity during prolonged exercise (Delamarche *et al*., 1992), which may also explain lower glycolytic metabolism, but is inconsistent with higher rates of lipolysis and fat oxidation. A transient decrease in insulin sensitivity and a compensatory increase in insulin concentration may also alter fuel use (Moran *et al*., 1999). Despite the indication that children rely more on fat as an energy source during exercise, there is no evidence that young athletes involved in endurance activities will benefit from a higher fat content in their diet (Burke *et al*., 2007). On the contrary, ingestion of high-fat foods before exercise may reduce (by 40%) the magnitude of growth hormone secretion during exercise. This was observed when children ingested a lipid-rich shake (0.8 g of fat per kilogram of body mass) 45 min before cycling intermittently for 30 min (Galassetti *et al*., 2006). If this growth hormone increase during exercise is important to muscle adaptation and growth, this response to high fat ingestion may have a negative effect.

Consumption of fat should be in accordance with public health guidelines (American Heart Association, 2005). Of the 25–35% of daily energy from fat, saturated fats should provide no more than 10%. Dietary guidelines also emphasize a low intake of *trans* fat and cholesterol (<300 mg). Young athletes aiming to reduce body mass or fat may overly restrict dietary fat intake. Aside from the concern regarding inadequate energy intake, and impaired growth and development, dietary fat restriction may result in an insufficient intake of essential fatty acids and fat-soluble vitamins. Strict elimination may also result in inadequate intake of protein-rich foods, including lean meats and dairy foods, and associated nutrients such as iron, zinc, and calcium (Petrie *et al*., 2004).

Protein. Children and adolescents have higher protein needs than adults to support growth. In fact, adequate intakes of both energy and protein are essential to maintain a positive nitrogen balance (Tipton, Jeukendrup, & Hespel, 2007). Limited data are available on the protein requirements of young athletes. In one of the few available studies, untrained children walked for 45–60 $min \cdot day^{-1}$ (3.2–6.4 $km \cdot day^{-1}$) for 6 weeks. Whole-body protein oxidation increased but protein synthesis and breakdown decreased, presumably to conserve protein and prevent negative nitrogen balance. This may also have been influenced by the children not adequately increasing energy intake to match requirements (Bolster *et al*., 2001). In a study employing resistance training (twice a week for 6 weeks), a down-regulation of protein metabolism in the children was also observed (Pikosky, Faigenbaum, Westcott, & Rodriguez, 2001).

In most western countries, protein intakes typically exceed requirements, so it is likely most young track and field athletes consume adequate amounts. In most circumstances, protein intake will be adequate if energy intake meets requirements, and even in studies of young athletes who typically restrict energy intake, protein intakes have usually been observed to be adequate (Bass & Inge, 2006). In adults, the upper level of protein requirement for athletics training is recommended to be 1.7 $g \cdot kg^{-1} \cdot day^{-1}$

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(Tipton *et al.*, 2007), and it is expected that this amount is also adequate for children and adolescents. Nevertheless, it is reasonable to conclude that athletes on more rigid energy restriction or "bulky", higher fibre vegan vegetarian diets (due to difficultly consuming adequate energy rather than sufficient protein) may be more at risk of not achieving adequate protein intakes.

Micronutrient intake

Iron. Inadequate iron intake and iron deficiency are commonly reported in athletes (Deakin, 2006). Adolescent female athletes in particular are at higher risk due to their menstrual losses. This group is also more likely to consume inadequate iron. Some studies report that up to 40–50% of female athletes have low ferritin stores (Rowland, Stagg, & Kelleher, 1991). Low iron intake may not necessarily result in anaemia, but chronically low intake may impair muscle metabolism (Beard, 2001) and cognitive function (Grantham-McGregor & Ani, 2001). Diagnosis of iron deficiency based on serum ferritin alone is problematic, as increases in plasma volume associated with the growth spurt and possibly as an acute response to training can present as a false-positive. Approaches to detection and clinical management have been reviewed elsewhere (Deakin, 2006). Low intakes can be ameliorated by providing young athletes with strategies for increasing dietary iron and optimizing conditions and forms of iron that are readily absorbable. Medically supervised supplementation may sometimes be required.

Calcium. Dietary calcium recommendations are based on the amount required to maintain calcium balance and promote optimum bone accretion rates. Calcium balance studies suggest there is a threshold for calcium intake beyond which any additional calcium does not result in further retention (reviewed in Kerr, Khan, & Bennell, 2006). When calcium intake is low during childhood and adolescence, higher calcium retention efficiencies (as high as 50%) partially compensate for the deficit (Abrams, Grusak, Stuff, & O'Brien, 1997). This is different from adults with skeletal deficiency, where retention rates of only 4–8% are observed (Kerr *et al.*, 2006). However, a very low calcium intake ($<400\ \text{mg} \cdot \text{day}^{-1}$) is deleterious for bone development and health (Lanou, Berkow, & Barnard, 2005).

Around 26% of bone mineral is accrued during puberty (Bailey, McKay, Mirwald, Crocker, & Faulkner, 1999). Many exercise interventions have demonstrated a positive influence of activity, particularly high-impact activities such as jumping, on bone accrual. Evidence also suggests that there is greater benefit if this is begun before puberty (MacKelvie, Khan, & McKay, 2002). In contrast, amenorrhoea in female athletes has a detrimental effect on bone mineral content (Manore *et al.*, 2007). Bone mass in amenorrhoeic athletes is below that of age-matched controls at weight-bearing sites (Drinkwater, Nilson, & Chestnut, 1984). Poor bone quality predisposes to bone fractures, and a lower bone mineral density is associated with an increased rate of bone fracture in girls (Goulding *et al.*, 1998) and boys (Goulding, Jones, Taylor, Williams, & Manning, 2001; Pires, Souza, Laitano, & Meyer, 2005). The occurrence of fractures was associated with low calcium intakes (Goulding, Jones, Taylor, Manning, & Williams, 2000; Pires *et al.*, 2005) and lower activity levels (Pires *et al.*, 2005). Despite the difficulty in determining the incidence of stress fractures in track and field athletes, prospective studies have reported a range of 11–21% (stress fractures per 100 athletes) (Nattiv, 2000).

Dietary supplements

Many young athletes are drawn towards dietary supplements and their promise of improved performance. In a survey among 32 UK junior track and field athletes (~18 years), 62% were using supplements, mainly multivitamins and minerals, with the expectation that they improve health, immune function, and performance (Nieper, 2005). In a study by O'Dea (2003) of Australian adolescents in the general community, supplements were used for perceived short-term health benefits, prevention of illness, improved immunity, to boost energy or sports performance, and correct poor dietary intake. Although vitamin and mineral supplementation may improve the nutritional status of youngsters consuming marginal amounts of these nutrients from food, there is no scientific evidence to support the general use of supplements to improve performance. Young athletes following reduced energy or vegetarian diet, who are amenorrhoeic or who are diagnosed with iron depletion, may benefit from supplementation under medical or dietetic supervision.

A popular supplement with young athletes is creatine monohydrate. In a survey of 1103 young athletes, 5.6% reported using creatine (Metzl, Small, Levine, & Gershel, 2001). Its use was more common among boys (8.8%) than girls (1.8%) and strength-dependent athletes (football players, wrestlers, gymnastics, and hockey players), but it was reported among athletes involved in every sport, including track and field (1.4%). Due to a lack of evidence on long-term safety, the use of creatine is not recommended for children under 18 years of age (American College of Sports Medicine, 2000). Although some case reports indicate adverse effects, most of these are anecdotal or applicable to individuals with

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underlying disease (Patel, Torres, & Greydanus, 2005).

Hydration and thermoregulation

Young athletes who perform prolonged or intense, intermittent exercise can present with dehydration (greater sweat loss than fluid intake), which may affect performance and health (Falk, 1998; Sawka, 1992). Despite the lower sweat rates of children than adults, laboratory studies with controlled exercise and environmental conditions show that children can potentially dehydrate as much as adults if no fluid is ingested (Meyer & Bar-Or, 1994). The age of the athletes also influences sweat loss. In a simulated duathlon race, older boys ($>$15 years) had a higher sweat rate ($\sim$1.3 litres $\cdot$ h^{-1}) than younger boys ($\sim$0.64 litres $\cdot$ h^{-1}) and both groups became dehydrated despite free access to water (Iuliano, Naughton, Collier, & Carlson, 1996). Fluid intake was higher during cycling and at rest than during the run, indicating that exercise mode and recovery periods affect voluntary fluid intake in adolescents (Iuliano *et al.*, 1996). During a triathlon race, about 50% of boys and girls dehydrated by 2–3%. One in three boys (8–13 years) dehydrated 2%, and 7% exceeded 3% dehydration (Wilk, Aragon-Vargas, & Bar-Or, 2001).

The influence of hydration status on exercise performance is most clearly understood for adults undertaking endurance exercise (Shirreffs, Casa, & Carter, 2007). There is no published literature on the influence of hydration status on performance in athletic events in young athletes but dehydration, by 2% of body mass, impaired basketball skills in boys aged 12–15 years (Dougherty, Baker, Chow, & Kenney, 2006).

Children show a greater increase in core temperature than adults as they become dehydrated (Bar-Or, Dotan, Inbar, Rotshtein, & Zonder, 1980). In addition to their lower sweating rate and higher metabolic cost of locomotion, other factors can make thermoregulation harder in children (Falk, 1998). Their higher surface area to body mass ratio causes a greater heat gain when air temperature is above skin temperature (Bar-Or, 1989). The heat acclimatization process may be delayed in children compared with adults (Inbar, Dotan, Bar-Or, & Gutin, 1981), so that when summer arrives, young athletes may be more vulnerable to heat-related problems (Bergeron, McKeag, & Casa, 2005; Godek, Godek, & Bartolozzi, 2005).

Children may not hydrate fully when they have water to drink *ad libitum* during exercise (Bar-Or *et al.*, 1980, 1992). Wilk and Bar-Or (1996) studied unacclimatized boys who cycled intermittently in the heat (35°C, 43% relative humidity) for 3 h. In separate sessions, they could drink plain water, flavoured water or the same flavoured solution with the addition of carbohydrate and sodium chloride (NaCl). Compared with plain water, voluntary ingestion was 45% greater with flavoured water; but the addition of carbohydrate (6%) and NaCl (18 mmol $\cdot$ l^{-1}) induced a further increase in voluntary drinking sufficient to prevent dehydration. Subsequent studies have confirmed these findings (Horswill, Passe, Stofan, Horn, & Murray, 2005; Rivera-Brown, Gutiérrez, Gutiérrez, Frontera, & Bar-Or, 1999; Rodriguez *et al.*, 1995; Wilk, Kriemler, Keller, & Bar-Or, 1998).

Although sweat sodium losses are generally lower in children than in adults (Meyer, Bar-Or, MacDougall, & Heigenhauser, 1992), maintaining hydration in children with sports drinks containing about 20–25 mEq $\cdot$ l^{-1} of sodium does not result in sodium overload and indeed a slight negative sodium balance may occur due to the sweat and urinary losses (Meyer, Bar-Or, MacDougall, & Heigenhauser, 1995). In adults, hyponatraemia (blood Na^+ concentration $<$130 mEq $\cdot$ l^{-1}) is mainly reported in long events ($>$4–6 h) when low sodium drinks are ingested in excess. Young athletes may also be at risk of hyponatraemia during exercise (Patel *et al.*, 2005), but this has not been surveyed.

To start training or competition euhydrated, young athletes may be advised to follow recommendations similar to those given to adult athletes (Shirreffs *et al.*, 2007). During exercise, they should drink periodically if necessary, with volumes depending on their sweat rates. If the activity is prolonged ($>$1 h) or intense and intermittent, sodium and carbohydrate should perhaps be added to a flavoured liquid. After exercise, water and sodium should be actively replaced if significant losses have occurred (Shirreffs, 2001). Young athletes seem to know about these general recommendations but do not follow them or are not aware of the specific amounts of fluids to be consumed (Nichols, Jonnalagadda, Rosenbloom, & Trinkaus, 2005).

Recommendations can be adapted to conditions that make young athletes vulnerable to water-electrolyte or metabolic disturbances. Many common paediatric diseases including asthma (Nystad, 1997) and Type 1 diabetes (Riddell & Iscoe, 2006) place no restriction on exercise (American Academy of Pediatrics, 2001) or participation in competitive sports. Dehydration in asthmatics may accentuate bronchoconstriction (Kalhoff, 2003). Other less common conditions are of interest because of very high sweat NaCl losses, such as in cystic fibrosis (Bar-Or *et al.*, 1992, Kriemler, Wilk, Schurer, Wilson, & Bar-Or, 1999), or increased risk of hyponatraemia, such as in renal diseases (Patel *et al.*, 2005).

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Ingestion of fluids and maintenance of euhydration does not necessarily prevent heat problems caused by the environmental stress. The American Academy of Pediatrics (2000) made recommendations regarding environmental heat stress based on the wet bulb globe temperature (WBGT) (Table II).

Conclusions

Children and adolescents have specific nutritional needs, and although the principles of sports nutrition are similar for children and adults, there are some important differences, particularly with respect to energy expenditure, fuel utilization, and thermoregulation during exercise. During this life stage, particularly in girls, there is an increased risk for inadequate dietary intake secondary to dieting to optimize physique. This increases the risk for energy deficiency, disordered eating, menstrual irregularity, and reduced bone density. Appropriate nutrition is critical during these growing years to maintain health, growth, and the development of athletic potential. The guidelines below provide recommendations to optimize and support participation of children and adolescents in the various disciplines of athletics.

Summary of nutritional guidelines for young track and field athletes

Consensus for:

- There is limited research on the nutrition requirements of young athletes and a need for further study.
- Compared with adults, studies with children and adolescents consistently suggest they have a higher cost of locomotion, greater fat oxidation, and less efficient thermoregulation.
- Young athletes, parents, and coaches would benefit from education on the importance of nutrition for optimizing growth, health, and athletic performance.
- Major differences in the dietary requirements of young athletes include increased requirements for energy, protein, and probably carbohydrate compared with their non-athletic peers. Intakes of micronutrients may also be elevated, particularly iron, but more research is required. Iron is the most commonly reported nutritional deficiency.
- Bone accrual during childhood and adolescence is critical to optimize peak bone mass. Adequate energy and dietary intake, particularly calcium, is important for regular weight-bearing physical activity, particularly if commenced before and maintained throughout puberty. Reduced bone mass increases fracture risk for athletes.
- Athletes aiming to reduce body mass or fat content are at a greater risk of an inadequate energy intake, which may result in delayed growth and maturation and, in female adolescents, amenorrhoea and reduced bone density.
- In following sports nutrition guidelines, young athletes should be well within the recommendations made by public health agencies. This will ensure that athletic participation from a young age will have a positive influence on dietary intake and future health.
- Young athletes should monitor their fluid intake and be educated in specific recommendations of hydration.
- When appropriate, young athletes should start exercise euhydrated and maintain hydration status close to euhydration during training or competition by drinking if necessary.
- After exercise that results in a significant sweat loss, water and electrolytes should be replaced.
- Bottled drinks should be readily available to facilitate ingestion and be based on individual preference.

Table II. Restraints on activities at different levels of heat stress.

WBGT (°C)	Restraints on activities
<24	All activities allowed, but be alert for prodromes of heat-related illness in prolonged events
24.0 – 25.9	Longer rest periods in the shade; enforce drinking every 15 min
26 – 29	Stop activity of unacclimatized persons and other persons with high risk; limit activities of all others (disallow long-distance races, reduce further the duration of other activities)
>29	Cancel all athletic activities

From American Academy of Pediatrics (2000), Committee on Sports Medicine and Fitness.

Consensus against:

- The classical method of glycogen loading is not recommended for young athletes and the modified version is only required for marathons or race walks, which are usually not undertaken in track and field events until athletes are at least 18 years of age.
- Supplements, unless clinically indicated, are not recommended.
- Young athletes should not ingest excessive volumes of drinks during exercise. They should

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be advised to monitor body mass before and after the exercise.

Issues that are equivocal:

- The effects of carbohydrate intake and increased glycogen stores on performance and other physiological and metabolic responses in young athletes are unknown.

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