Epidemic obesity in children and adolescents: risk factors and prevention

Eun Young Lee[1], Kun-Ho Yoon (✉)[1,2]

[1]Division of Endocrinology and Metabolism, Department of Internal Medicine, Seoul St. Mary's Hospital, College of Medicine, The Catholic University of Korea, Seoul 06591, Korea; [2]Institute of Catholic Ubiquitous Health Care, The Catholic University of Korea, Seoul 06591, Korea

Abstract   The prevalence of obesity among children and adolescents (aged 2–18 years) has increased rapidly, with more than 100 million affected in 2015. Moreover, the epidemic of obesity in this population has been an important public health problem in developed and developing countries for the following reasons. Childhood and adolescent obesity tracks adulthood obesity and has been implicated in many chronic diseases, including type 2 diabetes, hypertension, and cardiovascular disease. Furthermore, childhood and adolescent obesity is linked to adulthood mortality and premature death. Although an imbalance between caloric intake and physical activity is a principal cause of childhood and adolescent obesity, environmental factors are exclusively important for development of obesity among children and adolescents. In addition to genetic and biological factors, socioenvironmental factors, including family, school, community, and national policies, can play a crucial role. The complexity of risk factors for developing obesity among children and adolescents leads to difficulty in treatment for this population. Many interventional trials for childhood and adolescent obesity have been proven ineffective. Therefore, early identification and prevention is the key to control the global epidemic of obesity. Given that the proportion of overweight children and adolescents is far greater than that of obesity, an effective prevention strategy is to focus on overweight youth, who are at high risk for developing obesity. Multifaceted, comprehensive strategies involving behavioral, psychological, and environmental risk factors must also be developed to prevent obesity among children and adolescents.

Keywords   obesity; children; adolescents; epidemiology; risk factor; prevention

Introduction

In recent decades, obesity in children and adolescents (aged 2–18 years) has emerged as a serious health issue worldwide, including in Asian countries. The effect of obesity is evidenced in three aspects: (1) continuing obesity after adulthood [1,2]; (2) increased risk for diseases, such as type 2 diabetes, cardiovascular disease, chronic kidney disease, and cancer [3]; and (3) increased mortality and premature death [4,5].

Childhood obesity is linked to adult obesity [1,2]. A meta-analysis showed that obese children had five times higher risk of adult obesity than normal-weight children [6]. In another study, about 80% of obese adolescents remained obese in adulthood [7]. Childhood obesity affects various physical and mental health aspects during childhood (Table 1) [8–11].

One of the major consequences of obesity is type 2 diabetes. More than 85% of people with type 2 diabetes are overweight or obese [12]. In addition, the trends of the prevalence and incidence of type 2 diabetes are similar to those of obesity. Among children and adolescents, the incidence of type 2 diabetes has increased considerably as the prevalence of obesity has increased. Before the mid-1990s, only 1%–2% of children with diabetes were diagnosed with type 2 diabetes. However, recent studies have shown that the incidence of type 2 diabetes has increased up to 45% of all new cases of diabetes in children and adolescents [13,14]. Childhood obesity also increases the risk of cardiovascular diseases and mortality in adulthood. More than 50% of children with obesity have been reported to have at least one abnormal cardio-

Table 1 Complications of childhood and adolescent obesity

Psychosocial	Poor self-esteem, anxiety, depression, eating disorders, social isolation, lower educational attainment
Neurological	Idiopathic intracranial hypertension (Pseudotumor cerebri)
Endocrine	Insulin resistance, type 2 diabetes, precocious puberty, polycystic ovary syndrome (girls), hypogonadism (boys)
Cardiovascular	Dyslipidemia, hypertension, left ven tricular hypertrophy, coagulopathy, chronic inflammation, endothelial dysfunction
Pulmonary	Obstructive sleep apnea, asthma, exercise intolerance
Gastrointestinal	Gastresophageal reflux, nonalcoholic fatty liver disease, steatohepatitis, gallstones, constipation
Renal	Glomerulosclerosis
Dermatologic	Acanthosis nigricans, intertrigo, hidradenitis suppurativa, furunculosis, stretch marks
Musculoskeletal	Slipped capital femoral epiphysis, Blount's disease, forearm fracture, back pain, flat feet
Long-term risks	Carotid artery atherosclerosis, color ectal carcinoma, ischemic heart disease, stroke, short life span, premature death

metabolic profile [15]. Cardiovascular risk ratios, such as low HDL cholesterol, high systolic and diastolic blood pressure, and high triglyceride level, increased with the severity of obesity [16]. The relative risk for obesity-related diseases, such as hypertension, stroke, and ischemic heart disease, was 1.5- to 5.1-times higher in children with obesity than those without obesity [17]. Earlier study showed that body mass index (BMI) at age 13 was associated with mortality from coronary heart disease in adulthood (hazard ratio, 1.24 per 1-unit increase in BMI z-score in boys) [4]. In a 40-year follow-up study, overweight and obesity in childhood were strongly associated with 3.5-times higher cardiovascular mortality in adulthood [18]. Another study demonstrated that children with obesity had increased rates of premature adult mortality, with a relative risk of 1.4–2.9 compared with those without obesity [5,17].

Obesity is a multifactorial disease, and various genetic, behavioral, and sociocultural characteristics can affect its development; thus, early management of overweight and obesity by altering eating behavior and physical activity may be critical. Although many studies have investigated the effects of family-, school-, and community-based strategies to prevent obesity, these attempts showed minimal effect [19,20]; the cost-effectiveness of obesity prevention policies remains unclear [21].

Epidemiology of childhood and adolescent obesity

Although obesity rates vary among countries, its prevalence has increased over the past 40 years. Since 1980, obesity among children has doubled in more than 70 countries and has approximately tripled in some developing countries [22,23]. The rate of increase in obesity is higher in children than that in adults [22]. In addition, apart from a recent plateau in the prevalence of adult obesity in high-income countries, the prevalence of childhood obesity has continuously increased regardless of socio-demographic strata [22]. The prevalence of overweight and obesity in children and adolescents has increased significantly in developed countries; the prevalence reached 23.8% for boys and 22.6% for girls in 2013 compared with 16.9% for boys and 16.2% for girls in 1980 [24]. In developing countries, the prevalence also increased from 8.1% in 1980 to 12.9% in 2013 for boys and from 8.4% in 1980 to 13.4% in 2013 for girls [24].

In 2015, 107.7 million children were considered obese worldwide [22]. Although the overall prevalence of childhood obesity across 195 countries was reported as 5% in 2015, it was higher in countries with higher socioeconomic level [22]. The prevalence of childhood obesity was more than 10% in developing countries and even higher (> 20%) in developed countries [24]. Some Asian countries, such as Vietnam (1.6%) and Bangladesh (1.2%), had relatively low rates of childhood obesity [22]. However, the increased rates did not differ between Asian and Western countries. Moreover, in absolute numbers, China and India had the highest number of children with obesity [22,25].

The influence of socioeconomic and cultural environments on childhood and adolescent obesity is more crucial than that of genetic factors. The overall prevalence of childhood obesity was greater in countries with higher socioeconomic level than those in lower socioeconomic level countries [22]. In a community-based study, we observed that the prevalence of obesity increased in children from low-income families. Non-parental caregivers were also associated with an increase in childhood obesity (unpublished data). Similar results were found in previous studies [26–28]. Countries that are experiencing rapid development showed marked increases in childhood obesity. In China, the number of overweight and obese children aged 7–18 years increased by 28 times from 1985 to 2000 [29].

Risk factors

Genetic

Parental BMI is an important predictor of childhood obesity, which suggests a genetic effect [30]. Several genes have been linked to obesity. Although obesity is mostly polygenetic, some single-gene defects have been found to cause obesity. A mutation in the melanocortin 4 receptor gene (*MC4R*) is the most common gene defect, which is associated with a severe, early form of obesity in children [31]. The single nucleotide polymorphism (SNP) on the fat mass and obesity-associated gene (*FTO*) is linked to obesity [32]. Other genetic associations with obesity are defects in leptin, leptin receptor, proopiomelanocortin, and proprotein convertase [10]. Although genetic defects increase individual susceptibility to obesity, they account for less than 1% of the cases [33]. In addition, genetic susceptibility may affect weight when coupled with other contributing environmental and behavioral factors. Therefore, genetic factors may not be the sole cause of the marked increase in childhood obesity although they may play an important role in its development.

Behavioral

Diet has been studied extensively as a cause for obesity. Increased consumption of fast food and sugar-sweetened beverages is directly tied to the childhood obesity epidemic; over the last two decades, fast food consumption has increased threefold, in accordance with an increased prevalence of childhood obesity [34,35]. Frequent fast food consumption (⩾ 2 times/week) was associated with an increased BMI [36]. A prospective study observed that the obesity risk increased by 1.6 times for each additional serving of sugar-sweetened drink [37]. Obesity is often assumed to be caused by increased fat intake, but evidence suggests an inconsistent association between fat intake and obesity in children and young adults [38,39]. Furthermore, National Health and Nutrition Examination Survey (NHANES) data showed that fat consumption among US children has decreased over the past few decades, whereas the prevalence of childhood obesity has increased [40,41]. A recent study suggested that the type of dietary fat (e.g., trans fat) might be more important than total fat intake [8]. Eating patterns, such as number, regularity, and duration of meals, are also traditionally considered as obesity-related eating behavior [42]. In our previous study, we observed that habitual eating in the absence of hunger was significantly associated with obesity after adjusting for confounders [43]. This type of eating behavior in response to presence of food or an emotional state is defined as disinhibited eating, which leads to weight gain and binge eating in adults [44,45]. Consistent with our results, previous reports showed that girls eating in the absence of hunger had 4.6-times greater risk of being overweight [46].

Lack of physical activity and increased sedentary time also play important roles in the development of obesity. In a cross-sectional study, the obesity risk decreased by 10% for each hour of moderate-to-vigorous physical activity per day [47]. A sedentary lifestyle per se has been recognized as a risk factor for obesity and related diseases, independent of physical activity. Several studies have demonstrated an association between obesity and time spent viewing television, playing video games, or using a computer [48,49]. Moreover, in a national study, television watching was more closely related to adiposity than vigorous physical activity [50]. In our previous study, we observed that sedentary time, as measured by extracurricular study time, was associated with increased risk for obesity [43]. Shortened sleep duration is another risk factor for obesity. Several studies have found that sleep duration and/or sleep quality were associated with obesity [51–53].

Psychological

Children are more susceptible to psychological and emotional stress than adults. Unresolved stress affects eating behavior and often leads to increased food volume, eating speed, irregular meal times, and consumption of fast food and snacks. Consequently, these maladaptive coping strategies contribute to excess weight gain [54,55]. In several studies, environmental factors, including psychological stress, have demonstrated substantial influence on development of childhood obesity [56,57]. In our previous study, we also observed that eating under stress and impulsive eating tended to be worse among children with obesity compared with those without obesity [43]. This finding suggests that dietary habits that are driven by psychological causes may be important risk factors for obesity.

Despite the lack of conclusive causal relationship, previous studies showed that depression, anxiety, and low self-esteem were frequently observed in children with obesity [58–60]. Body dissatisfaction is another important psychological factor for obesity, especially in girls. A linear relationship between body dissatisfaction and increasing BMI was found in girls, whereas a U-shaped relationship was observed in boys [61,62].

Environmental

Environmental factors and lifestyle preferences may play major roles in the increasing prevalence of childhood obesity worldwide [63,64]. Environmental factors influencing children's food intake and physical activity are based on various settings such as home, school, and community [65]. As parent–child interactions can affect children's

behavior, such as their food choices and level of physical activity, the family environment plays a crucial role in childhood obesity [8]. These factors include family preferences with regard to food type and amount, meal time, dining out, and lifestyle (whether they are sedentary or physically active) [8,66]. A previous study demonstrated that living with an overweight mother and in a single-parent household was associated with childhood obesity [67]. School is where children spend most of their time and receive their primary education; therefore, school can influence children's behavior regarding food choices and physical activity [8]. The presence of fast food and soft drink vending machines in schools could also affect children's eating behavior [68]. In the community, the accessibility to healthy food and the presence of sidewalks, bike paths, and parks may affect the general lifestyle of residents [65].

Children and adolescents are more likely to be exposed to obesogenic environments as societies industrialize. Prepared or instant food are prevalent, provide large portion sizes and high caloric intake, and have relatively lower price than fresh vegetables or fruit [63,69]. Commercial advertising and marketing trends are focused on high glycemic foods, sugar-sweetened beverages, snacks, fast food containing excess fat, and large portion sizes. In those advertisements, children are often the target of the food industry. In US and Britain, children are usually exposed to about 10 food commercials per hour of television time [8]. In the Middle East, television advertising is mainly composed of soft drinks (37%), snacks (24%), confectionery (21%), and fast food (18%), especially during afternoon when children tend to watch television the most [70]. Such advertisements can affect not only children's immediate food choices but also their long-lasting taste preferences. In fact, children who were exposed to advertisements showed a high likelihood to choose an advertised food [71].

Opportunities for youth to be physically active have decreased for various reasons. The majority of children in the past walked or rode bikes to school, use a parent's car, or take a bus [72]. Using lift, remote control, and even drive-through restaurants could reduce physical activity [8]. Television and computer use is associated with prolonged sedentary time and decreased physical activity [73]. In addition, the widespread use of smart phones and tablets may erode physical activity time [74]. This lifestyle trend could make children obese. Easy access to television and the Internet could also make children more exposed to food commercials. Previous studies demonstrated that children were exposed to about 10 unhealthy food commercials per hour of television time [75,76].

Sociocultural factors also considerably affect the development of obesity. Our society tends to use food as a reward and a social ritual [66], thereby promoting the development of unhealthy relationship to food and increase the risk of obesity. An obsession with education could also decrease physical activity and increase sedentary time. Late-night studying is also accompanied by consumption of snacks, sodas, or fast food [54]. In our study, we observed an association between obesity and sedentary time, which was measured as extracurricular study time [43]. We also found that extracurricular study time was associated with more frequent fast food and/or soda consumption. This may aggravate childhood obesity through a vicious cycle of increased sedentary time and subsequent food intake.

Biological

Adipokines are one of the most studied biomarkers of obesity. Previous studies found various adipokines related to childhood obesity, such as leptin, adiponectin, visfatin, resistin, and adipocyte fatty acid binding protein [54]. A recent study showed that the production of lipopoly-saccharide binding protein in relation to microbial translocation was associated with increased BMI and insulin resistance in adolescents [77]. Among lipid profiles, the triglyceride-to-HDL cholesterol (TG/HDL-C) ratio showed an association with increased BMI and cardiometabolic risk factors [78]. Furthermore, the TG/HDL-C ratio is proven to be a good marker for insulin resistance and diabetes [79,80]. In our previous study, we found that the triglycerides/glucose index (TyG index, calculated by triglyceride [mg/dL] $\times$ fasting glucose [mg/dL] $\times$ 0.5) was associated with increased BMI and insulin resistance. The TyG index was also correlated with the TG/HDL-C ratio [81].

Prevention and management

Understanding childhood and adolescent obesity should encompass behavior, including eating and physical activities, and psychological and environmental factors. Childhood is a focal period for forming behavior related to eating and physical activity, and various environmental factors influence such behavior [82]. Many guidelines and reviews for childhood obesity have suggested multi-disciplinary strategies, including modifying environmental risk factors (Table 2) [10,25,83,84].

Although a recent Cochrane review concluded that current strategies to improve childhood obesity were weakly or inconsistently effective, a previous report suggested that a comprehensive approach including school life, home activities, environmental and cultural practices, and supportive parents and teachers would be promising policies and strategies [85,86]. A US preventive services task force reported that effective interventions are multi-faceted; that is, they incorporate information about eating,

Table 2 Comprehensive approach for childhood and adolescent obesity

Diet	Avoid consumption of calorie-dense, nutrient-poor foods
	Encourage consumption of whole fruits vs. fruit juice
	Eat breakfast daily
	Avoid skipping meals
Physical activity	Encourage at least 20 (optimally 50) minutes of vigorous physical activity at least 5 days per week
	Balance technology-related screen time
Psychological	Goal setting
	Contingent rewards
	Problem solving
Environmental	Foster healthy sleep patterns
	Encourage breastfeeding of infants
	Involve the entire family rather than only the individual
	Assess family function and address family stressors
	Incorporate school- and community-based engagement
	Apply a tax on unhealthy foods (e.g., fast foods, soft drinks, confectionery, and snacks)
	Label food with calories, ingredients, and nutrients

exercise, stimulus control, goal setting, and problem solving; include sessions targeting both parent and child; and provide supervised physical activity opportunities [83].

Prevention and management of obesity ultimately targets the negative energy balance by eating less and engaging in physical activities. Although this strategy seems simple, long-term weight reduction and/or maintenance of reduced weight is difficult to achieve. In adult studies, the actual maximum weight loss was only 10%, which again increased within a year [87]. Considering the relative intellectual and psychological immaturity of children and adolescents, managing obesity in these groups may be difficult. In addition, children are more susceptible to environmental factors, such as portion size or advertising. For these reasons, approaches to childhood obesity may require intensive and long-term treatment. The US preventive services task force report emphasized that intensive behavioral interventions were effective in programs of more than 26 contact hours, but the study did not find adequate evidence of the effectiveness for less intensive interventions [83]. In our previous study, we demonstrated that an intensive, integrated, and long-standing school-based program was associated with decreased BMI among children and adolescents aged 9–14 years [88]. National policies are also important environmental factors to prevent obesity. To reduce the consumption of unhealthy foods, some parts of US and Canada have applied a small tax on these items [89]. In Australia and New Zealand, national heart foundation run "Pick and Tick" symbol program, indicating that a food met certain nutrition standards [90]. This program can help people identify healthy foods easily. Some European countries, such as Sweden, Norway, Denmark, and Austria, imposed some regulations on television advertising to young children [91].

The key to successful obesity control is prevention rather than treatment. Once developed, managing obesity is difficult and often unsuccessful [11]. Furthermore, in most countries, the prevalence of overweight is higher than obesity among children [24]. Therefore, overweight children who are at high risk for obesity but who are not yet obese should be the target to prevent childhood obesity. A study has observed that children who were overweight at the age of 5 years had four-fold higher risk of becoming obese between ages 5 and 14 [92]. In our previous study, we observed that overweight children were more likely to change their BMI category, whereas most children with normal weight (95.3%) or obesity (91.2%) at baseline remained in the same BMI categories during one year of follow-up [43]. This finding implies that targeting overweight children may be more effective in preventing obesity than treating obese children. Hence, identification of risk factors and intervention in overweight children who are at high risk for obesity is an effective strategy to prevent childhood obesity. Lastly, childhood weight management strategies should begin at the earliest possible age [93].

Conclusions

Childhood and adolescent obesity has emerged as a major health problem in developed and developing countries. This condition is implicated in many chronic diseases and can lead to increased mortality and premature death. As childhood and adolescent obesity tracks adulthood obesity, its prevention could reduce adult obesity-related complications. Most interventions for childhood and adolescent obesity have used either family- or school-based programs. However, no single intervention can halt the rise of the growing obesity epidemic. Addressing childhood obesity also requires consideration of environmental factors and critical developmental periods when behavioral responses are formed. In addition, children at high risk for developing obesity should be identified and managed early to prevent obesity. Comprehensive and intensive interventions can improve weight status. Although further studies are needed to support the effectiveness and feasibility of widespread implementation of interventions, efforts to prevent and respond to childhood and adolescent obesity should be sustained.

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Compliance with ethics guideline

Eun Young Lee and Kun-Ho Yoon declare that they have no conflict of interest. This manuscript is a review article and does not involve a research protocol requiring approval by the relevant institutional review board or ethics committee.

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