Chapter 11
Childhood Obesity

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Key Points

- Childhood obesity is measured in many ways including body mass index (BMI) percentile and BMI standardized score. In addition to these measures of height and weight, direct measures of adiposity are encouraged in order to obtain a full-body composition profile.
- Obesity in childhood can lead to a host of comorbid conditions, but perhaps the most important risk is that these children are likely to become obese adults.
- The greatest likelihood of success in treating childhood obesity is through family-based lifestyle interventions.
- In addition to primary (population-wide strategies) and secondary (lifestyle interventions), tertiary prevention strategies (drug therapy or weight-loss surgery) have been developed to treat obesity in youth.

Keywords Adiposity • BMI • Family-based behavioral approach • Type 2 diabetes • Weight-loss surgery

Abbreviations

AGB	Adjustable gastric banding
BIA	Bioelectrical impedance analysis
BMI	Body mass index
BMI z-score	Standardized BMI
DEXA	Dual-energy x-ray absorptiometry
LSG	Laparoscopic sleeve gastrectomy
RYBG	Roux en Y gastric bypass
TLP	Traffic Light Program

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Introduction

The US childhood obesity prevalence rate has increased from 5.0 % in 1976–1980 to 8.4 % in 2011–2012 for preschool-aged children (ages 2–5 years) [1, 2]. More dramatic increases have been observed among children in middle childhood (ages 6–11) from 6.5 to 17.7 % and adolescents (ages 12–19 years) from 5.0 to 20.5 % within the same time period [1, 2]. Despite the sharp increases in obesity prevalence rates in the past 40 years, a review of the literature indicates the prevalence rates among children and adolescents are stabilizing and consequently plateauing [3], with a couple of exceptions. Among preschool-aged children, obesity prevalence rates have decreased since 2003–2004 when it was at 13.9 % [1]. On the other hand, obesity prevalence rates have not leveled off among (a) race/ethnic minority children and children from lower socio-economic status groups and (b) children classified with severe obesity: class 2 obesity category (>120 % of 95th percentile) and class 3 obesity category (>140 % of 95th percentile) [4, 5]. For instance, in 2011–2012, 16.7 % of Hispanic preschool-aged children and 11.3 % of black preschool-aged children were obese compared to 3.5 % of white preschool-aged children [1]. Further, the prevalence rates of class 2 obesity has increased from 3.8 % in 1999–2000 to 5.9 % in 2011–2012, and class 3 obesity prevalence rates has risen from 0.9 to 2.1 % within the same time frame [4]. These trends are particularly concerning because the groups that have historically been most impacted by obesity appear to be consistently increasing in terms of obesity prevalence.

Aside from the population-level trends, there are development trends that cause concern. Early childhood obesity tracks into adolescence and adulthood. Overweight 5-year-olds have been shown to be four times more likely to become obese by age 14 compared to normal weight peers [6]. Further, as much as 82 % of obese children become obese adults [7]. Thus, the developmental trends, along with the population trends and corresponding disparities, suggest that childhood obesity is an epidemic that all health professionals will face. This chapter provides an explanation of how measurement guidelines and various methodologies can be used to identify children at-risk for obesity as well as those that are obese. The chapter also briefly describes comorbidities associated with childhood obesity and strategies for treating childhood obesity.

Measurement Guidelines and Methodologies

Childhood overweight and obesity are weight status terms that are measured using body mass index (BMI). Most of the childhood obesity research has used BMI as an outcome measure. BMI is calculated by dividing the child's weight in kilograms by the square of child's height in meters [8]. The reference value is then plotted on Centers for Disease Control (CDC) growth curve charts that are gender- and age-specific to determine the BMI percentile [9]. The BMI percentiles are divided into four categories which are used to describe a child's weight status. Children with a BMI percentile less than 5th percentile are categorized as underweight, while children with a BMI percentile between the 5th percentile and less than the 85th percentile are categorized as healthy weight. Overweight children have a BMI percentile between the 85th percentile and less than the 95th percentile. Obese children have a BMI percentile at or above the 95th percentile [8]. BMI provides a measure of excess body weight (e.g., overweight status); yet, it is not a measure of direct body fat. However, it is considered to be correlated with adiposity.

An alternate measure to BMI that is also commonly used is standardized BMI, also referred to as a BMI z-score. BMI z-score is the transformation of the child's BMI into the number of standard deviations (SD) above and below the population mean BMI based on gender and age [10]. Similar to BMI percentiles that are divided into categories to describe a child's weight status, the same has been

done with BMI z-score. Weight status criteria using BMI z-scores are normal weight 0 SD (50th percentile), overweight ≥1.04 SD (85th percentile), obesity ≥1.64 SD (95th percentile), and severe obesity ≥2.33 SD [11]. For weight loss to be clinically meaningful (i.e., reduce health concerns), a reduction in BMI z-score of 0.5 SD over 6 months or at least 0.6 SD over 6–12 months [12] needs to occur. However, reduction in BMI z-score of 0.25 SD over 12 months is considered clinically relevant in improving cardiovascular risk factors (i.e., insulin sensitivity, total cholesterol/high-density lipoprotein ratio, and blood pressure) in adolescents [13].

Although BMI z-scores provide the opportunity to compare changes in weight status, BMI z-score compared to BMI is more sensitive to changes in weight status [12]. For instance, among obese children, any weight change that does occur is observed as less change because there is less variability at the upper end of the weight distribution. This is a problem when comparing the effects of obesity interventions because the heavier children will show less change in their BMI z-scores, despite having similar changes in BMI as the less heavy children [14].

Aside from weight status, there are various methods to measure adiposity, which include skinfold thickness, waist circumference, bioelectrical impedance analysis (BIA), and dual-energy x-ray absorptiometry (DEXA). Skinfold thickness, waist circumference, and BIA are fairly inexpensive, portable, and quick methods of collecting adiposity information from children. Skinfold thickness is measured using standardized calipers to capture a double layer of skin and subcutaneous fat lifted as a fold at various areas of the body, including but not limited to triceps, biceps, abdominal, thigh, and calf. Measurement reliability is low for skinfold thickness, and reference percentiles have not been published [15]. A tape measure around the abdominal region determines the circumference of the waist, which is suggestive of the amount of body fat in that particular area of the body. Previous research has used a waist circumference measurement ≥90th percentile for age and sex to be considered to be elevated percent body fat [16, 17], and this has been linked to increased risk of diabetes and other cardiovascular diseases [18]. Waist circumference establishes fat distribution in the abdomen region, but it does not provide a measurement for total body fatness [15]. BIA involves the child stepping on a scale that uses an electric current to differentiate between fat mass and lean tissue mass. The electrical current is unnoticeable to the child [15]. BIA measurements are considered to be reliable [15, 19], and the Tanita BF-689 (Tanita Corporation, Arlington Heights, IL) [20], which is designed for children, is highly specific for classifying children as over fat and obese [19]. However, it has also demonstrated to have a low sensitivity and specificity for healthy percent body fat classification [19].

Unlike the other methods, DEXA provides the most information and is considered the gold standard. DEXA scans the entire body in about 7 min using an extremely low amount of radiation to calculate fat mass, lean tissue mass, and bone mineral content for the whole body and for specific regions of the body [21]. DEXA is the most accepted method to calculate percent body fat; however, DEXA fails to be useful in community outreach settings as the machinery is expensive and not portable [19]. Despite their limitations, all of these methods are important for research, especially when wanting to create a comprehensive body composition profile.

Obesity-Related Comorbidities

The additional weight that overweight and obese children and adolescents carry places them at increased risk for physical and physiological consequences. Comorbidities include increased risk for worse overall health [22], functional limitations [22], orthopedic complications (e.g., spinal complications, slipped capital femoral epiphysis, and acute fractures) [23], earlier puberty and menarche in girls [24], obstructive sleep apnea [25], prediabetes and type 2 diabetes [26, 27], metabolic syndrome [26], and elevated blood pressure, blood lipids, insulin, and insulin resistance [28]. A majority of these health problems have traditionally only been observed in adults. Additionally, individuals that

experience either childhood or adolescent obesity are at risk for experiencing obesity in adulthood [7, 29] and experiencing further health complications, including colorectal cancer and gout among adult men, arthritis among adult women, coronary heart disease and atherosclerosis among both adult men and women [30], and consequently increased risk for mortality [26].

Psychological and social consequences may be even more common than physical and physiological comorbidities. At the core of emotional well-being is depression and self-esteem. Overweight/obese adolescents are at more risk of experiencing depression symptomatology and poor self-esteem compared to normal weight adolescents their age [22]. While depression may result in behaviors that promote obesity [31], negative social outcomes that result from obesity may increase symptoms of depression. For example, obese children are more likely to be bullied due to their deviation from ideal appearances [32], and being bullied is associated with depression and anxiety [33, 34]. In fact, it has been suggested that a reciprocal relationship exists between obesity and depression [35]. Binge eating, impulsivity, eating-disordered cognitions and behaviors, and body dissatisfaction have been observed among overweight, obese, and severely obese children [36–39]. Overall, the quality life of overweight/obese children has been described to be similar to that of children who have cancer [40].

The academics of overweight and obese children also suffer which has socio-economic consequences. Pediatric overweight and obesity have been linked to lower cognitive functioning [41] and standardized test scores [42], although some of the findings can be explained by socio-economic status, including parental education [43]. The decreased performance in the academic realm may result in harmful social consequences that persist into adulthood. For example, heavy women are less likely to attain post-secondary schooling compared to their non-heavy peers, which can negatively influence their occupational standing [44, 45]. Further, obese women are at risk for lower wages and consequently lower family income [45–47]. Last, heavy women are more likely to delay marriage and have lower odds of marrying compared to their thinner peers [45, 46].

Due to its diverse and widespread comorbidities, child and adolescent overweight and obesity have become a public health concern. If left unabated, more preventable deaths will be associated with obesity than with cigarette smoking, and deaths related to obesity could replace those prevented by improved treatment for cancer, heart disease, and diabetes [48]. Fortunately, receiving treatment for overweight/obesity may attenuate some of the negative physical, physiological, and psychological consequences.

History of Treatment Strategies

The general consensus in medicine throughout the nineteenth century was that carrying an extra 20–30 lb or more of fat was a health advantage that enhanced resistance when a person became ill. Unless obesity was extreme to the extent that it made it difficult to carry out normal activities, it was not identified as a problem. In this era, a slender figure was a sign of poor health in association with diseases like tuberculosis [49, 50]. It was not until the twentieth century that the position on overweight changed. American insurance enterprises began selling an increased amount of life insurance policies. The companies started to study the mortality rates of different groups of people and conditions in order to remain profitable. This resulted in the collection of comprehensive, longstanding statistics on health and mortality for thousands of people [49, 51].

A pioneer in this data collection was Oscar H. Rogers, a physician with the New York Life Insurance Company. Rogers conducted a systematic study of insured lives that included parameters such as height, weight, occupation, personal history, and family history. His findings in 1901 showed that a group of 1,500 policyholders who were 30 % or more overweight had a 35 % higher mortality rate [50, 52].

This evidence was critical for American insurance companies and drove the industry to further collect and analyze information on body weight. Insurance companies desired to insure policyholders of "normal weight," but lacked statistical support for their judgment. Louis I. Dublin, a statistician of the Metropolitan Life Insurance Company, calculated "average weights" from a comprehensive retrospective survey of New York Life Insurance policyholders. In 1908, Dublin compiled the *Dublin Standard Table of Heights and Weights* that became the primary reference of average weight. Dublin became one of the leading voices that spread the concerns of overweight throughout the medical community. Health professionals now had weight averages that were based on evidence [50, 53].

Although the statistics of insurance enterprises could not validate that excess weight directly caused increased mortality rates, the correlation was significant enough for insurers to adjust rates accordingly. The correlation, though debated, was also compelling enough for many health professionals to include it as part of their medical advice. Dublin's charts were published in popular newspapers and magazines like *The New York Times* and *McClure's Magazine*, which created an initial public awareness. Other life insurance studies confirmed that as excess bodyweight increased, life expectancy decreased. From 1900 to 1910, an increasing number of Americans were interested in knowing their exact weight at the doctor's office or with home scales. Weighing spring scales with weight charts were sold in increasing quantities throughout the following decades. In the years following 1910, it was common for middle-class families to pay close attention to standardized weights for children [51, 52].

By the 1930s, the medical profession no longer debated the health implications of increased fat mostly due to the insurance industry's continuing studies. In 1930, Louis Dublin published a paper that detailed the specific problems that occurred more frequently among individuals who were obese such as heart disease, diabetes, kidney disease, atherosclerosis, and brain hemorrhages. This paper was a historic turning point that resulted in increased research to investigate the link between excess weight and the large array of health problems. This paper, while partially flawed and not representative of the whole population, was viewed as compelling evidence of the risks associated with being overweight. Within 10 years, excess weight went from a topic that concerned only a few in the medical profession to being seen as a significant medical issue [49].

In the following years, it became evident that obesity was rarely caused by medical abnormalities within the body as it was previously thought. It also became evident that people generally underestimated what they consumed. After the 1930s, it was no longer unknown why people gained excess weight. Obesity appeared to be an accessible problem to solve. Education was the main intervention as doctors taught the calorie equation to their patients. While some individuals who were overweight successfully and permanently lost weight by reducing intake and increasing activity, most failed to do so. From the 1930s onward, a variety of methods were used to assist in weight loss. Drugs and hormones were prescribed that decreased appetite or increased metabolic rate such as dinitrophenyl and amphetamines. Diuretics and formula meal replacements were also commonly taken. It became apparent that the brain played a considerable role in weight gain, and some treatments took a psychological approach such as group therapies to target food addiction, loneliness, anxiety, and depression. As a whole, no method had a moderate or high success rate in reducing weight in the long run [49, 51].

In 1952, the director of the National Institutes of Health declared that obesity was a primary national health concern [49, 51]. At the same time, studies were being conducted on the behavioral management of obesity [54, 55]. These studies on "self-control of overeating" were the first to describe behavioral principles (e.g., stimulus control, shaping) that are still used in obesity management today to improve diet and physical activity. In 1973, a conference was held at the National Institutes of Health to bring experts studying obesity together and discuss "the need for heightened research on psychological, physiological, and biochemical determinants of this important health derangement" [56].

By 1980, there was significant and dramatic increase in the rates of adult obesity [57]. The prevalence of adult obesity had increased from 14.5 to 22.5 % over the course of about 15 years [57]. It was at this time that some of the first behavioral treatments for obesity in children were being published [58, 59]. Epstein's pioneering work in this field provided healthcare professionals with a model for how to promote healthy lifestyles in children and adolescents [59].

By early 1990, the attention shifted to the increase in childhood obesity. An article in *Science* discussed obesity alongside pressing conditions facing US adolescents: suicide, pregnancy, and decline in college aptitude test scores [60]. By the early turn of the century, considerable attention was being given to the comorbidities associated with childhood obesity. For instance, studies were beginning to demonstrate that obese children were experiencing hyperlipidemia and hypertension [61], type 2 diabetes [62], and atherosclerotic lesions [63]. Consequently, programs were developed in numerous settings to both prevent and treat obesity. In the traditional healthcare sense, these settings included but were not limited to hospitals, primary care, and specialty clinics. The need to deliver these services into the community also became apparent as many children that were most impacted were also less likely to seek medical care or be insured [64, 65]. Because children spend a majority of their day at school, interventions taking place at schools also became a priority.

Childhood Obesity Treatment Strategies

The numerous comorbidities associated with pediatric obesity make it clear that beginning the prevention and treatment of this condition in childhood is necessary. Overall, the most successful interventions use a multidimensional, family-based approach by focusing on modifications to diet, physical activity, and other lifestyle behaviors [66]. In a family-based obesity treatment program, the behaviors of both the parent and child are targeted with the ultimately goal to facilitate new healthy behaviors and a home environment that supports healthy eating and activity [66]. Since the home/family environment is a strong predictor of adolescent obesity [67], parents are viewed as the agents of change and their involvement and corresponding weight-loss success is critical to their child being successful in losing weight [68, 69]. Last, strategies used to modify behaviors include self-monitoring, stimulus control/cue control, and contingency management (e.g., positive reinforcement, social praise, rewards, and contracting) [66].

Several national committees have been formed to help provide childhood obesity treatment guidelines and recommendations. The US Preventive Services Task Force recommends pediatricians to screen for obesity in all children between 6 and 18 years of age and refer overweight and obese children to comprehensive behavioral treatment programs that focus on diet and physical activity, and provide behavioral counseling. Treatment should be moderate- (26–75 h) to high-intensity (>75 h). A treatment duration of 6 months and family involvement are also preferred [70]. Short-term benefits have been observed among obese children and adolescents that engage in moderate- to high-intensity behavioral interventions [71].

The Academy of Nutrition and Dietetics provides guidelines and recommendations for interventions targeting childhood obesity [72]. In addition, an expert committee comprised of representatives from 15 professional organizations, appointed experienced scientists and clinicians to develop recommendations regarding the prevention and treatment of childhood obesity [73]. The Academy discusses obesity prevention in terms of primary, secondary, and tertiary, while the expert committee uses a four-stage approach [72, 73]. The two approaches are discussed below, along with a brief example of primary, secondary, and tertiary prevention programs.

Primary Prevention

Primary prevention uses diet and physical activity messages or programs intended to prevent overweight or obesity or provide support to maintain weight. Primary prevention is targeted to all youth (i.e., population-wide intervention), without a specific focus on a particular weight status. Population-wide prevention, as is early intervention, is considered to be ideal in establishing healthy eating and physical activity habits before poor habits become ingrained. There is not a corresponding stage approach to primary prevention [72].

Primary prevention has taken place in childcare centers, schools, and community-based settings. Several primary prevention interventions have targeted preschool-aged children as young children are more responsive to behavior change compared to older children [74]. A number of these interventions have focused on improving nutrition and/or increasing physical activity. A recent trend in nutrition education programs is the use of garden-based nutrition education programs in childcare centers, schools, and community settings as a mechanism to learn about fruits and vegetables [75]. These primary prevention programs have shown to increase preference and consumption of fruits and vegetables, along with physical activity and science knowledge [76–79]. However, there is a dearth of studies that have focused on the use of garden-based nutrition education programs as a mechanism to prevent obesity or maintain weight status. Among Latino fourth- and fifth-grade students, Davis and colleagues [80] found that a 12-week, after-school gardening, nutrition, and cooking program not only increased fiber intake and decreased diastolic blood pressure, but it also reduced BMI and promoted less weight gain compared to a control group. More studies are needed to understand the association between nutrition education and obesity prevention and weight loss.

Secondary Prevention

Secondary prevention involves more structured intervention and strategies involving diet and physical activity intended to assist overweight or obese children with no weight-related comorbidities obtain a healthy weight. Secondary prevention corresponds to Stages 1–3 of the staged approach [72]. Stage 1 is referred to the Prevention Plus stage. In Stage 1, children who are overweight are encouraged to focus on these healthy habits and gradually improve BMI status. Families and care providers are encouraged to work together to identify health behaviors that most impact the child's energy balance. Once agreement has been reached on specific health behaviors, small and measurable steps should be taken to make changes. If the child has not made improvements in 3–6 months, Stage 2, Structured Weight Management, is encouraged. In this stage, children and families receive more structure and support for their targeted behavior change. Some of the main differences for this stage are providing the family with a planned diet, incorporating structured meals, and planned physical activity. Stages 3, Comprehensive Multidisciplinary Intervention, is suggested after Stages 1 and 2 have been attempted and do not appear intensive enough to curb the velocity of the child's weight gain. Some of the primary components of Stage 3 include a structured behavior modification program, systematic evaluation of body measurements and behavior change, and weekly appointments [73].

An example of a secondary prevention program is Epstein's Traffic Light Program (TLP) [81]. The TLP is a family-based behavioral treatment designed for overweight or obese children that focuses on modifying diet and physical activity. The purpose of the diet component of the TLP is used to decrease high energy density foods and increase low energy density foods [82]. Foods are categorized into the three colors of a traffic light based on their calorie and nutrient content.

- *Red* foods are high in calories and low in nutrient content. Anything above 5 g of fat and/or 15 g of sugar is considered a "red" food. Examples of these foods include potato chips, soda, and candy. It is recommended to eat these food sparingly and to eat seven or fewer *red* foods per week.
- *Yellow* foods are moderate in calories but include nutrients necessary for a balanced diet. Examples of these foods include skim milk, lean meats, and grains. It is recommended to eat these foods in moderation.
- *Green* foods are low in calories and high in nutrient content. These foods are primarily vegetables. It is recommended to eat these foods often.

Trials that use this program with children initially instructed parents and children to consume a restricted amount of calories (typically ranging from 900 to 1,200 kcal). This was later changed to 1,000 to 1,500 kcal/day [83].

In the physical activity component of the TLP, children and their parents are provided written manuals focused on advantages of increased physical activity and disadvantages of sedentary behaviors [84]. Physical activity is defined in terms of caloric expenditure and translated to activity points using number of calories burned in a 10-min period of the activity according to weight. Children and parents are taught to calculate the caloric expenditure of each activity in which they participate. Sedentary behaviors are defined as behaviors that compete for being active (e.g., watching television, playing videogames, talking on the phone). Sedentary behaviors, such as listening to music or completing homework, are not specifically targeted for reduction. However, participants are rewarded for a gradual increase in physical activity and a gradual reduction in sedentary behaviors. Once the participant reaches the goal of 15 or fewer hours of sedentary behavior a week or 150 activity points, they are expected to maintain this change.

Multiple investigations have found the TLP to be superior to control conditions in randomized studies. For example, Epstein and colleagues demonstrated that receiving the TLP is superior to no treatment [85] and to an attention placebo control condition [86, 87]. Perhaps the most impressive finding is that children who received the TLP demonstrated maintenance of effects in 10-year follow-up studies [88, 89].

Tertiary Prevention

Because behavioral interventions are not successful for all obese children, and the long-term success rate at 2 years post intervention is low [90], tertiary prevention was developed. Tertiary prevention is the most intensive and comprehensive treatment for overweight and obese children with comorbidities and the severely obese youth. The strategy is to resolve weight-related comorbidities or at least reduce their severity. Tertiary prevention corresponds to Stage 4, Tertiary Care Intervention [72]. Stage 4 is the final stage offered to some severely obese youth after Stages 1–3 do not appear to influence weight change. In other words, when behavioral and lifestyle changes are deemed unsuccessful among the severely obese, medical treatment is prescribed in the form of drug therapy or weight-loss surgery [73]. Compared to behavioral interventions, less is known about using medical treatment to alleviate childhood obesity. Medical treatment is seldom performed and is not the preferred choice of treatment [90].

Orlistat (Xenical; Roche Products), which is a gastrointestinal lipase inhibitor, is the only form of prescription weight-loss medication that is approved by the US Food and Drug Administration (FDA) for obesity treatment with adolescents 12 years of age and older [91]. Orlistat blocks the absorption of fat in the intestine by inhibiting lipase activity. Because Orlistat may reduce the absorption of fat-soluble vitamins, the FDA recommends children on Orlistat treatment take a daily multivitamin supplement that contains vitamins A, D, E, and K [91]. In addition, every meal should have no more than 30 % calories from fat. A non-prescription, reduced-strength version of Orlistat (Alli;

GlaxoSmithKline) was FDA-approved in 2007 for adult use, but not adolescents. Several studies have demonstrated the safety and efficacy of Orlistat on weight loss in obese adults [92–94]. Among children and adolescents, Orlistat is effective; yet, side effects (e.g., fatty/oily stool, fecal urgency) are common [95–99].

Sibutramine was briefly FDA-approved in 2009 for adolescents 16 years and older and considered to be effective in decreasing BMI [100–102]. Among adults, this drug treatment was associated with weight loss and maintenance [103, 104]. However, in 2010, this medication was withdrawn because a large clinical trial reported increased risk of non-fatal myocardial infarction and non-fatal stroke after long-term use (i.e., average 3 years) among older adults with pre-existing history of cardiovascular disease, type 2 diabetes, or both [103]. Similar, but less severe side effects (e.g., increased heart rate and blood pressure), had been observed among adolescents [100, 102].

Although weight-loss surgery for adolescents was first reported in 1980, it was not until 2004 that surgical and pediatric experts recommended this strategy as an appropriate treatment for severely obese adolescents [105]. There are several criteria that adolescents must meet to be eligible for the surgery [106]. Adolescents must have failed at least 6 months of a structured weight-loss program. A BMI in the 99th percentile with either serious comorbidities (e.g., type 2 diabetes, moderate, or severe obstructive sleep apnea) or other comorbidities (e.g., hypertension, insulin resistance, impaired quality of life or activities) is required. A BMI in the 99th percentile is equivalent to having an adult BMI greater than 35 (with serious comorbidities) or greater than 40 (with other comorbidities), which are the BMI criteria for adults to be eligible for weight-loss surgery [107]. Adolescents must also have reached 95 % of skeletal maturity based on radiography and reached a puberty maturity of a Tanner stage IV or V. Psychologically, adolescents must exhibit that they understand the dietary and physical activity changes that will be required of them for optimal post-operative success and the potential risks and benefits of surgery. Last, a supportive network needs to be in place during pre- and post-operative procedures [106].

The most frequent weight-loss surgery procedures conducted on adolescents include the roux en Y gastric bypass (RYBG), adjustable gastric banding (AGB), and the laparoscopic sleeve gastrectomy (LSG), with RYBG being the most common of the three procedures. RYBG procedure reorganizes the gastrointestinal tract to bypass the stomach and duodenum and creates an egg-size pouch. This new pouch is limited by the amount of food that it can hold. The concern with this surgery is that nutrients will not be absorbed properly due to the reconfiguration of the gastrointestinal tract. Specifically, deficiencies in thiamine, iron, calcium, and vitamins B12 and D have been observed [108, 109]. RYBG has been successful in helping adolescents lose weight and decrease cardiovascular risk factors, including elevated glucose (i.e., fasting glucose and HbA1c) and lipids (i.e., LDL-cholesterol and triglycerides) [110–112].

AGB and LSG are appealing to adolescents because they avoid intestinal bypass. AGB is a laparoscopic surgical procedure where a saline-filled band is placed around the stomach, just below the junction of the esophagus. This restrictive procedure creates a small gastric pouch. A saline solution is injected through a port surgically implanted on the abdominal wall under the skin when there is a need to adjust the band [72, 113]. AGB has been associated with helping adolescents lose significant amounts of weight and improve quality of life and depressive symptoms [114–116]. However, AGB is not FDA-approved for adolescents, and the information made available is through clinical trials designed to investigate the safety and effectiveness of the procedure [72]. Complications that occur among some recipients of AGB are band slippage (or band dislocation) which can lead to band erosion or pouch dilatation and require surgery to correct [117]. Over the years, this procedure has become the least popular of the three [118].

LSG is a procedure where a significant portion of the stomach is surgical removed. Specifically, the stomach is stapled into a smaller pouch that is the shape of a sleeve, banana, or half-moon tube. This results in individuals feeling fuller sooner and increases satiety [119]. It is hypothesized that greater satiety occurs because less ghrelin (i.e., hormone that stimulates hunger) is secreted by the lining of the fundus as a consequence of the fundus being resected in the gastrectomy [120]. Short-term data

suggest that it is safe and effective in helping adolescents lose weight and improve quality of life [121–123]. Trends indicate that this procedure is increasing in popularity [118]. Popularity is not only related to the positive outcomes of the surgery, but also because LSG is (a) surgically less technically challenging compared to RYBG and (b) does not involve implantation of an artificial device like AGB [124]. However, the stapling does place individuals at risk for post-surgery complications, and the procedure is irreversible [119]. Data that follow these adolescents into adulthood are needed to understand the sustainability of their weight loss and the reduction of their comorbidities. In addition, clinical trials that compare all three surgical methods are needed.

Future Directions

While current treatment strategies to reduce childhood obesity have shown some progress, childhood obesity remains a serious concern due to its high prevalence rate [1]. In order to further decrease the prevalence of obesity in children and adolescence in the future, more advanced strategies need to be implemented and newer observational and experimental research must be conducted.

Critical Periods for Weight Gain

An important aspect in attempting to reduce the prevalence of childhood obesity in the future is to identify periods of critical weight gain. Weight gain may not necessarily follow a smooth, continuous pattern. If there are instances where weight gain is disproportionally accelerated, it is essential to attempt to understand the fundamental causes and address them. A suspected period of significant weight gain among children has been during summer vacation and winter holiday break. During the holiday season, children from third to fifth grade gain an average 1.3 lb in weight and grew an average 0.3 inches in height; yet, this resulted in no significant difference in BMI [125]. In contrast, summer weight gain is an order of magnitude greater than over the general school year [126]. Fitness progress from school-based interventions is also lost during the summer vacation [126, 127]. An area for future development could include analyzing dietary assessments, along with physical activity, in children throughout an entire year in attempt to map changes in food consumption and physical activity. Data should also be collected on the environmental changes that may occur. Since informal childcare is linked with increased risk of obesity, summer weight gain could be accounted for by the different lifestyles under day-care centers, babysitters, and relative care [128].

Use of Social Media Marketing to Target Adolescents for Nutrition and Physical Activity Information

Social marketing is a method used to alter or maintain people's behavior and ideas for the benefit of society. It proved to be successful at targeting public health issues such as vaccination, breast-feeding, and tobacco usage. Social marketing has made notable progress in increasing exercise and improving diet among children [129]. Most methods of social marketing concerning childhood obesity that targets children include integrated school programs, advertisements, and books.

According to PEW Research Center 2015 data, 73 % of adolescents have smartphones, while 71 % use more than one social network site [130]. This indicates a potential setting to use as social marketing to decrease the prevalence of childhood and adolescent obesity [131]. While many programs use

social media for social marketing, there is little research on the effectiveness on targeting adolescents [132]. This may be an area for future development. In conjunction with artists, athletes, and entertainment figures that are popular among adolescents, information may be used to alter the behavior of overweight or obese children and adolescents. More research is necessary to present data on obese adolescents to understand whether variances in ethnicity, gender, socioeconomic status, and geographic status affect the level of participation with social media and technology-driven interventions. Further research is also needed to recognize what elements can be merged into social media that will increase the effectiveness of interventions to decrease the prevalence of childhood obesity. Even though social media marketing is not likely to be successful at reducing rates of obesity independently, it may be significant in combination with other interventions.

Conclusion

Although childhood obesity rates for the most part are stabilizing or plateauing, overall the prevalence rates remain high, and obesity-related comorbidities are influencing the physical, physiological, and psychological health of children. Several measurement guidelines and methodologies have been developed to assist with identifying children at-risk for obesity as well as those that are obese. The methodologies used to measure weight and adiposity each have their own sets of limitations; yet, when used together, they can build a comprehensive body composition profile. Guidelines by national organizations and committees, along with structured interventions and corresponding strategies, have been created to assist with lowering the weight status of overweight and obese children and related comorbidities. A multidimensional family-based behavioral approach that focuses on diet, physical activity, and behavior modifications has gained the most traction. For severely obese children that do not respond to behavioral interventions, medical therapy is available. Although medical therapy is considered safe and effective, it is not the preferred choice of treatment. Overall, significant gains have been made in understanding and treating pediatric obesity. Despite these gains, many children and families remain significantly impacted by this disease. Innovation from both researchers and healthcare providers is needed to further stem the tide of this epidemic.

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