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Article Title: Nutritional Considerations for the Overweight Young Athlete

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Abstract

Nutritional considerations for the overweight young athlete have not been thoroughly discussed in the scientific literature. With the high prevalence of childhood obesity, more children participating in sports are overweight or obese. This is particularly true for select sports, such as American football, where large size provides an added advantage. While sport participation should be encouraged because of the many benefits of physical activity, appropriate nutritional practices are vital for growth, and optimizing performance and health. The overweight young athlete may face certain challenges because of variable energy costs and nutrient requirements for growth and routine training, compared to non-overweight athletes. Special attention should be given to adopting healthy lifestyle choices to prevent adverse health effects due to increased adiposity. In this review, we aim to discuss special nutritional considerations and highlight gaps in the literature concerning nutrition for overweight young athletes compared to their non-overweight peers.

Introduction

The prevalence of childhood obesity has increased drastically over the past few decades. Although the rate of increase appears to be slowing down or leveling off (42), there remains a great number of youth affected by obesity. The World Health Organization (WHO) cut-points for overweight and obesity are defined as one or two standard deviations above the mean for body mass index (BMI) percentile for age, which is approximately the 84^{th} and 97.7^{th} percentile, respectively (128). Based on WHO cut-points, 31.5% of Canadian youth ages 5-17 years are overweight (19.8%) or obese (11.7%) (103). Similarly, 31.8% of youth are classified as overweight (14.9%) or obese (16.9%) in the United States (90), however, these prevalence rates were based on the Centers for Disease Control and Prevention (CDC) cut-points. CDC classifies overweight and obesity as $\geq 85^{th}$ and $\geq 95^{th}$ BMI-for-age percentile, respectively. Prevalence rates determined by WHO cut-points are not significantly different from when CDC cut-points are used (113). Abdominal obesity, as assessed by waist circumference, should also be considered when predicting future health risks. Evidence suggests that individuals with higher abdominal obesity have an increased morbidity and mortality risk (61). The prevalence of abdominal obesity in Canadian youth ages 12-19 years has increased from 1.8% in 1981 to 2.4% in 1988 and to 12.8% in 2007-2009 (62). These statistics provide great concern for the increased risk of metabolic complications developing during childhood. Consequently, preventative strategies to reduce health risks related to obesity are necessary.

The purpose of this narrative review is to provide an overview of weight management strategies in the context of nutrition and exercise. The review will discuss unique nutritional considerations for overweight children who want to be active through participating in sport. Increasing energy expenditure may benefit overweight children by elevating the utilization of excess energy stores. Sport participation appears to be a feasible and acceptable way to increase energy expenditure and potentially reduce weight gain in children (127). Nutritional advice and education is important for promoting optimal conditions for training and sport performance. The available resources for young athletes are geared towards non-overweight children, and do not include data on weight status (6, 76, 84, 91). Thus, nutrition for overweight young athletes is a topic that requires further discussion.

Expert Committee recommendations developed by a group of pediatric obesity experts suggested that treatment evaluations for overweight children should include a focused assessment of physical activity habits and diet (5). Weight-management programs are, unfortunately, not accessible to all communities and are often limited by resources; however, a lifelong pursuit of healthy eating habits and physical activity is critical for all children. Either within or outside of the clinical setting, a challenge is to find meaningful sources of physical activity for the child. While sport participation is an obvious choice, additional research and discussions on the efficacy of team sports for weight management are warranted. Currently, there is a paucity of observational data examining the influence of team sports on increasing regular physical activity and fitness, or reducing weight gain. A German study reported that children in organized sport more than once per week had greater physical fitness and were less likely to be overweight (33).

When examining cardiorespiratory fitness versus fatness, it appears that fatness has a stronger association with components of the metabolic syndrome than fitness in children (37). Furthermore, data in men show that within categories for BMI or abdominal fat, fitness attenuates cardiovascular disease risk factors (68). Weight management strategies for active overweight youth should go beyond assessing BMI and consider improving fitness and reducing abdominal fat, which are not often reported in studies. The role of physical activity and sport participation on this relationship is another area that requires further study.

Recent findings from a pilot randomized controlled trial providing an after-school soccer program versus health education for overweight children showed that children engaged in the soccer program had significantly lower BMI z-scores at 3 and 6 months than those with health education (127). Data on abdominal obesity and percent body fat were not reported, but waist circumference and skinfold thickness measurements will be included as secondary outcome measures in a follow-up study. Future research will assess the effectiveness of an intervention program that encourages team sport participation over a three year period (105).

Statistics on sport participation are limited, especially population data with information on overweight athletes. However, based on the available data, there appears to be a selection bias for participation of overweight young athletes in select sports (24, 38). Although the physical demands on the body to keep up with their non-overweight peers may be greater, overweight children have more muscle mass and absolute strength, as shown by greater knee extension and grip strength by Ervin and colleagues (39). Greater strength may compensate for possible disadvantages in quickness and agility. Additionally, as individual's participate in an increasing number of athletic activities, BMI of participants tend to be lower, except for sports with higher demands of power and strength, such as American football (24, 38). Elkins et al. (38) found that obesity was five-fold greater in boys who participated in football compared to other sports in a sample of inner city African American youth. In the Fairfax County Public School District in Northeastern Virginia, the prevalence of overweight and obesity (CDC cut-points) in 3970 young male athletes was 30.3% and 14.4%, respectively (24). The report increased concern for a higher prevalence of overweight or obesity in young male athletes when compared to NHANES (1999-2002) data, especially athletes involved with football, wrestling and/or rowing (24). Therefore, it is unreasonable to assume that all children with increased sport participation have lower BMIs compared to inactive children. One caveat in these reports on sport participation is that overweight was defined using BMI, which may be largely influenced by higher muscle mass. Whether these young athletes have greater abdominal obesity than their non-overweight peers should be assessed to identify future health risks. Unfortunately, these data were not available. Coaches should be careful to not reinforce poor health decisions if young athletes are being selected based on body size.

Most studies have classified overweight and obesity based on BMI. It is uncertain how many overweight young athletes have a healthy percent body fat, in which case weight loss may not be as relevant as maintaining weight and muscle mass. In a group of 203 schoolboy rugby players in Ireland, 68% were a healthy weight, 22% were underweight, and 9.7% were overweight (126) based on percent body fat groups defined by McCarthy et al. (73). This indicates that a proportion of young athletes remain classified as overweight based on excess adiposity. Larger studies to assess the prevalence of overweight, using percent body fat cut-points, in sport participation would be beneficial.

To excel in competitions or games, overweight athletes may have to work harder than non-overweight athletes because of the extra energy expended to complete the same tasks. However, if energy expenditure is increased, should energy intake be increased or maintained in the overweight child? The extent to which nutritional considerations depend on the volume and intensity of training relative to body mass is rarely investigated. Furthermore, weight stigmatization or the physical demands of a particular sport may lead to additional stressors and poor nutritional choices of the overweight child. In this review, we aim to discuss special nutritional considerations and highlight gaps in the literature in overweight young athletes compared to their non-overweight peers. We begin by providing an overview of energy requirements for children; literature on substrate utilization during exercise, macronutrient and micronutrient considerations, and hydration guidelines. While others have published works related to nutrition and the young athlete, none have specifically focused on the overweight young athlete. Potential psychosocial barriers for sport participation, which may indirectly impact dietary intake will also be presented briefly. We will use the term "children" to refer to individuals under the age of 18 years, unless nutritional information can be provided for a specific age-group.

Energy Requirements for Children

The nutritional requirements of children are different from adults, because children require additional nutrients for optimal growth and maturation, and should maintain a positive energy balance (energy intake > energy expenditure). Estimated energy requirements (EER) depend on age, sex, height, weight and the volume of training or physical activity level of an individual. It is difficult to establish precise energy requirements for children, because of the variable timing of the growth spurt, which does not occur at the same chronological age (82). EER suggested by the Institute of Medicine are divided into 4 physical activity levels (sedentary, low active, active and very active) (56). EER values are summarized in Table 1 (56). The calculation of EER values for non-overweight children include total energy expenditure (TEE) and an estimate of energy deposition resulting from childhood growth.

Among overweight children, special considerations for EER are necessary for meeting weight goals. Rapid weight loss in children is not advised and could lead to stunted growth or micronutrient deficiencies (56). Expert Committee recommendations (5) on weight goals state that weight maintenance of a child's baseline weight should be the initial step for children ≥ 2 years. For children ≥ 7 years, continued weight maintenance is an appropriate goal if BMI remains between the 85^{th} and 95^{th} percentile with no co-morbidities. However, in the presence of secondary complications related to obesity or a BMI above the 95^{th} percentile, weight loss of about 0.45 kg per month (15 g/day or an energy reduction of 108 kcal/day) is suggested. The child with the help of his or her family should first show an ability to maintain weight before starting weight loss goals (5). TEE equations for weight maintenance among overweight children provided by the Institute of Medicine can be used to guide energy intake (56).

Defining precise energy requirements for overweight young athletes is challenging because of variability in energy costs associated with growth and individual training sessions compared to non-overweight children and adults. When we observe energy costs at a given speed of locomotion, energy costs are greater in younger children than older children and adults when calculated per kg of body weight (65, 70). This difference may be explained by poor coordination between agonist and antagonist muscle groups during a child's first 10 years. There is a higher demand for metabolic energy because the antagonist muscles do not relax sufficiently when the agonist muscles contract (43). Within a given age group, Morgan et al. (81) suggest that interindividual differences and changes in physical development and body structure may explain some variability in boys and girls. As a result, it is not appropriate to use adult tables to estimate energy costs for children. For more information on compendiums of physical activity energy costs in children and existing limitations, readers are directed to other references (9, 52, 81). Overweight children are likely to have greater energy costs than non-overweight children and adults during walking or running conditions (3, 66). Moreover, less is known about training responses of children compared to adults. Among obese children, 4 weeks of endurance training (5 x 1-hour sessions per week at 50-60% VO_{2max}) led to an increase in TEE by 12% (11). Approximately half of the increase was accounted for by the direct energy cost of training and half by the energy expenditure after training (11). No studies have compared similar training effects to non-overweight youth using doubly labeled water. However, using accelerometry data, Bolster et al. (15) found non-overweight children also increased energy expenditure associated with physical activity above baseline after a training program. Among non-overweight children, physical training usually requires additional caloric intake on top of the calories needed to support growth and basal energy expenditure. Among overweight children, the intensity and volume of training sessions must be considered along with healthy weight maintenance or weight loss goals. Overweight young athletes may not have to increase daily caloric intake to compensate for the increased energy expenditure. This would likely lead to weight loss, which may be favorable for overall health if it occurs gradually over time, especially if it is accompanied by reduced abdominal obesity.

Among overweight children, caloric intake may vary significantly between individuals. We recommend that adjustments to dietary intake of overweight children be made with professional guidance, such as through regular follow-up visits with a physician or a dietician in a weight management program. Keeping track of the young athlete’s diet over a typical week and assessing total caloric intake and available nutrients is a good starting point. This will help identify any critical nutrients that are missing from the diet and what foods may be consumed in excess. Completing a detailed assessment and journal of regular physical activity would also help track potential changes in energy expenditure. A better understanding of individual energy requirements is certainly valuable, but the macronutrient and micronutrient composition of a child’s diet is also critical for sport participation and weight maintenance or weight loss. If overweight children do not exceed energy expenditure with higher energy intake from fat, protein and carbohydrate (CHO), regular sport participation may help reduce excess fat accumulation and cardiovascular risk. The following sections will discuss energy metabolism in non-overweight children and overweight children, as well as important considerations related to dietary composition for young athletes.

Protein Turnover

Protein provides the essential amino acids necessary for growth by promoting protein synthesis and maintaining lean body mass development. In order to retain a positive nitrogen balance, protein has to be ingested alongside sufficient energy intake so that protein is not used as a substrate for energy (91). Dietary modifications for obesity treatment are challenging because reduced caloric intake may subsequently lead to reduced protein turnover and greater protein utilization due to metabolic adaptations (115). Among obese children ages 8 to 10 years, a negative energy balance induced by a 6 week diet intervention showed reduced protein turnover, mainly due to slightly reduced protein synthesis. However, resting metabolic rate showed no changes with the intervention despite changes in protein turnover (36). Further research with longer duration longitudinal studies to examine reduced caloric intake on protein turnover is warranted.

Several adult studies have focused on hypocaloric diets, protein content, and exercise training, which may provide some insight for protein recommendations in overweight active individuals. Meckling & Sherfey (75), for example, studied a hypocaloric high-protein diet with and without exercise in a randomized trial with overweight and obese women on weight loss and markers of the metabolic syndrome. While all groups lost weight, the high-protein diet group was better than the low-fat, high-carbohydrate diet group at promoting weight loss and a positive nitrogen balance when the diet alone and diet with exercise interventions were provided. Target carbohydrate to protein ratios for the two diet interventions were 3:1 (low-fat, high-carbohydrate diet) and 1:1 (high-protein diet) (75). In the adult literature, there seems to be increasing support showing improved cardiovascular risk factors with a combined hypocaloric, high protein diet and exercise training intervention (75, 89, 130). Randomized controlled trials involving children are needed to determine if high protein diets are safe and beneficial for both non-active and active overweight children.

Very few studies have examined the effect of exercise training on protein turnover in children. One study by Bolster et al. (15) reported decreased protein synthesis and protein breakdown but no effect on net protein turnover in non-overweight pre-adolescent boys and girls after a 6 week walking program. Among obese children, Ebbeling & Rodriguez (35) reported slightly different results after 6 weeks of diet intervention followed by 6 weeks of combined diet and walking intervention. At the end of the 6 week diet intervention, the children had a negative energy balance and reduced net protein turnover. After the walking intervention, net protein turnover and nitrogen balance increased, but still remained below baseline levels. These results suggest that exercise can help minimize protein losses for obese children on a hypocaloric diet (35). To our knowledge, no studies have compared the effects of aerobic training versus resistance training on protein metabolism in overweight children.

In studies that measured protein turnover in young people after a resistance training program, results did not indicate a need for increased protein consumption (54, 79, 94). In response to a 6 week resistance training study in non-overweight children, Pikosky et al. (94) showed reduced protein synthesis and protein breakdown. However, increases in strength and mean nitrogen balance were found. Although the underlying mechanisms remain unclear, the authors suggested nutrient partitioning may have contributed to an increased nitrogen balance despite decreased net protein turnover (94). Nutrient partitioning was defined as a state in which nutrients are partitioned differently among metabolic organs and tissues to allow successful execution of a productive function (10, 94), such as down-regulating protein turnover in support of growth. Among untrained young males (~22 years), 12 weeks of resistance training resulted in increased net protein balance compared to baseline (54). This suggests that resistance training may result in improved efficiency of protein metabolism (54), and dietary protein requirements are not elevated but may even be slightly reduced. Thus, it is possible that whether overweight young athletes are participating in aerobic- or resistance-based training there is no additional demand to increase protein intake. However, this topic represents an important area for future research.

Protein Recommendations

The estimated average requirements (EAR) for protein in non-overweight children generally decrease with increasing age. EAR refers to the daily average nutrient intake level to meet nutrient requirements for half of the population, whereas the recommended dietary allowance (RDA) refers to the daily average nutrient intake level to meet requirements for nearly all (97-98%) of the population of healthy individuals for a particular age and gender group (59). In children ages 9-13 years, the protein EAR is 0.76 g/kg/day. For boys and girls ages 14-18 years, the protein EAR are 0.73 g/kg/day and 0.71 g/kg/day, respectively (56). For athletes, it has been reported that adults should aim for protein intake between 1.3-1.8 g/kg/day or closer to 2.0 g/kg/day during intense training (92). There is little information on protein requirements for children participating in regular exercise training. Young gymnasts and soccer players who participated in regular physical activity did not show significant differences in protein turnover compared to non-active peers (12, 13). However, past studies indicate that the RDA of 0.85-0.95 g/kg/day for children (56) is not enough for either active or non-active children to establish a positive protein balance (12, 14). Among young soccer players, Boisseau and colleagues (14) completed a short term repeated nitrogen balance study with three levels of protein intake: 1.4, 1.2 and 1.0 g of protein per kg of body weight. Using the coefficients of variation for maintenance and protein deposition, EAR and RDA were calculated. Boisseau et al. (14) suggested that adolescents should aim for an EAR of 1.2 g/kg/day and a RDA of 1.4 g/kg/day. Although there are insufficient data to verify that these recommendations are suitable for the overweight young athlete, no current evidence suggests that overweight children would require more or less protein than non-overweight children. No adult literature has looked at the influence of obesity on dietary protein requirements either. Therefore, this may be an area that requires future attention and reevaluation because of the present high prevalence of obesity.

The timing of protein intake is also important to consider. Protein consumption split between meals throughout the day and after training could help maintain lean tissue development. Research involving adults suggests that the ingestion of protein approximately every 3 hours and early in recovery is ideal for maintaining net protein balance (79). Studies in non-overweight children also support the benefits of protein consumption after exercise (80, 125), however future work examining the timing of protein intake in children and its benefits for overweight children is necessary.

Carbohydrate and Fat Metabolism during Exercise

CHO and fat are the major sources of energy during submaximal exercise. A better understanding of substrate utilization during exercise in overweight children would help provide appropriate recommendations and adjustments to diet when necessary. The main storage form of CHO is glycogen found in the liver and skeletal muscle. At the onset of exercise, most of the CHO utilized is derived from muscle glycogen, but as the duration of exercise continues the contribution of plasma glucose increases and muscle glycogen decreases (108). Fat utilized during exercise consists of free fatty acids (FFA) released from adipose tissue triacyglycerol (TAG) and transported in the bloodstream to the skeletal muscle, as well as FFA derived from skeletal muscle TAG (72).

The balance between CHO and fat utilization during exercise is regulated by the intensity of exercise. CHO oxidation rates increase progressively with exercise intensity, while absolute fat oxidation rates increase from low to moderate exercise intensities and decrease at high intensities (18, 72). Thus, CHO versus fat utilization may be sport specific depending on the type of exercise performed. Other factors that may influence fuel selection include diet, puberty, sex, cardiorespiratory fitness, duration of exercise, substrate availability and delivery to skeletal muscle, and adiposity (1, 47, 118). The literature shows that pre-pubertal children tend to have a preferential use of fat over CHO during low to moderate intensity exercise compared to post-pubertal children and adults (71, 99, 116). Thus, biological age is an important factor to consider when discussing nutrition for young athletes.

Scientific data on CHO oxidation rates in overweight compared to non-overweight children during exercise are sparse. McMurray & Hosick (74) reported greater CHO oxidation rates expressed per kg of fat free mass in overweight girls compared to non-overweight girls at three treadmill speeds (4.0, 5.6 and 8.0 k/h). However, when CHO oxidation rates were adjusted for percent VO_{2max}, the difference was eliminated. Similarly, CHO oxidation rates adjusted for fat free mass were greater in overweight boys compared to non-overweight boys (74). There was a trend showing lower CHO oxidation rates in the boys compare to the girls, but no significant difference (74).

Children have different fat oxidation profiles compared to adults, which may be explained by changes during puberty (71, 99, 116). Fat oxidation rates relative to fat free mass during exercise decreases with pubertal development in non-overweight (99) and obese boys (132). The exercise intensity that elicited the maximal fat oxidation rate (FATmax) also decreased with puberty (99, 132). Only a few studies have examined fat oxidation in overweight or obese children compared to non-overweight children (25, 60, 67, 74, 131). At higher exercise intensities above 40% VO_{2peak}, fat oxidation is lower in obese boys compared to non-obese boys (131). However, other studies have showed that fat oxidation rates adjusted for fat free mass are not influenced by weight status (67, 74). Most fat oxidation studies in youth were completed in boys, and to our knowledge only one published study (74) has compared boys and girls, showing no gender differences. In addition, there is little information on fat oxidation profiles in obese girls compared to non-obese girls. Studies have shown that pre- or early-pubertal girls do not have differences in fat oxidation rate between obese and non-obese girls, however in pubertal girls, excess weight resulted in higher fat oxidation rates when adjusted for fat free mass (25, 60). Obese girls appeared to oxidize more fat during exercise than non-obese girls to compensate for excess fat availability (25, 60). Further research is required to examine sex differences in fat oxidation rate during exercise in young athletes.

To our knowledge, there are no studies that have assessed CHO or fat oxidation in trained overweight children. However, a study in recreationally trained overweight and non-overweight men produced interesting findings (31), which may provide some insight for overweight young athletes. Trained overweight men (n=12) and trained non-overweight men (n=12), matched for cardiorespiratory fitness, did not have significant differences in maximal fat oxidation rates during exercise or FATmax. Maximal fat oxidation rate and FATmax were associated with VO_{2max}, but not percent body fat or BMI (31). These findings suggest that physical fitness is an important factor to consider when observing substrate metabolism profiles between individuals, possibly even more so than overweight or obesity status. Among overweight young athletes and non-overweight young athletes, it is likely that no differences in substrate oxidation at the same relative exercise intensity would be found if both groups had the same cardiorespiratory fitness.

Overweight athletes may not require different nutritional considerations compared with their non-overweight peers. However, the composition of diets before exercise, particularly exogenous CHO intake may change the percent contribution of endogenous fat and CHO to total energy expenditure during exercise (26, 122). The advantages and disadvantages of CHO-enriched sports drinks are discussed in more detail in the fluid intake and hydration section below.

Carbohydrate Recommendations

The RDA for CHO for adults and children is 130 g/day and is based on the average minimum amount of glucose used by the brain (56). The RDA values do not consider CHO necessary for glycogen replacement after exercise. Petrie et al. suggested that for young athletes at least 50% of total daily energy intake should be from CHO sources (91), which should consist of more complex CHO sources such as whole grains, and less simple CHO sources such as white bread or white rice (44). This falls within the Accepted Macronutrient Distribution Range (AMDR) for children, which is 45-65% of energy (56). For example, if an active male had a daily caloric intake of 2,043-3,263 kcal/day (56) and he consumed 50% of total daily energy from CHO, his average CHO intake would be 255-408 g/day. According to macronutrient intake values summarized from several studies in children, CHO consumption is about 200 g/day in non-overweight children, 300 g/day in adolescents and up to 500 g/day in young athletes (84, 91).

Unfortunately, we do not know for certain if the CHO recommendations listed above would sufficiently maintain muscle glycogen stores among overweight young athletes. Other factors to consider include the mode and intensity of exercise during a training session or sport competition. As the intensity of aerobic exercise increases, CHO utilization is increased (18, 72). Regular training at high intensities or for extended periods of aerobic exercise among young athletes could place a greater demand on endogenous CHO stores. It is thought that young children have a poorer glycolytic capacity compared to adults, which may be due to reduced enzymatic content or activity and glycogen storage in the muscle (98, 99, 122). To this end, the use of sports drinks and/or appropriate post-exercise nutrition may be favorable training aids to consider. These items are discussed in more detail below.

There remains a lack of empirical evidence to create distinct nutrition guidelines for overweight young athletes that would be different from non-overweight athletes. The study by Croci et al. (31) would suggest that different nutrition guidelines for CHO and fat intake are not necessary, assuming similar fitness levels and relative intensity of physical activity between overweight and non-overweight children. If the overweight child athlete was to use more CHO compared to fat than his or her non-overweight teammate, metabolic processes within the body have the capacity to replenish CHO stores via gluconeogenesis. In the presence of CHO availability, another assumption is that the capacity to match CHO utilization with availability is not impaired (ie. metabolic flexibility) in overweight children (2). With adequate caloric intake, flexibility of the system should allow for nutrient partitioning, although the timing of this is unclear. There is also insufficient knowledge about how and when children replenish their energy stores in recovery.

Dietary Fat Recommendations

The AMDR for total fat is 25-35% of energy for children ages 4-18 years (56). There is no adequate intake or RDA suggestions for total fat intake, because we do not have sufficient data to determine a level of fat intake that would be inadequate or prevent the development of metabolic diseases. However, essential fatty acids, including linoleic and linolenic acid, are important for proper growth and development (56). Among adolescent boys, the adequate intake for linoleic acid and linolenic acid are 16 g/day and 1.6 g/day, respectively. Among adolescent girls, the adequate intake levels suggested for linoleic acid is 11 g/day and for linolenic acid it is 1.1 g/day (56). Other types of fat such as cholesterol and trans fatty acids should be limited in the diet, and saturated fats should make up less than 10% (45). Common weight management strategies for overweight children include choosing more non-fat or low fat dairy products as sources of calcium and protein, such as skim or 1% milk and low fat yogurt (44).

During postprandial conditions, a greater availability of FFA in overweight children may be used as a preferred fuel source during exercise (25, 60). Despite greater fat utilization, general dietary fat recommendations should be followed as a potential method to reduce percent body fat if not within the healthy range. Additionally, research supports that exercise can help improve lipid profile in children. Acute exercise effectively reduced postprandial TAG concentrations on the following day in non-overweight boys and girls (120, 123). There is no evidence to indicate that adjusting dietary fat intake would be beneficial for young athletes and enhance sport performance in any way.

If optimizing fat oxidation during training is a goal for the overweight athlete, special attention may also be given to macronutrient profile over time. However, more research is required to adapt and translate available findings to children. Research in obese adults found that a low CHO, high fat diet over 8 weeks shifted fuel utilization towards greater fat oxidation during exercise, while the high CHO, low fat diet intervention did not (17). Although interesting, the low CHO diet (35% protein, 61% fat, 4% CHO) is outside of the AMDR ranges for both fat and CHO, and we would not recommend such extreme macronutrient composition changes to the diet of children. Another study involving obese adults reported that a low glycemic diet versus a high glycemic diet for 8 weeks also improved fat oxidation (114). This diet intervention should also be carefully reviewed and studied in children under safe conditions to determine its appropriateness. Future work with overweight children in this area is necessary.

Post-exercise Nutrition

Post-exercise nutrition is essential for replenishing nutrients, promoting recovery and optimizing exercise training benefits. It is well accepted that protein consumption in early recovery helps fuel muscle protein synthesis (20, 64, 93). Most of the research is in adults, but recent studies in children also showed improved whole body protein balance with post-exercise protein intake (80, 125). In non-overweight active children, whole body protein balance was measured during recovery and after three post-exercise beverages were provided (control, low protein (~0.18 g/kg body weight) and high protein (~0.32 g/kg body weight)). Whole body protein balance was positive for all conditions at 9 hours after exercise, while only the high protein beverage helped the young athlete maintain a positive whole body protein balance for 24 hours post-exercise (80). The protein source used in the study was skim milk, which is thought to maintain protein balance better than a CHO-enriched sports drink or water in non-overweight children (125). Therefore, the consumption of lean protein options (lower in saturated fats) is preferred. We do not suspect that the macronutrient composition of a post-exercise snack should be different between overweight and non-overweight young athletes.

After exercise, adequate fluids, electrolytes, and CHO are also important to replace muscle glycogen and ensure rapid recovery. CHO intake immediately after exercise is recommended because glycogen stores are replenished more efficiently during the first hour after exercise (23). Refueling snacks that contain small amounts of protein also help facilitate muscle glycogen storage (23). The Joint Position Statement by the American Dietetic Association, Dieticians of Canada and the American College of Sports Medicine suggests CHO intake of approximately 1.0-1.5 g/kg body weight in the first 30 min of recovery and again every 2 hours for 4-6 hours (107). How applicable these recommendations are for children has not been well addressed by research. This may be good target for some children, as the recommendation matches with data showing total CHO oxidation in children to be about 1.0-1.5 g per kg of body weight per hour during heavy exercise (100). Among adults, research indicates that high glycemic CHO sources were better than low glycemic CHO sources for increasing muscle glycogen levels at 24 hours post-exercise (22). However, post-exercise CHO should be considered along with the overall diet, as isocaloric CHO versus CHO plus protein and fat resulted in similar glycogen synthesis rates in adults (21, 107, 110). Given that overweight children may have weight management goals and should avoid over consumption of nutrient-poor calories, we recommend a nutrient-dense snack instead of simple sugars. Whole grains and fruits and vegetables are good sources of CHO and other important nutrients such as vitamins, minerals and dietary fibre (76). Other than non-fat or 1% milk or yogurt, other post-exercise options for the early recovery period could include nutrient-dense foods such as a whole-wheat peanut butter sandwich, fruit and vegetables, or assorted nuts.

Micronutrient Recommendations

Iron

Iron is an important micronutrient to monitor for young athletes, especially during growth and development. It is a critical component of hemoglobin that aids in the transportation of oxygen and carbon dioxide in the blood. Other roles of iron include extracting oxygen from hemoglobin in muscle tissue and acting as an antioxidant (106). Iron is stored as ferritin and is circulated as transferrin. It is rare for athletes to develop anemia, but reduced serum ferritin levels is common in young athletes in various sport disciplines (29, 86). Iron stores are influenced by dietary intake, iron loss and absorption. Adequate protein intake enhances iron absorption, while diets high in CHO and fats could inhibit iron absorption (91). Iron stores can also be affected by changes in muscle mass and nutrition, as well as menstruation in females (109).

Iron deficiency can impair muscle metabolism through hindered oxygen transport to skeletal muscle and affect cognitive function (19, 51). Female athletes are more likely to have iron deficiency (86), but sport involvement and training can lead to greater iron losses in both young males and females (29, 34, 63, 87). Iron deficiency seems to be increased in overweight children based on data from the National Health and Nutrition Examination Survey III (1988-1994) (83). Iron deficiency increased as BMI increased, and was particularly common in overweight children ages 12-16 years (83). To the best of our knowledge, no one has assessed whether there is a greater prevalence of iron deficiency in overweight child or adult athletes. Screening for iron deficiency in overweight children may be something that requires greater attention, especially if the children are involved with regular training.

In boys and girls ages 9-13 years, the RDA for iron is 8 mg/day. In boys and girls ages 14-18 years, the RDA is 11 mg/day and 15 mg/day, respectively (57). Caution should be taken when providing iron supplements to young athletes. Further discussion about iron supplementation may be found elsewhere (106). Potential risks of iron overload, when excess iron is stored in the organs of the body, include direct erosion and irritation of the gastrointestinal mucosa, damage of lipid membranes, proteins or DNA, inflammation or supporting the growth of pathogens (111). Although iron supplements may be beneficial if dietary intake of iron is poor, young athletes do not require more than the RDA. Additional iron does not appear to provide any performance benefits in young athletes (106, 124).

Calcium and Vitamin D

Calcium intake is critical for children and adolescents for obtaining an optimal peak bone mass. Vitamin D functions to enhance calcium absorption in the gut, maintain normal mineralization of calcium and phosphate in the bone and has a vital role in bone growth and bone remodeling (30). It is estimated that about 90% of bone mineral density is acquired by age 20, with a large proportion of bone mineral density occurring at the time of puberty (4, 46). Inadequate calcium and vitamin D intake and low bone mineral density may increase the risk of bone fractures and the development of osteoporosis later in life (48, 49, 95, 102).

Most adolescents, including both non-overweight and overweight children, are not meeting the recommended guidelines for calcium intake. In the U.S. from 1999-2004, only 30% population obtained the recommended amount of calcium in participants 2 years and older (88). Adequate calcium and vitamin D intake is particularly important in overweight children because of their increased risk for fractures (119), which may be explained by a lower bone mineral content for body weight (50). Goulding and colleagues (50) found that bone mass (total body mineral content and bone area) relative to body weight was reported to be 2.5-10.1% less than predicted values in overweight and obese children compared to non-overweight children. Increasing physical activity is a way to counteract the potential lower bone mineral content in overweight children and reduce the risk of fractures (4, 97). Improved strategies to encourage children and their parents to meet the recommended guidelines are crucial.

Calcium intake has major influences on calcium retention in adolescents. The RDAs for calcium and vitamin D for children ages 9-18 years are 1300 mg/day and 5 ug/day, respectively (57). Hill et al. (55). found that overweight and obese adolescents had greater calcium retention with increasing calcium intake compared to non-overweight adolescents, but found no effect of BMI on calcium retention at low calcium intakes. Future studies are needed to confirm if higher calcium intake leads to higher bone mineral accretion in overweight children compared with non-overweight children. To date, there are no studies that have examined calcium intake in overweight adults or child athletes compared to non-overweight athletes.

Fluid Intake and Hydration

Dehydration is likely to occur in young athletes during or after prolonged and intermittent exercise, especially when fluid loss through sweat is not matched by fluid intake. Fluid and electrolyte loss may vary between athletes, and is affected by temperature and humidity of the environment, as well as the duration and intensity of training sessions (40, 76). Children produce more metabolic heat per kg of body weight during exercise than adults (7), which is attributed to a greater surface area to body weight ratio in children versus adults (27). Greater heat stress is more likely to occur in children because they absorb heat from the environment more readily and have a lower sweating capacity than adults (7, 27, 41). With dehydration, core temperature rises faster in children compared to adults (8).

Voluntary dehydration, defined as inadequate fluid intake even when fluid is offered *ad libitum* during exercise, commonly occurs in children (8). Since young athletes tend to start training sessions hypohydrated, particular attention should be given to hydration status at the start of exercise, during and after training (76). Based on recommendations published by the Institute of Medicine, water consumption in boys and girls ages 9-13 years should be 2.4 L/day (~8 cups) and 2.1 L/day (~7 cups), respectively, whereas boys and girls ages 14-18 years should have 3.3 L/day (~11 cups) and 2.3 L/day (~8 cups) (58). A summary of sweat rates in young athletes reported that exercise increased fluid requirements above baseline by 0.5-1.0 L/day (91). Among overweight children, thermoregulatory responses and sweating volume are presumed to be similar to non-overweight children (69, 112). Therefore, we believe hydration recommendations should be similar for overweight and non-overweight athletes.

Water is usually the best option for hydration for young athletes (28). Sports drinks are popular among adult athletes; however, their reputation for sport performance of young athletes is controversial. Due to marketing schemes that emphasize optimal athletic performance and the need to replenish fluid loss and electrolytes, sports drinks are often consumed by children when they are commonly unnecessary (28). Careful consideration is required to assess the pros and cons of sports drink consumption for each individual, especially overweight young athletes. Although a CHO-enriched drink (glucose + fructose) ingested before exercise prolonged time to exhaustion (~40%) compared to the water and glucose alone trials, it resulted in the sparing of endogenous fuels in non-overweight children (101). With sports drink consumption, boys compared to men also preferentially utilize more exogenous CHO than endogenous CHO during cycling exercise (122). Among obese boys, CHO ingestion before 60 min of exercise decreased endogenous fat utilization by over 50% (25). As a result, for overweight young athletes trying to maintain or reduce weight, sports drinks would increase caloric intake and lead to poorer endogenous fuel metabolism.

On the contrary, sports drinks can provide several benefits when consumed appropriately, such as during prolonged exercise (>1.5-2 hours) or on training or tournament days that include frequent bouts of high intensity exercise with short recovery periods (78). Dougherty et al. (32) also reported improved performance of basketball skills in young boys with a 6% CHO drink with electrolytes compared to a placebo drink. In general, sports drinks consist of 6-8% CHO with mainly glucose, sucrose or fructose and the electrolytes sodium, potassium and magnesium. Benefits of this drink composition include improving hydration and fluid absorption, maintaining blood glucose and replenishing electrolytes lost through sweating (28, 78). The flavouring of sports drink with sodium and chloride encourages fluid intake in children and helps prevent dehydration (129). Additionally, sports drinks are beneficial because greater sodium and chloride concentrations in the sweat of children compared to adults (77) could increase the risk of hyponatremia, particularly when combined with sweating rates and excessive sodium-free fluid consumption (78). Unfortunately, very little is known about hyponatremia and electrolytes lost during exercise in children. Generally, water should be promoted as the primary source of hydration but can be combined with sports drink ingestion if rapid replenishment of CHO, fluids, and electrolytes are required. The main caveat for overweight young athletes is the excess caloric intake, which may be insignificant if weight management goals are still achieved.

Potential Barriers to Sport Participation

The reality for many youth is that excess adiposity creates stigmatisms that can have negative psychosocial consequences. Some of these psychosocial consequences include weight bias and body image disturbance, which have been linked to low self-esteem and depression (53, 96, 121). Overweight children may be at a greater risk for low self-esteem (121). The link between obesity and low self-esteem is likely due to social factors related to weight status such as teasing from peers and weight-related criticism by parents that affect self-esteem (53, 96). Weight stigmatization creates bias and social marginalization, which results in peers viewing overweight children as different and undesirable (104, 117). As a result of weight stigmatization and teasing, unhealthy weight control behaviours, such as dieting, fasting, binging and the use of laxatives and diuretics are more common in overweight adolescents than non-overweight adolescents (16, 85).

There is insufficient data to determine how psychosocial consequences of obesity directly affect sport participation in overweight children. We do not know if overweight athletes are as susceptible to low self-esteem and depression as non-active overweight children. For overweight children already involved with sports, there may be less social marginalization. Strauss and Pollack (117) found that even though overweight children were more likely to be socially isolated than non-overweight children, decreased television time, increased levels of sport participation and increased participation in school clubs led to more friendship nominations (ie. less social marginalization) among overweight and non-overweight children. Given the many benefits of sport participation, we should continue to examine and discuss strategies that improve psychosocial and physical health in overweight young athletes.

Summary

Due to a high prevalence of childhood obesity, a greater number of young athletes may be overweight. Certain sports may actually select overweight children based on their large size. Pediatric obesity treatments and weight management programs advocate better healthy eating habits and increased physical activity. For overweight children, sport participation is a great outlet and environment for increasing energy expenditure, especially if their body weight does not lead to a disadvantage compared to other children. Appropriate nutritional guidelines are critical for optimal growth and health, as well as training and performance. Yet, there remains a paucity of research concerning nutrition for overweight young athletes. To attain adequate energy sources for growth and maturation while participating in regular training sessions can be challenging for children, but even more so if there are additional energy restrictions to meet weight loss goals. Weight management may result in a hypocaloric diet and/or a negative nitrogen balance in overweight young athletes. Currently, there is limited research to determine if more or less protein and CHO should be recommended in overweight young athletes compared to non-overweight young athletes. Fat intake, micronutrients, post-exercise nutrition and hydration are also important areas to consider. In addition, overweight children may experience psychosocial barriers that could contribute to unhealthy eating behaviours. The identification and acknowledgement of gaps in knowledge and challenges will help develop recommendations for overweight youth that desire to train and compete in sport. Opening discussions about nutrition for the overweight athlete will hopefully result in future research and solutions that will encourage more sport participation, eliminate barriers, and optimize health and athletic performance for these children.

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Table 1 - Estimated Energy Requirements for Boys and Girls Ages 9-18 Years of Age

	Age (years)	**Estimate Energy Requirements (kcal/day)**			
		Sedentary PAL	**Low Active PAL**	**Active PAL**	**Very Active PAL**
Boys	9-13	1530 – 1935	1787 - 2276	2043 - 2618	2359 – 3038
	14-18	2090 - 2383	2459 - 2823	2829 - 3013	3283 - 3804
Girls	9-13	1415 - 1684	1660 - 1992	1890 - 2281	2273 - 2762
	14-18	1690 - 1731	2024 – 2059	2334 - 2368	2831 - 2883

PAL, physical activity level.

*Adapted from Institute of Medicine Dietary Reference Intake macronutrients report (56).