Off the Growth Curve: The Challenge of Childhood Obesity

Aaron L. Carrel, MD; David B. Allen, MD

ABSTRACT
Childhood obesity is an increasingly recognized problem. Health professionals caring for children and adolescents are in a key position to promote behavioral and environmental changes. Still, there is confusion regarding medical evaluation, communication with the family about the implications, and specific treatment goals. This review summarizes appropriate medical evaluation and common sequelae of childhood obesity, and presents a proactive multidisciplinary approach to evaluate and treat childhood obesity.

INTRODUCTION
Childhood obesity is a common occurrence; however, clinicians still fail to identify it as a serious health problem. Many health professionals characterize obesity as arising from lack of self-control, while in fact weight is regulated by a complex order of appetite regulation and energy metabolism controlled by specific hormones. This paper reviews recent concepts and data relating to childhood and adolescent obesity, makes recommendations for primary care professionals regarding treatment, and describes a multidisciplinary, comprehensive treatment approach. Although the evidence base is insufficient to provide specific guidelines for assessment and treatment of all aspects of childhood obesity, the following recommendations reflect critical reviews of the literature and are based on “expert committee guidelines.”

BACKGROUND
National Center for Health Statistics (NCHS) data indicates that nearly 1 in 5 children in the United States is overweight. Because it is difficult to obtain direct measures of body fat, and since body weight tends to be highly correlated with adiposity, weight-for-height measures are generally used to classify overweight children and adolescents. Classifications that have been used include weight-for-height percentiles, percent of ideal body weight, skinfold measurements, and body mass index (BMI). BMI is currently the most accepted and widely used measure to screen for obesity. BMI, expressed as body weight in kilograms divided by the square of height in meters (kg/m²), is a “weight-for-height index.” BMI criteria for adults have been based on mortality outcomes, but no risk-based criteria have been established for children. However, data demonstrates that childhood obesity is linked to continuing obesity into adulthood. Adult BMI criteria utilize a single cutoff value for both genders and all ages; however, in children and adolescents, age- and gender-specific reference curves are used because of differences in body composition for stages of growth and pubertal changes. The NCHS has revised smoothed gender- and age-specific BMI percentiles, based on data from the National Health Examination Survey (NHES) and National Health and Nutrition Examination Survey (NHANES). Clinicians have long been familiar with childhood growth curves and “percentiles” specific to gender and age. For clinical evaluation of childhood obesity, it has been suggested by “an expert panel” that an overweight child be defined as a BMI greater than the 95th percentile for age. Children with a BMI between the 85th and 95th percentiles are considered “at risk for becoming overweight.” Regardless of the method used to classify overweight children, studies have demonstrated high prevalence rates and consistently increasing trends since the 1960s.

Causes of Obesity
Weight gain occurs when energy intake exceeds energy utilization. Causes of obesity are multifactorial, resulting from environmental influences that create energy...
imbalance characterized by relatively sedentary lifestyles, ready access to an abundance of higher-caloric foods, and possibly genetic susceptibility. Research suggests that obesity may be clustered in families, and that some individuals are more vulnerable than others to weight gain and obesity. Genetic susceptibility has been proposed through several mechanisms, including low resting metabolic rate, lower level of lipid oxidation rate, and poor appetite control. Since research has not answered questions regarding how to affect these hormonal regulations in childhood, taking control over the behavioral aspects (food intake and daily activity) continues to be the most important variable in controlling childhood weight gain.

**Medical Assessment**

Medical assessment for childhood obesity should begin with careful review of the growth curves. An attempt is then made to identify underlying causes or secondary complications of weight gain.

Aside from overnutrition, identifiable exogenous causes of obesity are rare. Genetic syndromes associated with obesity, such as Prader-Willi, Bardet-Biedl, or Cohen syndromes, present with dysmorphic facial features, developmental delay, and sometimes retinal changes or deafness in addition to obesity. Children with genetic obesity may demonstrate poor linear growth in addition to developmental delay and dysmorphic facial features.

Endocrinologic causes of weight gain may include hypothyroidism, growth hormone deficiency, and Cushing’s syndrome. All of these conditions include poor linear growth, or even linear growth cessation as part of the clinical picture. A history of normal growth, or even linear growth acceleration would generally exclude these possibilities. Thus, a review of the childhood growth curve may be the most important tool to help rule out medical causes of weight gain. With no history of developmental delays, linear growth deceleration, or abnormal eating behaviors, most children with obesity can be assumed to have a caloric imbalance with greater consumption than utilization of calories.

Although obesity may not have an underlying endocrine or medical explanation, it may result in secondary complications. Obesity can cause complications in many organ systems, both independently and in association with other diseases. Specifically, obesity is associated with the development of Type 2 diabetes mellitus (T2DM), coronary heart disease, respiratory complications such as sleep apnea, hypertension, and some malignancies.

### Table 1. Medical Conditions Associated with Childhood Obesity*

<table>
<thead>
<tr>
<th>Medical Findings</th>
<th>Potential Conditions</th>
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<tbody>
<tr>
<td>Developmental delay</td>
<td>Genetic obesity</td>
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<tr>
<td>Poor linear growth</td>
<td>Hypothyroidism, Cushing's syndrome</td>
</tr>
<tr>
<td>Headaches</td>
<td>Pseudotumor cerebri</td>
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<tr>
<td>Snoring, daytime somnolence</td>
<td>Sleep apnea</td>
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<tr>
<td>Hip or knee pain</td>
<td>Slipped capital femoral epiphysis</td>
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<tr>
<td>Oligomenorrhea</td>
<td>Polycystic ovarian syndrome</td>
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<tr>
<td>Acanthosis Nigricans</td>
<td>Insulin Resistance, Type 2 diabetes</td>
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<tr>
<td>Hirsutism</td>
<td>Polycystic ovaries, Cushing’s syndrome</td>
</tr>
<tr>
<td>Blurred optic disks</td>
<td>Pseudotumor cerebri</td>
</tr>
<tr>
<td>Abdominal pain/tenderness</td>
<td>Gallbladder disease</td>
</tr>
<tr>
<td>Limited hip range of motion</td>
<td>Slipped capital femoral epiphysis</td>
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*Adapted from Barlow and Dietz

### COMMON MEDICAL CONSEQUENCES OF CHILDHOOD OBESITY

**Growth**

Overweight children tend to demonstrate linear growth acceleration, have advanced bone ages, and have altered timing of puberty (girls tend to develop earlier and boys tend to show delayed puberty). Longitudinal studies of children who became overweight demonstrate that height gain accelerates after excessive weight gain. Growth hormone (GH) and insulin-like growth factor-1 (IGF-1) work in tandem to coordinate linear growth during childhood and early adolescence. Although obese children tend to demonstrate lower levels of GH, levels of free IGF-1 are significantly elevated, which may partially explain the normal to increased linear growth and their tendency to hyperinsulinemia.

**Glucose Intolerance**

Recent studies illustrate the marked increase in glucose intolerance, insulin resistance, and overt T2DM in the general population. The direct relationship of increasing BMI with impairment of glucose tolerance has also been demonstrated. Further, recent observation demonstrates that T2DM accounts for one third of new cases of diabetes in children in the Cincinnati area; the incidence of T2DM among adolescents in the Cincinnati area has increased 10-fold since 1982. The mechanism by which obesity causes T2DM in adolescents may be similar to that observed in adults. Visceral fat correlates directly with basal insulin secretion,
stimulated insulin secretion, and insulin resistance.\textsuperscript{13} Studies have also demonstrated that a high body mass index (BMI) in childhood is closely correlated with insulin resistance.\textsuperscript{14}

\textbf{Acanthosis Nigricans}

Acanthosis nigricans (AN) is characterized by a dark, rough appearance to the skin, commonly located on the back of the neck and axillae. This lesion is characterized histologically by papillomatosis and hyperkeratosis and is associated with hyperinsulinemia.\textsuperscript{15} Exercise improves insulin sensitivity, and over time may lead to a diminished quality of the AN in many individuals.

\textbf{Ovarian Function}

Obesity impacts reproductive function early in life. Obese girls have an earlier onset of puberty (ovarian activation), and an increased risk of hyperandrogenism and anovulatory cycles. Polycystic ovarian syndrome (PCOS) is characterized by elevated androgen production, anovulatory cycles, and insulin resistance. Polycystic ovaries are only 1 possible feature of this syndrome, and need not be present. Oligomenorrhea (menstrual cycles longer than 35-40 days) identifies women at high-risk of PCOS, as well as impaired glucose tolerance, T2DM, cardiovascular disease, and hypertension. Recent investigations have demonstrated that the prevalence of functional ovarian hyperandrogenism, hyperinsulinism, and dyslipidemia is increased in adolescent girls with a history of premature adrenarche.\textsuperscript{16} Hyperinsulinism and dyslipidemia may be detectable before and during pubertal development. In some girls, various combinations of these conditions have been related to reduced fetal growth, indicating that these constellations or sequences may have a prenatal origin.

\textbf{Cardiovascular Disease}

Approximately 20\% of obese children between age 5-11 years have elevated systolic or diastolic blood pressure.\textsuperscript{17} In fact, obese adolescents account for almost 40\% of cases of juvenile hypertension. The Bogalusa Heart Study revealed that high blood pressure is 8.5-fold more likely in obese adolescents as young adults than in non-obese adolescents.\textsuperscript{6} Obesity is felt to contribute toward hypertension by causing hyperinsulinemia, activation of the sympathetic nervous system, and activation of the renin-angiotensin system, which result in enhanced renal absorption of sodium and decreased natriuresis. Further, adolescent obesity, particularly in boys, is associated with deleterious effects on total cholesterol. Tershakovec et al report the evaluations of some important risk factors for cardiovascular disease (CVD) in this cohort. The relationships between adiposity and cholesterol level, and adiposity and insulin levels were independent of each other, suggesting an increased risk of CVD.\textsuperscript{18} A 40-year follow-up of overweight children reveals double the rate of cardiovascular disease and hypertension, and triple the rate of diabetes compared to non-obese children.\textsuperscript{19}

\textbf{Respiratory Disease}

Obese children carry a risk for restrictive airway disease caused by the difficulty in respiration from the increased mass of adipose tissue, increased inflammatory component, as well as obstructive disease caused by fatty deposition along the airway added to the tonsillar and adenoidal hypertrophy that is common at a young age. Obstructive sleep apnea, with carbon dioxide retention, hypoxia, and right ventricular hypertrophy, is a potential cause of morbidity and mortality. Symptoms may include snoring, enuresis, daytime somnolence, irritability, or poor school performance. Sleep disorders often are related to obesity in children. A study of 41 children with significant obesity revealed that one third reported symptoms consistent with sleep apnea, and one third had abnormal sleep studies.\textsuperscript{20}

\textbf{Addressing Physical Inactivity}

The Surgeon General’s Report recommends 30 minutes of moderate physical activity on most days of the week.\textsuperscript{21} Unfortunately, most American adults do not receive the health benefits of regular moderate physical activity. In fact, 85\% do not engage in moderate activity 5 or more days per week, and 40\% do not participate in any leisure time activity. Thus, childhood has been identified as a critical period for nurturing lifetime activity behavior, and school physical education a primary institution for promoting active lifestyles. Consequently, an attractive starting point for collaborative effort is the school setting, a commonly shared environment where both active and passive decisions regarding physical activity, food choices, and attendance can be reasonably controlled and programmatically altered. Successfully addressing this problem is challenging in both the health care and education environments: school personnel lack training, resources, and institutional support for intervention, while health care professionals generally report that office-based intervention strategies are inconsistent. Coordination of these environments offers the best chance to improve the general fitness of children and prevent and treat excessive weight gain during childhood.
Childhood obesity is now considered one of the most important nutritional issues in the United States, yet often our message is one of “weight” rather than an often-overlooked factor important to all children’s health: level of fitness.

What is the evidence that cardiovascular fitness has an independent role in health?—In adults, level of fitness more accurately predicts cardiovascular and all-cause mortality than weight status. Physical activity also improves insulin sensitivity, independent of changes in weight and body composition in adults. In children, physical activity not only improves insulin sensitivity, but also has beneficial effects on hormones that promote lean mass accretion. Thus, efforts to improve insulin sensitivity in children may be best focused on increasing physical activity rather than simply restricting calories for weight control.

Indisputable evidence links obesity to various health problems, and these associations are dose-related, temporally consistent, and biologically plausible, and the same can be shown for physical inactivity. However, the majority of studies examining obesity and health have not adequately measured or documented physical activity. Particularly in studies involving children, physical activity is often “measured” by questionnaire, or self-report, rather than by direct measurement of increased work performed or energy expended. Use of maximal exercise tests (max VO2) to quantify cardiovascular fitness is an objective measurement that is much stronger than self-reported physical activity as a predictor of many health outcomes. A growing number of studies have shown that obese individuals with at least moderate cardiovascular fitness have lower rates of all-cause mortality than their normal-weight but unfit peers.

Fitness as a treatment for obesity related metabolic changes—Obesity, insulin resistance, and hypertension (metabolic syndrome) is now found in 4.2%-8.4% of children and adolescents. Depending on the definition (WHO vs NCEP), the incidence of the metabolic syndrome in obese adolescents jumps to 17%-34.1%. The Aerobics Center Longitudinal Study demonstrated that cardiovascular fitness attenuates the effects of the metabolic syndrome on all-cause mortality and cardiovascular mortality in adults. These results also indicated that physical activity might be a valuable tool in the treatment of the metabolic syndrome and prevention of other health problems. Further, there is increasing evidence for the role of inflammation in the pathogenesis of insulin resistance, and the role of physical activity in reducing this inflammation is growing.

Lifestyle interventions, while challenging, can be successful. The Diabetes Prevention Program demonstrated a reduction in the incidence of diabetes in high-risk individuals with lifestyle intervention. For children it has been shown that additional exercise and healthy nutritional changes can be successfully promoted in varying environments. The most successful programs incorporate consistent dietary guidelines, reduced television viewing time, and increased physical activity into children’s daily routines, along with changes in the school environment. For example, the “Planet Health” school program successfully reduced BMI in grades 6-8. Whereas promoting increased physical activity centered at school can demonstrate positive changes, decreasing sedentary time such as television viewing has also demonstrated success at achieving relative decreases in BMI. In most of the school-based studies to date, endpoints included body weight, body fat or BMI. When obesity alone is the endpoint, however, other beneficial outcomes may be obscured: e.g. the Pathways project failed to reduce childhood obesity in Native American school children, but did succeed at improving dietary intake and increasing physical activity.

Obesity and fitness of Wisconsin school-aged children—The prevalence of overweight children in the United States has increased dramatically in the past 30 years. Nationwide, the prevalence of obesity has increased from 19% in 1977-1978 to 32% in 1994-1996. Weight gain is seen in younger ages, and in Wisconsin the prevalence of overweight children ages 2-5 years was 8% in 1998. In 1999, the Wisconsin Youth Risk Behavior Survey (YRBS) was administered to 1336 students in grades 9-12 throughout Wisconsin. The average self-reported female BMI was 22.2, and the average self-reported male BMI was 23.2; 14% had a BMI greater than 27, and 40% reported that they were actively trying to lose weight. During the past 2 decades, the requirement for and time allotted to physical education classes has decreased. In high school, enrollment in daily physical education classes dropped from 42% in 1991 to 25% in 1995. Modern lifestyles, including school agendas, contribute to less support for physical activity in our daily lives. Yet, it is important to encourage and facilitate healthy choices regarding physical activity and diet during the school-age years, because behavior patterns begin during these ages.

Schools play a critical role in promoting general fit-
ness. The Institute of Medicine recommends that schools conduct annual assessments of students’ weight, height and BMI and make that information available to parents.\textsuperscript{37} Limited data on this currently exists, other than the national YRBS, and the only data for younger children are from a survey of low-income children enrolled in federally funded programs such as WIC (Women Infants and Children).

**A MULTIDISCIPLINARY APPROACH**

A multidisciplinary “Pediatric Fitness Clinic” has been developed for children facing obesity, weight gain, or low levels of fitness. As dietary and activity behaviors are potentially modifiable, these are obvious targets for obesity prevention and treatment efforts. The Pediatric Fitness Clinic, initiated at the University of Wisconsin Children’s Hospital, combines the expertise of a pediatric endocrinologist, pediatric sports medicine physician, pediatric nutritionists, and exercise physiologists. The role of the clinic is that of medical evaluation, nutrition and body composition assessment, and nutritional and exercise intervention, as well as ongoing management. Increasing childhood fitness, rather than weight reduction per se, is a primary goal of the clinic.

Children are evaluated with at least 1 caregiver present, and a careful medical assessment is completed. The language and demeanor of clinicians is very important at this assessment. Because of the value our society places on appearance, and a common misconception that obesity results from laziness or lack of control, overweight children and their families may feel embarrassed, or ashamed. Clinicians caring for these children must use sensitivity and a conviction that obesity is an important and chronic condition that can be treated. Although this approach takes additional time, it can be powerful when attempting to modify behaviors. To be effective, the pediatrician must remain non-judgmental and avoid pervasive negative attitudes about obesity.

Our initial evaluation includes individual time with a nutritionist, exercise physiologist, and pediatrician. The evaluation takes place at a Sports Medicine facility, an environment that helps to encourage physical health rather than medical illness. We allow extended time for appointments, and the presence of other health professional disciplines addressing a viewpoint other than just “medical.” The success of our approach is based on the following principles:

- Treatment should include the entire family and occur when a readiness to make change is present.
- Dietary history and changes should be detailed and specific.
- A “hands-on” approach to increase physical activity should be used.
- Realistic goals should be set.
- Maintenance and ongoing support should be provided.

Treatment of childhood obesity involves the entire family. Parents play an essential role in purchasing and preparation of food, in addition to regulating the variety and quantity of food offered. Access to high-calorie snacks and eating out are family issues. Parents may provide encouragement or discouragement of physical activities, and provide transportation and access to physical activities. We emphasize the impact of the entire family sitting down and having a meal together.

Evaluations and ongoing monitoring focus on prescribed changes in nutrition and exercise, in addition to medical intervention. After an initial evaluation, children are encouraged to increase physical activity and are invited to participate in an after-school exercise class, which provides hands-on aerobic training by our exercise physiologists. Also, children are given individual exercise prescriptions they can perform at home. This model, which incorporates “simultaneous” efforts of the dietician, exercise physiologist, and physician, provides a positive environment in which to improve nutrition and exercise.

**Approaches to Promote Physical Activity in Your Community**

Recently, more information has arisen about the role that fitness can play as an intervention. The Bogalusa Heart Study has shown that childhood obesity is a powerful predictor of the insulin resistance later in life.\textsuperscript{38} One limitation of that study is that it did not consider the role of cardiovascular fitness. Because of the strong inverse correlation between fitness and fatness, it is possible that the deleterious consequences ascribed to obesity may be partially due to low fitness. If this is true, it would be logical that interventions toward childhood obesity should address and prevent low activity levels in addition to adiposity.

Diverse causes of childhood obesity arise from a pervasive “toxic” environment that collectively facilitates increased caloric intake and reduced physical activity. An effective strategy for prevention and treatment of childhood obesity, therefore, must be similarly pervasive, collaborative, and emblematic of a strong public health system. An attractive starting point for collaborative effort is the school setting, where both active and passive decisions regarding physical activity, food choices, and attendance can be reasonably controlled and programmatically altered. By changing the physical education environment to increased activity, and fo-
cusing on fitness for lifelong participation, rather than team-oriented activities, we have reported improvements in cardiovascular fitness, body fat, and insulin sensitivity. This school-based intervention highlights the success that medical systems and schools can achieve when coordinated efforts occur.

SUMMARY

- 15%-20% of children are obese.
- Many children do not engage in regular physical activity.
- Age- and gender-specific BMI percentile is a quick and easy way to screen for childhood obesity.
- Treating childhood obesity relies on positive family support and lifestyle changes involving the entire family.
- Children can learn to increase their activity, and childhood activity habits can persist into adulthood.
- Healthy attitudes about eating and activity can promote positive changes that result in long-term success.
- Primary care professionals can positively influence family changes centering around diet and exercise.
- Increasing physical activity is an underappreciated method for reducing metabolic problems seen with obesity.

REFERENCES


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