Body Composition in Children

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Assessment of Body Composition
in Children in 1989 (25 Years Ago)

In his 1989 article “Body Composition in Children,” Lohman wrote about the progress made during the 1980s in assessing body composition and the relation of body composition to health. He wrote, “The assessment of body composition in children has taken on greater significance because of the need to study the prevalence of obesity in children and youth, the need to better document the tracking and genetics of body fatness, the need to relate fat patterning in childhood and fat patterning in adults, and the need to assess changes in the prevalence of obesity over time in a given population” (69). In the present article, we revisit these issues, review progress over the past 25 years and suggest where research needs to go in the years ahead.

A number of body composition studies in children before 1989 showed that Body Mass Index (BMI) had a larger error than skinfold thicknesses when predicting percent body fat (54,86). Studies since that time have elucidated the reasons why BMI is limited for estimating fatness, showing that variation in maturity, muscle mass, water content, bone mass and leg length all confound the relation of fatness to the ratio of weight-to-height squared, and contribute to the large prediction error (SE ± 5–7% fat) when estimating % fat for a given individual. Although skinfold thicknesses gave more accurate estimates of percent fat than BMI, often its errors were larger than desirable. We now know errors were inflated by the use of adult models to convert body density to percent fat which were unsuitable for children. Recognizing the problem, Lohman and colleagues developed a four-component approach to estimate body composition in children and adolescents using hydrostatic weighing, total body water by deuterium dilution, and body mineral content from forearm photon absorptiometry. That research showed that body density in children was significantly affected by variation in the water and mineral content of the fat-free body, especially in prepubescent children (67). Earlier work by Foman et al., (31) had shown similar developmental changes in the composition of fat-free body in children from birth to 10 years of age.

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Using the four component model to adjust body density for age- and maturation-related variation in fat-free mass (FFM) components (i.e., body water, protein and mineral) it was possible to develop more valid and more accurate equations for estimating composition from skinfold thicknesses. The skinfold equations developed to estimate body density and percent fat, using the four-compartment model as the criterion method, are still used today. Other field methods including anthropometry and Bioelectrical Impedance Analysis (BIA) were reviewed in the 1989 article, with the aim of discussing their utility for estimating body fatness in children. Among laboratory methods, the four-compartment model was the best, and since that time it has become the reference method of body composition assessment in children.

A landmark publication of body composition research in youth as well as adults was published in 1985 (2). Twenty-four experts from several disciplines all contributed to new approaches and applications for body composition assessment (2).

Before 1989 the 85th and 95th percentiles for triceps skinfold thickness were often used to define overweight and obesity. At that time many investigators were reluctant to use body fat from skinfold equations as an index of obesity because the relationship between skinfolds and total body fat was influenced by age, physical maturation and race, and the relationship between skinfolds and percent body fat was not yet well established in children. With the development of more valid models in children, the skinfold method became better accepted. Using this approach, Lohman estimated the prevalence of obesity in the U.S. population in children and adults using the NHANES 1978 national probability data (75) based on the triceps and subscapular skinfold thickness (69). Around this time more research was initiated showing the relationships between chronic disease risk factors and body composition in children.

For example, Jack Wilmore (107) was one of the first investigators to show the prevalence of cardiovascular disease (CVD) risk factors increased with fatness in 8- to 12-year-olds. In addition, in the Bogalusa Heart Study, a landmark study of the natural history of heart disease in children, skinfolds thicknesses were used to show directly that increases in blood lipids and blood pressure were associated with increases in fatness (33,94,102). Results from the Bogalusa Study and other studies led to work in the 1990s to define obesity in children in terms of body fatness (25% for boys and 32% for girls) based on CVD risk factors. Based on this early research, the notion of health-related physical fitness was further developed to include estimates of body fatness. Other work in body composition assessment and disease risk showed the importance of fat distribution and the additional risk associated with truncal fat for chronic disease in children. The subscapular skinfold site was identified as an important site for risk assessment (13).

The secular increase in body fatness in children was identified by several researchers using skinfolds during the 1980s and concern for the health of U.S. children grew (44,88,89). Research from longitudinal growth studies showing tracking of body fatness over time made tracking an important area of study for understanding genetic contribution to individual profiles of health from children to adulthood (35,39,45) and added to the concern over the emerging pediatric obesity epidemic.
Body Composition Assessment

A major focus of work in body composition assessment research over the past 25 years was the development of new methods for assessing fat, muscle, and bone as well as continuing to improve field methods. Wider application of new methods, such as dual energy x-ray absorptiometry (DXA), led to establishment of national body composition norms for 8–18 year olds based on DXA. In addition, revision of height and weight growth curves using data from NHANES (NHANES, 1976–1980) collected before the current obesity epidemic led to establishment of BMI-based definitions of overweight and obesity and further evaluation of BMI as a body composition field method.

**Multicomponent Models.** The use of multicomponent (MC) models as a reference method in children and adolescents is limited to a few studies since 1990. In adults MC models have been established as reference methods for body fat content with an accuracy of 1–2% (6). While the reliability of the four-component approach is well established in adults (37,108) few reliability studies have been carried out in children. One exception is the work of Butte et al. (14), who developed a MC model for estimating body composition in infants and young children up to 2 years of age.

**Densitometry.** With the development of reliable estimates of body density from air displacement plethysmography (ADP), a new laboratory method is now widely available for use in children that does not require submersion in water. An excellent review of the comparison of ADP and underwater weighing is given by Fields et al. (28). Individual variation in the components and density of fat-free body mass is a major limitation of both methods, as well as potential errors arising from assumptions related to thoracic gas volume, residual volume, intestinal gas, test conditions, subject size, body temperature, and age. All are discussed by Fields et al. (28). Use of a MC model to estimate composition from density is essential with both ADP and underwater weighing to obtain valid and accurate estimates of body fat and fat-free mass.

**Dual-Energy X-Ray Absorptiometry.** DXA is now well established as a low-dose radiation laboratory method for estimating body composition in children. One of the key validation studies was carried out by Sopher et al. in a large sample of children and adolescents (97) using an MC criterion method. The prediction error between DXA %fat and MC %fat was 3.7% and the mean difference between methods was 1%. At higher % fat values (>30% fat) DXA overestimated fatness and at lower % fat (<15%) DXA underestimated fatness. The reproducibility of DXA in children over 5 weeks has been estimated by Figueroa-Colon et al. (29), who showed that DXA estimates of fat and lean were highly reproducible. Additional validation studies have been completed by Roemmich et al. and Wang et al. (87,109). While DXA provides valid measures of lean, bone mineral and fat, it is not yet accurate enough to be used as a reference method in children (6).

**DXA-Based Percent Fat National Norms.** A smoothed reference distribution of percent body fat for U.S. children and adolescents aged 8- to 18 years was
developed by Ogden et al. (80), based on NHANES 1999–2004 data representing 4,520 boys and 4,344 girls. This work represents a milestone in the application of body composition assessment methods to the U.S. population of children and youth. A detailed report of the DXA results is published and the work of Kelly et al. (57) provides further details on these reference norms for body composition. For most ages half of U.S. boys are over 25% fat and half of girls are over 32% fat (Figures 1 and 2). Underlying the validity of DXA estimates of percent fat is the work done by Schoeller et al. (92) to correct for the underestimation of fat mass in the Hologic 4500A DXA.

**Skinfolds and Body Fatness.** Many skinfold equations using the two-component model have been developed in children over the past 40 years. Because many of these equations are based on body density, they overestimate body fatness, especially in prepubescent children. In the 1990s several investigators tested triceps and subscapular skinfolds equations (96), derived from the four-compartment model (68), on other samples and populations of children (96). Ideally, to cross-validate these equations, the criterion method needs to be a reference method that is not dependent on 2 compartment model assumptions. The work of Roemmich (87) and Wong et al. (110) used a four-component model to cross validate several field method equations. Wong et al. (110) found the quadratic skinfold equation of Slaughter et al. (96) to be applicable to adolescent girls.

**Bioelectric Impedance Analysis (BIA) in Children (BIA).** BIA equations have been developed for children of various ages and ethnicities (51). In Lohman’s 1992 monograph “Advances in Body Composition Assessment” he showed comparable predicted errors (3.5–3.8%) in young adults across 6 laboratories where skinfolds and bioelectric impedance procedures were carefully standardized before the study was implemented. Thus, these two methods can be used with comparable prediction errors when a standardized protocol is followed. In children, body water as a fraction of FFM varies with age and maturation and BIA equations on specific populations need to be validated against a MC model with adjustments for the hydration of FFM. The BIA equations of Houtkooper et al. (53) and Boileau et al. (10) made important contributions to this area for children. An excellent review article on BIA and athletes (73) emphasizes the challenge of finding generalized equations that have been properly cross-validated.

**Body Mass Index (BMI) in Children.** Research on BMI as a measure of fatness in children has shown a large prediction error for the individual (5–7% SEE). Nevertheless, children are likely to be overweight if they are above the 95th percentile of BMI for their age (19,36,64,85). For children between the 85th and 95th percentile, BMI is less effective in identifying excess fatness. The use of BMI in the clinical setting is well described by Daniels et al. (18)

**Fat Distribution.** Four major fat depots have historically been defined—subcutaneous adipose tissue (SAT), intermuscular and intramuscular, and visceral adipose tissue (VAT). Of these four depots, only subcutaneous fat can be assessed using traditional anthropometric methods, i.e., skinfolds thicknesses. A variety of indices based on ratios of subcutaneous skinfold sites (e.g., triceps, subcapular) can be used to characterize body fat distribution and fat patterns, e.g., appendicular versus truncal fat patterns and lower body versus upper body fat distribution.
Although DXA does not specifically measure intra-abdominal fat, it does measure regional adipose tissue in the abdominal area (which is a composite of SAT and VAT), and DXA software provides estimates of android versus gynoid soft tissue composition. Imaging techniques such as CT and MRI are necessary to quantify the

Figure 1 — Selected percentiles of smoothed percentage body fat from DXA among boys aged 8–19 years: United States, 1999–2004 (80)

Figure 2 — Selected percentiles of smoothed percentage body fat from DXA among girls aged 8–19 years: United States, 1999–2004 (80)
remaining fat depots, and have made it possible to distinguish normal fat patterning from pathological, providing multiple cross-sectional images that can be used to reconstruct tissue volumes including total, subcutaneous, and visceral adipose tissue, as well as skeletal muscle, bone and organs (38 63,95). MRI and CT imaging can also be used to pinpoint the location of ectopic fat (fat stored in nonadipose depots) in and around organs and muscle (including perirenal, pericardiac, intrahepatic, and intramyocellular fat deposition), whose presence has emerged as a significant predictor of cardiometabolic risk in children (41). Using these methods, findings in adults of the strong associations between VAT, ectopic fat, and cardiometabolic risk have been extended to children and adolescents.

**pQCT Developments.** Peripheral Quantitative Computed Tomography (pQCT) is a lower radiation adaptation of traditional computed tomography that is increasingly accessible for studies in children and youth (58). In contrast to DXA, pQCT measures volumetric density (g/cm³) and not the area-projected mass in g/cm². Unlike DXA, because pQCT can determine size and density independently, it is not confounded by growth (83). pQCT has other advantages; with pQCT technology, cortical and trabecular bone can be analyzed separately, information about bone geometry is obtained, and bone strength with respect to bending, torsion and compression can be calculated from the bone’s cross-sectional geometry. Using the same principles underlying estimation of bone parameters, pQCT can provide measures of soft tissue area (e.g., muscle and subcutaneous adipose tissue) and composition (26). In children and youth, with pQCT one can determine whether bone growth is appropriately adapted to muscle growth (22,83). Recent research has shown muscle density, a surrogate for muscle fat content, is significantly related to bone strength in prepubertal girls (26). Higher levels of skeletal muscle fat content may impair bone development and contribute to lower bone strength and greater fracture risk, although more research on this hypothesis is certainly needed. Application of pQCT in studies of adaptations in the muscle-bone functional unit will undoubtedly increase.

**Body Composition and Health**

Over the past 25 years important advances have taken place relating body fatness to cardiovascular risk factors. Less progress has been made in the areas of sports medicine and eating disorders.

**Secular Trends in Children.** The secular increase in body fat that began in the 1980s continued in the 1990s and into the 2000s (30, 79). The most recent estimates of obesity prevalence (2009–2010 compared with 1999–2000) indicate significant increases in prevalence for males but not for females (78). The recent summary of body composition estimates using DXA for children and adolescents indicate that more than 50% of boys are above 25% fat and more than 50% of girls are above 30% fat at most ages (Figures 1 and 2).

**Risk Factors and Body Composition.** Despite the widespread appreciation for the role of obesity in metabolic disease risk, accepted body composition standards for children and youth have been lacking. Historically, child and adolescent overweight and obesity have been defined by age- and gender-specific percentiles of BMI (59). Although convenient and cost-effective for large-scale screening, BMI is a surrogate
for body composition, moderately correlated at best with more direct estimates of body fat, and susceptible to misclassification in individuals with greater than average fat-free mass for height. Recognition of the limitations of BMI coupled with greater emphasis on development of health-related fitness standards, led to development of body fat standards based on risk for high levels of metabolic disease risk factors. An early analysis, using data from the Bogalusa Heart Study, showed increased risk (on average) for high levels of biomarkers (e.g., blood pressure, lipids, and lipoproteins) in boys above 25% fat and girls above 30% fat (106). In contrast, Freedman et al. (34) related skinfold percentiles and BMI percentiles to CVD risk factors and showed the higher degree of risk for boys and girls over the 95% percentile for both approaches. Their work has also shown a similar degree of association between high levels of BMI and of skinfold percentiles to CVD risk factors, even though BMI predicts body fatness less well than skinfolds (34). These standards were incorporated in the Fitnessgram Health-Related Fitness Test (105) and have been used across the nation in schools wherever Fitnessgram has been used.

The Fitnessgram Body Composition Standards were recently revised. Past standards were viewed as “static”, since they applied a constant cut-off to all ages and were not consistent with body fat growth curves. In the recent analysis, body fat standards were developed using data from the NHANES surveys, a population-based survey of the United States. Several analyses were done, which showed the relationships between body fat and cardiometabolic disease risk factors (42), described gender-specific body fat growth curves (60), and developed body fat standards against health-related criteria (62). A novel feature, relevant to today’s public health challenges, was the use of Receiver Operating Characteristic (ROC) analysis to examine presence of metabolic syndrome across levels of body fatness to develop the standards. The ROC analysis quantifies the sensitivity and specificity of various cut points for detecting the outcome of interest. In the final analyses, the new percent fat standards were linked (using ROC analysis) to BMI levels to define BMI cutoffs that would categorize youth into the same risk categories as percent fat (61). Thus, rather than a somewhat arbitrary percentile (or norm)-based definition of risk, the new BMI cut points are linked back to percent fat and disease risk. Future work is needed to validate these standards in other large U.S. samples and other populations. Nevertheless, they will likely see widespread use in schools at least since Fitnessgram has recently been adopted as the National Youth Fitness Test promoted by the President’s Council on Youth Fitness and Sports for use in all schools in the United States.

In their review chapter, Sardinha and Teixeira (90) cite several articles that indicate truncal fat in children is more predictive of CVD risk factors than limb fat and that waist circumference is an additional predictor. They also show that the effect of fat distribution on CVD risk factors varies with the risk factor being examined.

**Central Adiposity.** Upper body or central adiposity is a risk factor for poor health in children, independent of total adiposity (70). Adverse health effects associated with central adiposity are likely related to the accumulation of VAT in and around organs. (16). Waist circumference (WC), a noninvasive and easily implemented anthropometric measure, is used as a surrogate for intra-abdominal visceral adipose tissue (91, 99). Research has documented relationships between high WC and increased risk of hypertension, diabetes, dyslipidemia, and metabolic syndrome in both adults and children (55). While WC represents different ratios (and volumes)
of adipose tissue, the measure cannot be used to discriminate among fat depots (e.g., proportion of VAT versus SAT). Despite this obvious limitation, studies using imaging methods that are able to distinguish abdominal VAT from SAT (e.g., MRI, CT) have confirmed WC as a strong predictor of VAT in children (81).

Establishing Minimum Weight in Athletes. One of the success stories in the use of body composition assessment methods is their application to estimate minimum weight in children (5–7% fat in boys and 12–14% fat in girls is the consensus of body composition experts), so that athletes can be protected from competing at unhealthy weights, especially during growth and development. The development of the skinfold approach in high school wrestlers is well described by Lohman in his monograph (66). The work published by Thorland et al. (100) is now widely used to estimate minimum weight in high school wrestlers throughout the United States.

Eating Disorders. In clinical settings, body weight is often used as a proxy for body fat and somatic protein stores and is compared against clinical parameters to determine risk of morbidity and mortality. Absolute weight reduction to less than 55–60% of ideal body weight (IBW) places an individual at the limits of starvation (40), while the minimum survivable body weight in humans is placed between 48% and 55% of IBW (a BMI of approximately 13 kg/m²). In children and adolescents, differential changes in body composition due to growth confound interpretation of BMI, and prevents application of the parameters for malnutrition and minimum weight established for adults. Consequently, BMI-for-age percentiles, (3) which provide tools for clinicians to compare growth of the child against the reference population and make inferences about nutritional status (59) including screening for malnutrition and identifying eating disorders, are used for children and youth of both sexes (ED). In addition to anthropometric data and BMI calculations, the presence of ED may be confirmed by additional clinical markers, including amenorrhea in postpubertal females, and an intense fear of gaining weight and/or denial of seriousness of weight loss (in both sexes). Criteria for ED diagnosis have been established (1) and tools to confirm the presence of ED are available (74). Groups at particularly high risk of developing eating disorders include athletes and performers who participate in sports and activities that reward a lean body habitus (e.g., gymnastics, running, wrestling, dance, modeling).

Training Studies. Concern that caloric restriction may contribute to nutrient deficiency and impaired growth has stimulated interest in promoting energy expenditure through increased physical activity for achieving and maintaining optimal weight for height and body composition in children and youth. Structured activity of an appropriate mode (i.e., resistance exercise) can increase fat-free mass, including its muscle and bone fractions, with important consequences for energy balance, since FFM is the main determinant of resting metabolic rate. Exercise training can also influence substrate utilization, consequently playing a role in how ingested nutrients are partitioned into fat and FFM. In children and youth, like adults, the average effect of exercise on fat and fat-free mass is modest and interindividual variation is substantial (48). Certainly, genetics play an important role. Unfortunately our ability to predict responders and nonresponders remains limited and this is an important area for future research. The results from a series of studies from Gutin and colleagues have shown exercise training without dietary restriction contribute to improvements in cardiometabolic biomarkers in youth.
(49), including insulin sensitivity, lipid profile, indices of inflammation, endothelial function, cardiac parasympathetic activity, and carotid intima-media thickness. The results of physical activity interventions on body composition and biomarkers are strongest in obese youth and for some biomarkers, including changes in fasting insulin and triglyceride levels (56). Although moderate intensity physical activity is commonly the target of interventions based on the rationale that youth are more likely to engage in lesser intensity activity, some evidence indicates that vigorous physical activity may be more beneficial for prevention of excess adiposity and for promoting a favorable biomarker profile (49), which is consistent with studies showing that vigorous PA is significantly associated with lower levels of fatness and higher levels of fitness compared with moderate PA. In the general population, higher doses may be needed (49). Gutin and Owens (49) speculate that doses greater than 300 min per week of controlled MVPA may be needed to prevent accretion of general and visceral fat, and also to influence cardiometabolic biomarkers (7).

**Physical Activity and Body Composition.** Physical activity (PA) is inversely correlated with body weight and body fat and positively correlated with FFM in children and youth (77); while the absolute magnitude of these associations are low, these relationships are significant. Prospective studies have demonstrated a significant and inverse relationship between habitual physical activity and weight gain in children (9). This association has been observed even in very young children (preschool age), where low levels of physical activity (as estimated from doubly labeled water) were associated with higher body fat content (20). In addition, a growing body of evidence has linked low physical activity and high body fatness in children and adolescents with risk of metabolic syndrome, placing these individuals at increased risk of early-onset Type 2 diabetes and cardiovascular disease (104). While few population studies have focused on these relationships in children and adolescents, limited cross-sectional data suggest metabolic syndrome prevalence is more common in adolescents with low PA levels (compared with moderate or high; 82). Children’s physical fitness (a physiological trait defined in terms of cardiorespiratory capacity which is moderately correlated with physical activity) modifies the influence of fatness on metabolic risk, where high fitness/low fatness children have decreased metabolic risk compared with children who have low fitness/high fatness (23). Exercise interventions show modest adaptations in body composition such as reductions in VAT (21) even without changes in BMI, and improvement in markers of metabolic syndrome (8,12,17,27,71,76,93,101). Based on these and other data that also support an inverse relationship between PA and metabolic syndrome in youth, experts have recommended PA as a therapeutic prevention tool (12).

**Weight Loss Interventions and Long Term Body Composition Effects.** An extensive review of lifestyle programs on children obesity over the past 30 years shows short-term benefits in both weight loss and CVD risk factors (52). However, very few studies, with the exception of Epstein et al. (25), have studied the long-term effectiveness so critical to the prevention of adult obesity. In the past 15 years (1993–2007) two large obesity prevention trials (15,46) and one large physical activity trial (103) were carried out in children and adolescents. In each trial statistically significant changes in physical activity or BMI were accomplished,
however in all three studies, the changes were modest and there was no follow-up on any of the cohorts to assess whether the changes were sustained. Body composition was assessed using skinfold thicknesses or BIA in two of the three trials. In the Pathways study (3rd to 5th grades) skinfold thicknesses were found to be a more reliable measure of change than BIA (65). In the study by Group et al. only BMI was used as an indicator of the change in body composition (46).

**Tracking.** The predictive value of overweight in childhood for overweight in adulthood is an important area to continue to investigate. In one of the key studies related to tracking Guo and Chumlea (47) found the predictive value of child BMI for overweight at 35 years increased from childhood to early adolescence and from early adolescence to later adolescence. For 18-year-olds with BMI above the 60th percentile there was a 34% chance for men and 37% for women of being overweight at 35 years. Additional work by Freedman and Sherry (36) show even greater tracking for BMI at the 95th percentile in children.

**What Does the Future Hold? New Directions**

**Multicomponent Models and Cross-Validation of Body Fat Equations**

Future work using MC models as a reference method (rather than DXA or ADP) is essential to developing improved skinfold and BIA equations. Leading candidates for valid skinfold equations in the general population (96) and in the athletic population for minimal weight (100) need further cross-validation in both male and female athletic groups. The development of sport-specific equations for minimum weight in various athletic groups especially in Olympic competitors is greatly needed. Ultrasound as an objective way to estimate a minimum fat thickness may provide a standardized approach to safeguarding the health of adolescent as well as adult athletes (6).

**Improved Body Composition Training.** With the Arlie Conference on Standardization of Anthropometry (1987) and the publication of the Anthropometric Standardization Reference Manual, many body fat-anthropometric equations were published using standardized measurements (1988–2000). After 2000, many body composition equations were developed in children without standardized site description, as the Anthropometric Reference Manual was not published after 2000. At the same time, the International Society for the Advancement of Kinanthropometry redefined a set of standardized anthropometric dimensions (98) and developed a training program for certification in the use of anthropometry for growth and development, sports and health. Over the past 20 years, many practitioners have received training using this approach.

Although our field of body composition has standardized approaches to body composition assessment for several methods (5,50), there is no training program for certification in most of these protocols. Thus, many methods and formulas are being used at present for the assessment of body composition. A recent survey indicates that skinfold thicknesses, BIA, DXA, and body density are frequently used in the field to assess body composition (72). Future efforts are needed to develop a standardized training program for body composition.
Body Composition and Health

Risk Factors. In children and youth, like adults, cardiometabolic biomarkers that underlie cardiovascular disease and type 2 diabetes, such as insulin resistance, lipid profile, blood pressure, inflammation, left ventricular geometry, parasympathetic activity and endothelial function, tend to cluster (49). Currently, there is no agreed upon definition of metabolic syndrome in youth and consequently its prevalence is uncertain (32). Additional work is needed to develop accepted, standard criteria for screening for metabolic syndrome in the pediatric population and for understanding the effects of interventions.

One thing that is clear is the strong role of obesity in cardiometabolic risk. Visceral adiposity is a particularly strong correlate of metabolic syndrome and of many of its individual contributing biomarkers in adults (43). Little research has been done in children on so called ectopic fat depots which potentially contribute to metabolic dysregulation. In adults, muscle fatty infiltration contributes to risk of insulin resistance and other metabolic impairments (43,84). Some research has shown skeletal muscle fat content may impair bone development and lower bone strength in young girls (26). While it is clear VAT is associated with metabolic risk starting in childhood, there remains very limited information regarding its etiology or degree to which various combinations of exercise and diet can influence the progression during childhood. Future studies should continue to work on improving our understanding of these relationships, as well as determining the optimal dose of PA for the prevention and treatment of pediatric obesity.

The prevalence of Type 2 diabetes has increased in recent decades coinciding with the increased prevalence of obesity. During puberty, insulin resistance increases as a normal consequence of development, returning to prepubertal levels near midto-late adolescence. Obesity compounds metabolic impairment and increases the risk that a child will not regain normal glucose metabolism. Future work in designing long term interventions for prevention of Type 2 diabetes in youth is essential.

An extensive report titled “Fitness Measures and Health Outcomes in Youth” (4) indicates that no national-level assessment of youth fitness over the past 20 years has been conducted. Several key recommendations were made, including, “A national survey of health-related physical fitness in youth should be carried out to include measures of cardiorespiratory endurance, body composition and musculoskeletal fitness.” Collection of risk factor data and linking measures of health-related fitness with metabolic dose as risk factors would be desirable.

Tracking and Genetics. Genetic influences on trainability, tracking, and lifestyle interventions designed to modify body composition in children and adolescents will be a key area of study in the coming decade. The excellent review article by Bouchard (11) highlights key findings from the HERITAGE Family Study related to the heritability of maximal oxygen uptake in response to 20 weeks of standardized exercise training. Large scale studies with weight loss and body composition changes using a design similar to HERITAGE need to be carried out. In addition, future tracking studies are needed of body fat and fat distribution to better identify those children who can most benefit from treatment before adulthood. The work of Eissa et al. (24) shows the importance of using fat-free mass index and fat mass index in addition to BMI in tracking studies.
Improved Methods for Estimating Minimum Weight and Hydration for Athletic and Eating Disorder Populations. Of great need in the field of sports medicine is the development of accurate and practical methods for estimating minimum weight in all sports and especially in Olympic athletes who are under increasing pressure to reach minimum fat levels that may risk both their short and long term health. One such method, the use of ultrasound to estimate fat thickness at several locations (6), may lead to a minimum level of fat thickness equivalent to a minimum level of body fat. For valid testing of body composition and minimum weight, it is important that the measurements are collected in the euhydrated state. Tests of dehydration from urine osmolarity, specific gravity and multifrequency BIA approaches need further development to improve their predictive value for estimating dehydration. A simplified, accurate test of dehydration has eluded investigators in sports medicine for the past 50 years. For the eating disorder population little is known of the body composition changes with short and long-term recovery. With the use of DXA, this area can be investigated and the results can be used to enhance the treatment programs, especially for improved muscle and bone mass.

References


