MAYO CLINIC

REVIEW

Review of Childhood Obesity: From Epidemiology, Etiology, and Comorbidities to Clinical Assessment and Treatment

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Abstract

Childhood obesity has emerged as an important public health problem in the United States and other countries in the world. Currently 1 in 3 children in the United States is afflicted with overweight or obesity. The increasing prevalence of childhood obesity is associated with emergence of comorbidities previously considered to be "adult" diseases including type 2 diabetes mellitus, hypertension, nonalcoholic fatty liver disease, obstructive sleep apnea, and dyslipidemia. The most common cause of obesity in children is a positive energy balance due to caloric intake in excess of caloric expenditure combined with a genetic predisposition for weight gain. Most obese children do not have an underlying endocrine or single genetic cause for their weight gain. Evaluation of children with obesity is aimed at determining the cause of weight gain and assessing for comorbidities resulting from excess weight. Family-based lifestyle interventions, including dietary modifications and increased physical activity, are the cornerstone of weight management in children. A staged approach to pediatric weight management is recommended with consideration of the age of the child, severity of obesity, and presence of obesity-related comorbidities in determining the initial stage of treatment. Lifestyle interventions have shown only modest effect on weight loss, particularly in children with severe obesity. There is limited information on the efficacy and safety of medications for weight loss in children. Bariatric surgery has been found to be effective in decreasing excess weight and improving comorbidities in adolescents with severe obesity. However, there are limited data on the long-term efficacy and safety of bariatric surgery in adolescents. For this comprehensive review, the literature was scanned from 1994 to 2016 using PubMed using the following search terms: *childhood obesity*, *pediatric obesity*, *childhood overweight*, *bariatric surgery*, and *adolescents*.

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Childhood obesity has emerged as one of the most important public health problems in the United States and other countries in the world.[1,2] The increasing prevalence of childhood obesity has led to the emergence of multiple serious obesity-related comorbidities[3] that not only threaten the health of those affected but also promise to place a large strain on the health care system. In addition, obesity in childhood tracks strongly into adulthood, particularly in those with severe obesity and/or a strong family history of obesity.[4,5] For this comprehensive review, the literature was scanned from 1994 to 2016 using PubMed using the following search terms: *childhood obesity, pediatric obesity, childhood overweight, bariatric surgery,* and *adolescents*.

DEFINITION OF CHILDHOOD OBESITY

The term *obesity* refers to an excess of fat. Because of the unavailability and high cost of techniques that directly measure body fat, body mass index (BMI), derived from the body weight and height, has emerged as the accepted clinical standard measure of overweight and obesity for children 2 years and older. Body mass index is calculated by dividing the body weight in kilograms by the height in meters squared. In general, BMI provides a reasonable estimate of adiposity in the healthy pediatric population.[6] However, BMI may slightly overestimate fatness in children who are short or who have relatively high muscle mass and may underestimate adiposity in a substantial proportion of children, such as those with reduced muscle mass due to low

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ARTICLE HIGHLIGHTS

- Childhood obesity has increased in epidemic proportions both in the United States and worldwide. We discuss the epidemiology of childhood obesity including the trend toward increasing prevalence of severe obesity in children.
- Children with obesity are at high risk for multiple comorbidities previously considered to be "adult" diseases. We discuss the association of childhood obesity with type 2 diabetes mellitus, hypertension, dyslipidemia, obstructive sleep apnea, nonalcoholic fatty liver disease, and other diseases.
- Lifestyle modifications including dietary changes aimed at decreasing total caloric intake, increasing physical activity and decreasing sedentary time are crucial for weight management.
- Pharmacotherapy may have a role in the treatment of pediatric obesity, but evidence is scant.
- Bariatric surgery is effective in achieving weight loss and improving comorbidities in adolescents with severe obesity. We discuss the indications for bariatric surgery in adolescents and the data on the efficacy and safety of these procedures.
- We discuss the components of family-based lifestyle interventions for weight loss.

levels of physical activity.[7] Therefore, BMI should be viewed as a surrogate measure of adiposity and its strengths and limitations should be considered when used in clinical and research settings. For children younger than 2 years, weight for length is the accepted measure of overweight and obesity.

Waist circumference and waist-to-hip ratio can be used to assess abdominal obesity, whereas skinfold thickness is helpful as an indicator of adiposity.[8-11]

Because children experience constant fluidity in height and weight as a result of normal growth and development, the norms for the absolute level of BMI in children vary with age and sex. In 2000, the National Center for Health Statistics and the Centers for Disease Control and Prevention (CDC) published BMI reference standards for children between 2 and 20 years of age.[12] Similarly, the World Health Organization (WHO)[13] developed growth standards through the WHO Multicentre Growth Reference Study to describe normal child growth from birth to 5 years under optimal environmental conditions. Although probably not ideal for all segments of the pediatric population, these standards have been applied to all children everywhere, regardless of ethnicity, socioeconomic status, and type of feeding. The CDC recommends using curves based on the WHO child growth standards for infants and toddlers younger than 2 years and the CDC/National Center for Health Statistics growth references for children 2 years and older.[12]

The following BMI-based definitions are used for *overweight* and *obesity* for children and adolescents between 2 and 20 years of age:

- *Overweight:* BMI at or greater than 85th to less than 95th percentile for age and sex
- *Obesity:* BMI at or greater than 95th percentile for age and sex
- *Severe obesity:* BMI at or greater than 120% of the 95th percentile, or BMI at or above 35 kg/m^2 (whichever is lower).[14,15] This corresponds to approximately the 99th percentile, or BMI *z* score at or above 2.3 above the mean.[16,17] Some experts recommend classifying obesity in 3 classes: class I obesity (BMI at or above 95th percentile to less than 120% of the 95th percentile), class II (BMI at or above 120% to less than 140% of the 95th percentile, or BMI at or above 35 kg/m^2), and class III (BMI at or above 140% of the 95th percentile, or BMI at or above 40 kg/m^2).[15]

EPIDEMIOLOGY

Prevalence

Currently, about one-third of children and adolescents in the United States are classified as either overweight or obese.[1] The prevalence of overweight or obesity increases with advancing age: 22.8% of preschool children (age, 2-5 years), 34.2% of school-aged children (age, 6-11 years), and 34.5% of adolescents (age, 12-19 years) are afflicted with overweight or obesity[1] and 8.4% of preschool children (age, 2-5 years), 17.7% of school-aged children (age, 6-11 years), and 20.5% of adolescents (age, 12-19 years) have obesity.[1]

The prevalence of obesity varies by racial, ethnic, and socioeconomic factors. Childhood obesity is more common in African Americans,

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American Indians, and Mexican Americans than in non-Hispanic whites.[1,14,18] Obesity is also more prevalent in low-income populations.[19,20] Hereditary factors have a strong effect on the prevalence of obesity in children. Obesity in 1 parent increases the risk of obesity in the child by 2- to 3-fold, and up to 15-fold if both parents have obesity.[4]

Trends

The prevalence of obesity has increased dramatically in school-aged children (age, 6-11 years) and adolescents (age, 12-19 years) between 1976 and 1980 and between 2009 and 2010 (from 6.5% to 18.0% in children and from 5.0% to 18.4% in adolescents).[21,22] However, the percentage of children and adolescents in each weight category remained almost stable between 2000 and 2012.[1] In addition, limited evidence suggests that obesity prevalence may have decreased in preschool-aged children (age, 2-5 years) from 13.9% in 2004 to 8.4% in 2011 and 2012.[1] However, this isolated finding has yet to be replicated and will need to be monitored over time to engender confidence about whether this is truly representative of a real trend.

Despite the recent plateau in the overall prevalence of childhood obesity in the United States, the prevalence of severe obesity in children aged 2 to 19 years has continued to increase. In 2012, 5.9% of children had severe obesity (defined in this report as BMI $\geq$120% of the 95th percentile, or BMI $\geq$35 kg/m^2).[15]

Tracking of Childhood Obesity Into Adulthood

Unfortunately, a high percentage of children with obesity carry their adiposity into adulthood. The tracking of obesity into adulthood is affected by age of the child,[23,24] severity of obesity,[25] and presence of parental obesity.[4] Older age is associated with greater persistence of obesity into adulthood, and therefore most adolescents with obesity will continue to be obese during adult life.[24,26] The severity of obesity is also important: 71% of adolescents with severe obesity in 1 study[27] continued to have severe obesity in adulthood compared with only 8% of adolescents with nonsevere obesity. In addition, parental obesity has been shown to increase the risk of adult obesity by more than 2-fold in children younger than 10 years.[4]

ETIOLOGY

Childhood obesity is the consequence of an interaction among a complex set of factors that are related to the environment, genetics, and ecological effects such as the family, community, and school.

Environmental Factors

The etiological factors for childhood are extremely complex.[28] Psychosocial and emotional distress contribute to excess weight gain in children via maladaptive coping strategies such as eating to suppress negative emotions, appetite up-regulation, and low-grade inflammation.[28,29] Eating behaviors in children and risk of childhood obesity have been shown to be associated with parental feeding styles, stress, and depression.[30] Other crucial proposed effects include perinatal factors,[26,27] birth size,[31] catch-up growth,[32] breast-feeding status,[33] antibiotic use,[34] environmental chemicals,[35] microbiota,[36,37] and adverse life experiences.[38]

Several factors in the current "obesogenic" environment have resulted in increased caloric consumption, such as increasing use of sugar-sweetened beverages, sweet snacks, fast foods containing excess fat, large portion sizes, and high glycemic foods.[39-42] Consumption of sugar-sweetened beverages (including fruit juice) has been postulated as an important contributor to the development of obesity in children.[43,44] In nationally representative surveys of children in the United States, sugar-sweetened beverages supplied an average of 270 kcal/d, representing 10% to 15% of the total caloric intake.[42] Consumption of fast food has also been purported to contribute to the increasing prevalence of obesity.[45]

The changes in the environment contributing to increased caloric intake have been accompanied by factors predisposing to decreased caloric expenditure such as reduced levels of physical activity and increasing time spent in sedentary activities such as use of television, computers, phones, and tablets.[46,47] The amount of time spent watching television and the presence of a television in a child's bedroom have been shown to be directly related to the prevalence of obesity in children and adolescents.[48,49] This association can be explained by several potential mechanisms including displacement of physical activity and adverse effects on the quality

and quantity of foods consumed.[50,51] The use of electronic games has also been associated with obesity during childhood.[52] As children spend a substantial amount of time and consume a considerable proportion of their daily calories at school, the school environment has an effect on the development of childhood obesity.[53,54]

Genetic Factors

Heritable factors appear to be responsible for 30% to 50% of the variation in adiposity.[55] Although polygenetic obesity is by far the most commonly observed, several single gene defects and syndromes associated with obesity have been identified (Table 1). However, these account for less than 1% of childhood obesity in tertiary care centers.[56,57] Children with genetic syndromes associated with obesity typically have early-onset obesity and characteristic features on physical examination, such as short stature, dysmorphic features, developmental delay, or intellectual disability (mental retardation), retinal changes, or deafness. Prader-Willi syndrome is the most common syndrome associated with obesity, and children have hypotonia and feeding difficulties during infancy (often with failure to thrive), followed by hyperphagia and subsequent development of obesity.

The most common single gene defect currently identified in children with obesity is mutations in the melanocortin 4 receptor.[58,59] Other gene defects include those in leptin, leptin receptor, proopiomelanocortin, and proprotein convertase. Mutations causing deficiencies in leptin and leptin receptor genes are rare, and only a few cases of leptin or leptin receptor mutations have been reported, most from consanguineous families.[60]

There is also increasing evidence for the role of epigenetic factors in the development of obesity. These epigenetic factors may modify the interaction of environment, microbiome, and nutrition in promoting weight gain.[37]

TABLE 1. Secondary Causes of Pediatric Obesity

Monogenic disorders	**Endocrine**
Melanocortin 4 receptor haploinsufficiency	Hypothyroidism
Leptin deficiency	Glucocorticoid excess (Cushing syndrome)
Leptin receptor deficiency	Growth hormone deficiency
Proopiomelanocortin deficiency	Pseudohypoparathyroidism
Proprotein convertase 1	**Psychological**
Syndromes	Depression
Prader-Willi	Eating disorders (binge eating disorder and night eating disorder)
Bardet-Biedl	**Drug induced**
Cohen	Tricyclic antidepressants
Alström	Glucocorticoids
Albright hereditary osteodystrophy	Antipsychotic drugs
Beckwith-Wiedemann	Antiepileptic drugs
Carpenter	Sulfonylureas
Neurologic	**Hypothalamic causes**
Brain injury	Tumor
Brain tumor	After brain surgery/radiation (craniopharyngioma)
After cranial irradiation	ROHHAD/ROHHADNET syndrome
Hypothalamic obesity	

ROHHAD = rapid-onset obesity with hypothalamic dysfunction, hypoventilation, and autonomic dysregulation; ROHHADNET = rapid-onset obesity with hypothalamic dysfunction, hypoventilation, and autonomic dysregulation with neural crest tumors.

Endocrine Disorders

Endocrine causes of weight gain are identified in less than 1% of children and adolescents with obesity.[56,57] Most children with endocrine disorders resulting in weight gain have poor linear growth, short stature, and/or hypogonadism.[57] The endocrine disorders causing weight gain include either endogenous or exogenous glucocorticoid excess (the use of corticosteroid medication or Cushing syndrome), hypothyroidism, growth hormone deficiency, and pseudohypoparathyroidism type 1a (Albright hereditary osteodystrophy) (Table 1).

Sleep

There is increasing evidence for an association between shortened sleep duration and/or poor sleep quality and obesity.[61,62] Sleep may also have an association with decreased insulin sensitivity, independent of the association with adiposity.[63]

Medications

Several medications can contribute to weight gain such as glucocorticoids,[64] antipsychotic drugs including risperidone and olanzapine,[65] and antiepileptic drugs.[66]

Hypothalamic Obesity

Acquired hypothalamic lesions such as craniopharyngioma, particularly after surgery and/or

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cranial radiation, and diencephalic tumors can present with weight gain. Patients may have symptoms of increased intracranial pressure such as headache and vomiting and may also have symptoms of panhypopituitarism. Weight gain may also be seen in patients after cranial trauma or inflammatory disease affecting the hypothalamus.

COMORBIDITIES OF CHILDHOOD OBESITY

Childhood obesity is associated with comorbidities affecting almost every system in the body including, but not limited to, the endocrine, gastrointestinal, pulmonary, cardiovascular, and musculoskeletal systems. Many of the comorbidities encountered in youth with obesity, including type 2 diabetes mellitus (T2DM), dyslipidemia, obstructive sleep apnea (OSA), and steatohepatitis, used to be previously considered "adult" diseases. The severity of these comorbidities typically increases with the severity of obesity.[67]

Cardiometabolic and Cardiovascular

Children with obesity are at an increased risk of hyperinsulinemia, insulin resistance, prediabetes, and subsequently T2DM.[68-71] The prevalence of prediabetes and T2DM varies with severity of obesity, race, ethnicity, and age of the child. Those who present with T2DM during adolescence appear to have more rapid deterioration of glycemic control and progression of diabetes-related complications such as microalbuminuria, dyslipidemia, and hypertension as compared with those who present later in life.[72-74] Children with obesity also have a high prevalence of other cardiometabolic risk factors including elevated blood pressure,[75,76] low levels of high-density lipoprotein cholesterol, and elevated levels of triglycerides.[76-78] Echocardiographic findings include left ventricular hypertrophy, increased left ventricular and left atrial diameter, and systolic and diastolic dysfunction.[79,80]

Endocrine

Obesity may be associated with early onset of sexual maturation in girls and with accelerated linear growth and advanced skeletal maturation.[81,82] Adolescent girls are also at higher risk of developing hyperandrogenism and polycystic ovary syndrome. Manifestations of polycystic ovary syndrome can include menstrual irregularities, acne, and hirsutism.[82]

Pulmonary

Children with obesity have a considerably higher prevalence of OSA than do healthy weight children.[83] The prevalence and severity of OSA increase with increasing BMI.[84] Children with severe obesity may also have alveolar hypoventilation associated with severe oxygen desaturation.[85] Childhood obesity has also been shown to be associated with asthma.[86]

Gastrointestinal

Nonalcoholic fatty liver disease (NAFLD) in children is strongly associated with obesity. The spectrum of NAFLD can range from simple steatosis to progressive steatohepatitis and cirrhosis.[87,88] Nonalcoholic fatty liver disease is now the most common cause of liver disease in children.[89] Although most patients with NAFLD are asymptomatic, laboratory abnormalities include elevations in levels of liver transaminases (alanine aminotransferase and aspartate aminotransferase), alkaline phosphatase, and gamma-glutamyl transpeptidase.[90,91] Imaging may confirm the presence of fatty liver, indicated by increased echogenicity on ultrasonography, but liver biopsy is the only way to reliably distinguish between simple steatosis, steatohepatitis, and fibrosis and can also be helpful in excluding other causes of elevated levels of serum aminotransferases.

Musculoskeletal

Childhood obesity increases the risk of various musculoskeletal problems including impairment in mobility, increased prevalence of fractures, lower extremity joint pain, and lower extremity malalignment.[92,93] Obesity is also a risk factor for unilateral or bilateral slipped capital femoral epiphysis and for tibia vara.[94,95]

Psychosocial

Psychosocial consequences of childhood obesity are common and include poor self-esteem, anxiety, depression, and decreased health-related quality of life.[96-98] Children with obesity are more likely to become victims of bullying and discrimination.[99] Women who had obesity during adolescence have been

noted to have lower family income, lower rates of marriage, and higher rates of poverty as compared with their normal weight peers.[100]

Dermatologic

Acanthosis nigricans, a marker of insulin resistance, is a common finding in children with obesity.[101] Other skin abnormalities include intertrigo, hidradenitis suppurativa, furunculosis, and stretch marks.[101]

Neurologic

Childhood obesity is associated with a higher risk of idiopathic intracranial hypertension (pseudotumor cerebri). Clinical symptoms include headache, vomiting, retro-ocular eye pain, and visual loss.[102]

Long-Term Risks

Children whose obesity persists into adulthood have a significantly increased risk of T2DM, hypertension, dyslipidemia, and carotid-artery atherosclerosis than do adults who were never afflicted with obesity.[5] Higher BMI during childhood has also been associated with an increased risk of fatal and nonfatal cardiovascular events during adulthood in both men and women, though this may be partially mediated by the association between childhood obesity and adult obesity.[103]

CLINICAL EVALUATION OF THE CHILD WITH OBESITY

The clinical evaluation of the obese child is directed at identifying the cause of obesity and obesity-related comorbidities. The evaluation includes a complete history and physical examination.[104,105]

A complete history and physical examination are usually sufficient in determining the cause of childhood obesity. Dietary history should consist of details of eating habits including frequency, content, and location of meals and snacks as well as intake of calorie-dense foods such as fruit juice and soda. Physical activity assessment should include details of time spent in unstructured play, organized sports, school recess, and physical education as well as screen time (television, video games, mobile phones, and tablets). Medical history should include details about medications that may cause weight gain such as glucocorticoids, antipsychotic drugs, and antiepileptic drugs. A developmental history is important as developmental delay may point toward a chromosomal or genetic cause for obesity. A complete review of systems is helpful in determining an underlying etiology for the weight gain, such as Cushing syndrome or hypothalamic tumor. The review of symptoms is also helpful in screening for obesity-related comorbidities such as OSA. Family history of obesity and obesity-related comorbidities is a predictor of persistence of obesity into adulthood. Performing a comprehensive psychosocial screening including collecting details related to depression, peer relationships, and disordered eating habits is crucial.

Physical examination should include measurement of height and assessment for dysmorphic features suggestive of a chromosomal or monogenic cause and for Cushingoid features. Most children with exogenous obesity are tall, whereas children with genetic and endocrine causes of obesity tend to have short stature. Blood pressure should be measured with an appropriate sized cuff.[106]

There is lack of standardization and consensus on when to screen and the types of laboratory screening tests to perform in children with obesity. Most experts recommend that children afflicted with overweight, that is, BMI between the 85th and 95th percentiles, who are free from risk factors should have measurement of a fasting lipid profile.[105] These children should also undergo measurement of fasting blood glucose or hemoglobin $A1_c$ and aspartate aminotransferase and alanine aminotransferase levels if they are 10 years and older and have 1 or more of the following risk factors: elevated blood pressure, elevated lipid levels, currently using tobacco, or have a family history of obesity-related diseases.[105] A fasting lipid profile is recommended for all children with BMI $\geq$95th percentile even in the absence of risk factors.[105] In addition, transaminases and fasting blood glucose or hemoglobin $A1_c$ are recommended for all children with BMI $\geq$95th percentile starting at 10 years of age even in the absence of risk factors.[105] If the results of the fasting lipid profile are normal, repeat screening is recommended every 2 years. If the results are borderline, repeat screening in 1 year is recommended, and if the results are

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abnormal, repeat screening in 2 weeks to 3 months is recommended.[107] A fasting lipid profile should be repeated every 2 years in children 10 years or older if their BMI is ≥85th percentile in the presence of risk factors or if their BMI is ≥95th percentile regardless of risk factors.[105] In 2011, the US National Heart, Lung, and Blood Institute expert panel recommended universal screening between 9 and 11 years of age and again between 17 and 21 years of age and selective screening at other ages.[107] The universal screening guidelines, however, remain controversial, with concerns related to lack of data on the effect of early detection of dyslipidemia on cardiovascular disease during adulthood, fear about psychological effect of early diagnosis of dyslipidemia, and low predictive value of childhood lipid screening.[108]

Children with signs and symptoms suggestive of a genetic or endocrine cause for the weight gain may need specific testing. In addition, children with signs and symptoms suggestive of comorbidity such as OSA may need specific testing such as an overnight polysomnogram.

CLINICAL INTERVENTIONS FOR THE TREATMENT OF CHILDHOOD OBESITY

The Expert Committee on the Assessment, Prevention, and Treatment of Child and Adolescent Overweight and Obesity recommends a staged approach to weight management in children. (Table 2).[109] Stage 1 (Prevention Plus) includes specific dietary and physical activity recommendations, such as encouraging fruit and vegetable consumption and limiting sedentary activities such as watching television, playing video games, and using computers. If there is no improvement in BMI in 3 to 6 months, stage 2 (Structured Weight Management) should be considered. This stage includes recommendations on low–energy-dense, balanced diet; structured meals; supervised physical activity of at least 60 min/d; 1 hour or less of screen time per day; and self-monitoring through food and physical activity recording. Referral to dietitians is needed for this stage. Monthly contact is recommended and should be tailored to the needs of the patient and family. Advancement to the next stage (stage 3, Comprehensive Multidisciplinary Intervention) is recommended depending on responses to treatment with stage 2, age, health risks, and motivation of the patient and family. Stage 3 is characterized by more frequent patient-provider contact and more active use of behavioral strategies and monitoring. Weekly visits for the first 8 and 12 weeks, followed by monthly contact, are recommended as being most efficacious. Moderate to strong parental involvement is recommended for children younger than 12 years. This stage requires a multidisciplinary team with expertise in childhood obesity, including a behavioral counselor (eg, social worker, psychologist, and trained nurse practitioner), registered dietitian, and exercise specialist. Primary care offices with dietitians and behavioral counselors can deliver these services with community partners such as public health programs, local schools, Head Start, Young Men's Christian Association and Boys and Girls Club. Children with inadequate response to stage 3 treatment, health risks, and motivation should be considered for stage 4 (Tertiary Care Intervention). This stage often includes the use of meal replacement, low-energy diets, medications, and/or surgery. Stage 4 requires a multidisciplinary team with expertise in childhood obesity at a pediatric weight management center that has specific clinical and research protocols for the assessment of outcomes and risks.

The weight loss goals are determined by the child's age and severity of obesity and related comorbidities.[109,110] Weight maintenance might be an appropriate goal for children who have mild obesity because BMI

TABLE 2. Suggested Staged Approach to Weight Management in Children and Adolescents

- *Stage 1 (Prevention Plus)* can be implemented in a primary care office setting, 5 or more servings of fruits and vegetables per day, minimize or eliminate consumption of sugar-containing beverages, <2 hours of screen time and >1 hour of physical activity per day
- *Stage 2 (Structured Weight Management)* can be implemented in a primary care office with a dietitian, includes stage 1 guidelines plus increased structure of meals and snacks with attention to energy density of foods
- *Stage 3 (Comprehensive Multidisciplinary Intervention)* can be implemented in a primary care office with a multidisciplinary team and outside facilities for structured physical activity, includes stage 2 guidelines plus increased structured physical activity and dietary program
- *Stage 4 (Tertiary Care Intervention)* can be ideally implemented in a pediatric weight management center with a multidisciplinary team with expertise in pediatric obesity, includes in addition to stage 3 recommendations, medications, extremely structured dietary regimens, or bariatric surgery

will decrease as children gain height. In contrast, weight loss is recommended in children with severe obesity and those with comorbidities. It has been suggested that a weight loss of 1 lb/mo is safe in children between 2 and 11 years of age whereas weight loss of up to 2 lb/wk is safe in adolescents with severe obesity and comorbidities. However, it should be noted that little to no evidence supports these specific recommendations; rather, they represent expert opinion.[110]

Behavioral strategies targeted at decreasing overall caloric intake, decreasing sedentary time, and increasing physical activity are the cornerstone of pediatric weight management (Table 3). Family-based behavioral approaches that include the child's parents or caregivers are recommended.[110-112] Exclusive parental participation has been shown to be effective in the treatment of childhood obesity[113-115] and noted to give better results as compared with participation of the child only.[114] Motivational interviewing is a nonjudgmental and patient-centered counseling technique that entails reflective listening and addresses a patient's ambivalence to change and uses the patient's values to resolve that ambivalence. This technique has been shown to be a useful tool in the treatment of pediatric obesity.[116,117]

Obtaining accurate assessments of barriers to healthy eating and physical activity, including those that are financial and cultural, is crucial to identify specific behaviors to target for change. Behavioral modification interventions include self-monitoring of food and physical activity as well as control of stimuli that contribute to or elicit unhealthy behaviors.[118] Appropriate goals for healthy behavior should be "SMART," *s*pecific, *m*easurable, *a*ttainable, *r*ealistic, and *t*imely.[119]

There is lack of consensus on what the best structured dietary strategies for weight loss are in children. Diets with modified carbohydrate intake such as low glycemic index diets and low carbohydrate diets have been shown to be as effective as standard portion-controlled diets for weight management in children with obesity.[120,121] However, adherence to the modified carbohydrate diets may be low and children may be unable to follow these types of regimens, particularly in the long term.[122] Some programs use the "traffic light" format that labels food as red, yellow, and green on the basis of the energy density of the foods (red foods being most calorie dense and green foods being least calorie dense).[50] Children are encouraged to eat green foods more often and red foods rarely. The NuVal nutritional scoring system is another helpful way to obtain comprehensive nutritional information with a simple number between 1 and 100, in which higher scores represent better nutrition (https://www.nuval.com).

Semistructured dietary approaches that are aimed at encouraging children and their families to select food groups of lower energy density, such as fats, and decreasing portion size are best used for weight loss in children.[112,118]

Physical activity goals should be determined by the child's age, personal preferences for the type of physical activity, and exercise tolerance. It is recommended that children 6 years or older participate in 60 minutes or more of physical activity per day.[123] Toddlers should be allowed 60 to 90 minutes per 8-hour day for moderate- to vigorous-intensity physical activity, including running; and 90 to 120 minutes are recommended for preschoolers.[124] Unstructured physical activity, including outdoor play, should be encouraged in younger children, whereas older children should be encouraged to participate in structured physical activity such as after-school sports. It is also recommended that "screen time" (other than homework) be limited to less than 2 h/d for children older than 2 years, whereas those younger than 2 years should

TABLE 3. Behavioral Treatment Strategies for Obesity During Childhood and Adolescence

Dietary approaches
1. Encourage intake of ≥5 servings of fruits and vegetables daily
2. Decrease intake of calorie-dense foods such as saturated fats, salty snacks, and high glycemic foods such as candy
3. Minimize intake of sugar-containing beverages
4. Minimize eating outside home and fast food in particular
5. Eat breakfast daily
6. Avoid skipping meals
Physical activity
1. Decrease sedentary behavior such as watching television, surfing the Internet, and playing video games to <2 h/d
2. Engage in fun and age-specific exercise that is appropriate to the individual's abilities
3. Increase intensity, frequency, and duration of exercise gradually as tolerated
4. More than 1 h of physical activity daily

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avoid "screen time" altogether. Because of the increasing evidence for an association between shortened sleep duration and obesity,[62,125] good sleep hygiene and adequate amount of sleep (10-13 hours a night for preschoolers and 8-10 hours a night for teenagers) should be recommended. "My Plate" (http://www.ChooseMyPlate.gov/), Let's Go! 5-2-1-20 Maine program (http://www.letsgo.org/), and Let's Move (http://www.letsmove.gov/) are excellent resources for promoting healthy eating and active lifestyle.

Lifestyle interventions of moderate or high intensity (defined as 26-75 or >75 hours of provider contact, respectively) are effective in achieving short-term (up to 12 months) weight improvements in children, but these may not be feasible in primary care settings or even specialty pediatric weight management programs.[126] Low-intensity interventions (<25 hours of provider contact, typically spread over 3-6 months) are feasible in a primary care setting and are recommended. However, low-intensity interventions have been shown to have weak or inconsistent effects.[126-128]

Behavioral interventions for treating overweight and obesity in children and youth are associated with a low to moderate treatment effect. The reported weight loss and BMI reductions have been modest, ranging from 1 to 3 kg/m^2 of BMI.[3,127-130] In addition, dropout rates tend to be high.[127,129,130]

PHARMACOLOGICAL THERAPY

The role of pharmacological therapy in the treatment of obesity in children and adolescents is limited.[14,131] Orlistat is the only medication currently approved by the Food and Drug Administration for the treatment of obesity in adolescents (age, ≥12 years). Orlistat is a lipase inhibitor that blocks absorption of about one-third of the fat ingested in a meal. The recommended dose of orlistat is 120 mg 3 times a day with meals. Orlistat is also available as an over-the-counter medication at a lower dose of 60 mg 3 times a day. The efficacy of orlistat is modest: 1-year placebo-subtracted changes in BMI less than 1 kg/m^2.[132,133] Adverse effects limiting the use of orlistat include diarrhea, abdominal pain, flatulence, and greasy stools. Orlistat blocks absorption of fat-soluble vitamins and therefore administration of a multivitamin is recommended.

Metformin, a drug approved for the treatment of T2DM in children 10 years and older, has been used off-label for weight loss in several trials but results in modest reductions in BMI only (placebo-subtracted BMI decrease of 1.1-1.4 kg/m^2).[134,135]

Other medications that have been used off-label for the treatment of obesity in children include topiramate[136] and glucagon-like peptide-1 analogs such as exenatide.[137,138] However, these studies were either uncontrolled or included small sample sizes; therefore, more trials are needed to better understand the efficacy and safety of these medications for the treatment of pediatric obesity.

BARIATRIC SURGERY

Bariatric surgery in adults has been shown to result in significant and sustained decreases in BMI and several obesity-related comorbidities as well as reduce mortality.[139,140] As a consequence, bariatric surgery has been performed in adolescents with severe obesity for several decades. There has been an increase in the number of bariatric surgery procedures in adolescents: a 5-fold increase from 1997 to 2003 and a 3-fold increase from 2000 to 2003.[141,142] Despite the increasing trend, bariatric surgery is infrequently performed in adolescents. In fact, less than 1% of all bariatric procedures in the United States are performed in adolescents. A total of 771 bariatric procedures were performed in 2003[142] and 1600 procedures in 2009.[143]

Types of Bariatric Procedures

Laparoscopic sleeve gastrectomy (LSG) and Roux-en-Y gastric bypass (RYGB) are the most commonly performed procedures in the United States.[144] An adjustable gastric band (AGB) comprises less than 5% of procedures performed in adolescents. The results of a National Institutes of Health–sponsored study involving 5 centers (Teen-Longitudinal Assessment of Bariatric Surgery) suggest that bariatric surgery is safe and effective in adolescents with severe obesity.[145,146] The Teen-Longitudinal Assessment of Bariatric Surgery study is one of the first and largest prospective studies to systematically investigate the short-term and long-term efficacy and safety of bariatric surgery in children.

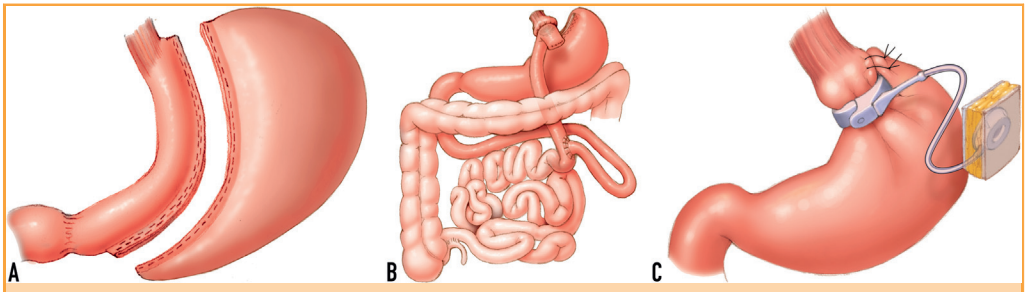

FIGURE. A, Sleeve gastrectomy. B, Roux-en-Y gastric bypass. C, Adjustable gastric band.

Laparoscopic sleeve gastrectomy involves resection of most of the greater curvature of the stomach, resulting in the creation of a tubular stomach (Figure A). This procedure was traditionally performed as the first part of a 2-stage weight loss procedure for extremely high-risk obese adults but is now being used as a stand-alone procedure. Laparoscopic sleeve gastrectomy is an attractive procedure for adolescents because of a lower risk of micronutrient deficiencies (because the procedure does not result in malabsorption) and less complexity of the procedure itself in comparison to RYGB. The RYGB procedure involves the creation of a small (<30 mL) proximal gastric pouch that is divided and separated from the distal stomach and is anastomosed to a Roux limb of small bowel 75 to 150 cm in length (Figure B). This procedure therefore results in restriction of caloric intake as well as malabsorption of food along with vitamins and minerals.

Reduced caloric intake due to reduced capacity of the stomach and neuroendocrine mechanisms such as an increase in postprandial concentrations of total peptide YY after RYGB are thought to play important roles in weight loss after bariatric procedures. Dramatic improvements in diabetes and insulin resistance are seen immediately after RYGB even before any significant weight loss. These may be attributed to an increased secretion of incretins such as glucagon-like peptide-1 or simply as a result of dramatically reduced caloric intake.[147] The AGB is a tight prosthetic band that is placed around the entrance to the stomach and therefore compartmentalizes the stomach (Figure C). The gastric band is not Food and Drug Administration approved for adolescents younger than 18 years.

The following criteria have been recommended by the American Society for Metabolic and Bariatric Surgery to select adolescents for bariatric surgery[148,149]:

1. Body mass index $\geq$35 kg/m^2 and a severe comorbidity, with significant comorbidity with short-term effects on health (eg, moderate to severe OSA [apnea-hypopnea index >15], T2DM, pseudotumor cerebri, or severe and progressive steatohepatitis), or BMI 40 kg/m^2 or above with more minor comorbidities
2. *Physical maturity*, defined as completing 95% of predicted adult stature based on bone age or reaching Tanner stage IV. This criterion is based on theoretical concerns that rapid weight loss might inhibit statural growth if an adolescent has not reached near adult height
3. History of lifestyle efforts to lose weight through changes in diet and physical activity
4. Ability and motivation of the patient and family to adhere to recommended treatments pre- and postoperatively, including vitamin and mineral supplementation
5. Appropriate understanding of the risks and benefits of surgery on behalf of the adolescents
6. Supportive but not coercive family

According to expert guidelines from the American Society for Metabolic and Bariatric Surgery, contraindications for surgical weight loss procedures in adolescents include[148,150]

1. Medically correctable cause of obesity
2. An ongoing substance abuse problem (within the preceding year)
3. A medical, psychiatric, psychosocial, or cognitive condition that prevents adherence to postoperative dietary and medication regimens or impairs decisional capacity

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4. Current or planned pregnancy within 12 to 18 months of the procedure
5. Inability on the part of the patient or parent to comprehend the risks and benefits of the surgical procedure

Preoperative evaluation of adolescents before bariatric surgery should be performed by a multidisciplinary team consisting of a pediatric obesity specialist, experienced bariatric surgeon, nurse, dietitian, and pediatric psychologist or psychiatrist.

Postoperative management includes advancement of the diet from clear liquids to a protein-containing liquid diet, then high protein shakes to puree, and subsequently solid, normal consistency foods over a period of several months. Lifelong vitamin and mineral supplementation is recommended to prevent the development of nutritional deficiencies as a result of decreased intake and/or malabsorption. The typical supplementation regimen includes a daily standard multivitamin with folate and iron, calcium, vitamin D, and daily or monthly vitamin B_{12}. Pregnancy prevention is recommended for at least 12 to 18 months after surgery because of the potential adverse effects of weight loss and micronutrient deficiencies on the mother and fetus.

In a prospective study of 242 adolescents with severe obesity who underwent bariatric surgery (predominant RYGB and LSG), at 3 years postoperatively, clinically significant decreases in BMI were seen (in LSG from 50 kg/m^2 at baseline to 37 kg/m^2 and in RYBG from 54 kg/m^2 at baseline to 39 kg/m^2).[144] Bariatric surgery also results in a significant improvement in comorbidities such as T2DM, elevated blood pressure, dyslipidemia, markers of inflammation and oxidative stress, fatty liver disease, and abnormal kidney function as well as quality of life and depression.[144,151-155]

Short-term complications of bariatric surgery include wound infections, leakage at anastomotic sites, pulmonary embolism, small bowel obstruction, gastrojejunal strictures, and gastrogastric fistula.[146,153] Complications of the AGB include band slippage, gastric obstruction, and pouch dilatation.[154] Long-term complications include nutritional deficiencies of iron, vitamin B_{12}, thiamine, and vitamin D.[144] Iron deficiency is the most common nutritional problem, with prevalence of low ferritin levels increasing from 5% at baseline to 57% 3 years after surgery.[144] The adherence to recommendations for nutritional supplementation has been noted to be poor in adolescents. Therefore, appropriate patient selection and long-term follow-up is recommended after bariatric surgery.

CONCLUSION

Childhood obesity has emerged as one of the most pressing medical and public health problems of our day. The prevalence is unacceptably high, and the rate of increase in severe obesity continues to climb. The etiology of the disease is multifactorial and complex, stemming from an interaction among genetic and biological factors, environmental factors, and ecological effects. Childhood obesity is associated with several comorbidities that affect physical and mental health. The multitude of serious comorbidities associated with childhood obesity necessitates effective treatment modalities. A staged approach to treatment is recommended, with initial management being implemented in primary care and with focus on healthy eating habits and active lifestyle. Those with poor response to interventions in primary care and with significant health risks should be managed by a multidisciplinary team with expertise in childhood obesity. Pharmacotherapy and/or bariatric surgery should be considered if there has been no response to structured weight management with a multidisciplinary team. Additional research is needed to evaluate the efficacy and safety of these modalities.

Abbreviations and Acronyms: **AGB** = adjustable gastric band; **BMI** = body mass index; **CDC** = Centers for Disease Control and Prevention; **LSG** = laparoscopic sleeve gastrectomy; **NAFLD** = nonalcoholic fatty liver disease; **OSA** = obstructive sleep apnea; **RYGB** = Roux-en-Y gastric bypass; **T2DM** = type 2 diabetes mellitus; **WHO** = World Health Organization

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