

Potential mechanisms in childhood obesity: causes and prevention

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This chapter reviews the scientific evidence on obesity in children. It provides a synthesis of research findings, including the scope of the global problem, prevalence trends, risk factors, prevention, and recommendations made by leading experts and health organizations. In this chapter, we use “children” to mean both children and adolescents, including the age range 0–19 years.

Childhood obesity rates have increased over the past two decades in most countries worldwide, while the prevalence seems to have plateaued in certain high-income countries [1]. This stabilization in some high-income countries is due in part to campaigns and policy changes made by those countries within the past decade. The trends in childhood obesity rates and the large variations in the rates and trends between countries provide useful insights into the drivers of the epidemic. Multiple

biological, behavioural, family, and societal factors affect a child’s risk of developing obesity. Because children are different from adults, special attention and efforts are needed to help them develop healthy eating patterns and physical activity behaviours and maintain an optimal body weight. Furthermore, childhood is an important stage in life at which to tackle the obesity epidemic, considering that childhood obesity tends to track into adulthood.

The global childhood obesity epidemic: trends and variation between countries

The obesity epidemic has become a global public health crisis. Childhood obesity (including overweight and obesity) is an important contributor to adult obesity, diabetes, and other noncommunicable chronic diseases worldwide. Data have shown a substantial increase during the past

three decades in the prevalence of obesity in children in both high-income countries and low- and middle-income countries, although there are large differences between countries in the prevalence rates and increasing trends [2–7]. Over the past two decades, many developing countries, such as Mexico, China, and Brazil, have experienced an increase in the prevalence of obesity that is more rapid than the increase in some developed countries, even though the prevalence rates are lower in developing countries. This suggests that childhood obesity is a growing problem in many developing countries, and thus it is an opportune moment for researchers to intervene.

A recent comprehensive study estimated the global, regional, and national prevalence of overweight and obesity in children and adults in 1980–2013 using data collected from a large number of countries [6].

The study reported that the prevalence had increased substantially in children in developed countries; in 2013, 23.8% (95% uncertainty interval [UI], 22.9–24.7%) of boys and 22.6% (95% UI, 21.7–23.6%) of girls were overweight or obese. The prevalence had also increased in children in developing countries from 1980 to 2013, for boys from 8.1% (95% UI, 7.7–8.6%) to 12.9% (95% UI, 12.3–13.5%) and for girls from 8.4% (95% UI, 8.1–8.8%) to 13.4% (95% UI, 13.0–13.9%). A large variation in the prevalence between countries was observed. The study concluded that obesity has become a major global health challenge; not only is the prevalence of obesity increasing, but also no national success stories have been reported during the past three decades. Urgent global action is needed to help countries to intervene effectively. Some of the study's conclusions are consistent with those of a previous study based on findings from approximately 75 countries, which also projected that the prevalence of childhood obesity would continue to increase unless effective programmes were implemented [7].

Recent data indicate that the prevalence of childhood obesity in some developed countries (e.g. some European countries and the USA) seems to have reached a plateau [1, 5, 8]. The stabilization is thought to be a result of programmes, including national policies, designed to prevent childhood obesity in those countries.

The global patterns of the childhood obesity epidemic (consistent increasing trends in a large number of countries, the large variations in the prevalence of obesity by country, the increasing trends within countries, and the levelling off or decline in some developed countries) also provide useful insights into the causes of the problem.

Causes and drivers of the global childhood obesity epidemic

Obesity is a result of a positive energy balance (i.e. energy intake that exceeds energy expenditure). Many factors affect an individual's eating and physical activity behaviours. The factors are more complex for children than for adults, because of the many differences between them. Many factors have contributed to the increase in the prevalence of obesity in children. Briefly, these factors include unhealthy eating patterns, lack of physical activity, increased sedentary behaviours (i.e. screen time), and short sleep duration (which results in a positive energy balance, and thus excessive weight gain), as well as other factors, such as parenting and family factors, school factors, social norms, and community food and physical activity environments that affect children's eating and physical activity behaviours [4, 9, 10].

During recent years, researchers and key related public health organizations, including the World Health Organization (WHO) and the United States Institute of Medicine (now known as the National Academy of Medicine), have argued that the increase in the prevalence of childhood obesity results from many changes in society; in particular, it is due to social and economic development and policies in the areas of agriculture, transportation, urban planning, the environment, education, and food processing, distribution, and marketing. These factors have contributed to unhealthy eating patterns, lack of physical activity, and increased sedentary behaviours in children. The worldwide increases in the prevalence of childhood obesity are attributable to a global shift in dietary patterns towards increased intake of energy-dense foods that are high in fats (saturated and trans-fatty

acids) and in sugars but low in other, healthy micronutrients. The trend towards decreased physical activity levels – because of the increasingly sedentary nature of recreational activities, changing modes of transportation, and urbanization – is an additional driver that compounds the global childhood obesity epidemic [5].

Table 9.1 lists a set of risk factors for excessive weight gain in children. Some of the biological, genetic, life-stage, lifestyle, and environmental risk factors are highlighted here.

Genetic factors (and gene–environment interactions)

A large body of evidence, including studies on twins, siblings, nuclear families, and extended pedigrees, has shown the heritability of obesity, including measures of body mass index (BMI) and body fat, especially in twin studies [11–13]. Advances in genotyping technologies have raised hopes and expectations that genetic testing will pave the way to personalized medicine and that complex traits such as obesity will be prevented even before birth [11]. For example, a recent systematic review and meta-regression analysis examined BMI heritability and differences in BMI heritability by population characteristics, such as sex, age, time period of observation, and average BMI, as well as by broad national-level socioenvironmental factors [13]. Based on findings from 32 twin studies in various countries worldwide, BMI heritability was found to range from approximately 30% to 90%, and the heterogeneity of BMI heritability was found to be significantly attributable to differences in study subjects' age, time period of observation, average BMI, and the economic development levels of the study populations.

Given the shifts in people's dietary and physical activity patterns under the influence of obesogenic

Table 9.1. Risk factors contributing to excessive weight gain in children

Category	Specific factors and examples
Genetic and biological predisposition	Some minority ethnic groups (e.g. Native Americans in the USA), high birth weight, rapid weight gain during infancy, early adiposity rebound
Dietary intake/food choices	Child feeding practices, energy intake, energy density of diet, consumption of sugar-sweetened beverages, large portion size, snacking
Physical activity and sedentary behaviours	Screen time, automobile use for transportation, decline in walking/cycling to school
Parental and family characteristics	Low family socioeconomic status in developed countries, high-income groups in developing countries, parental obesity, maternal diabetes, smoking during pregnancy, mothers who were overweight before the pregnancy, social deprivation, parenting practices, parental eating patterns and physical activity
Environmental risk factors	Community and school environments that contribute to energy overconsumption and inadequate physical activity, fast-food outlets, lack of park and recreation space, lack of health clubs, technological development
Factors with conflicting evidence or lack of adequate evidence (partially due to limited research)	Gut microbiota, duration of breastfeeding, maternal parity, maternal marital status at birth, delivery type, gestational weight gain, maternal postpartum weight loss, social norms, peer influence, ideal body type

environments, the fact that not all children become obese indicates the presence of susceptibility and resistance, as well as the importance of the effect of the interaction between genetic and environmental factors on development of childhood obesity. Paediatric obesity is a complex phenotype and is modulated by unique gene–environment interactions that occur during early periods of life. Susceptibility could be mediated through a failure of appetite regulation, leading to increased energy intake, or via diminished energy expenditure.

Risk factors during early life stages, including prenatal factors

Experiences during early life stages (including prenatal factors, such as exposures that women experience, and postnatal factors, such as infant and young child feeding) can have important, long-term impacts on future health. According to the International Society for Developmental Origins of Health and Disease (DOHaD Society), a poor start to life is associated with an increased risk of several disorders, especially non-communicable diseases, throughout

the life-course [14]. These diseases include obesity, cardiovascular disease, type 2 diabetes, osteoporosis, some forms of cancer, and some other diseases. The environmental exposures that affect future health and disease risk include parental lifestyle and diet, smoking, obesity, and exposure to chemicals that are endocrine disruptors or toxins. A growing body of evidence supports the statement of the DOHaD Society and argues for related interventions that target women, including young women, to ensure better pregnancy outcomes [14].

Many studies have been conducted to examine the effects of early-life factors on the risk of childhood obesity. Both prenatal factors, such as gestational weight gain, and postnatal factors, such as feeding practices during infancy, have been studied. Gestational weight gain is used as an indicator of prenatal factors. Research suggests that the offspring of overweight or obese women tend to have higher birth weights and more body fat, and have increased risks of developing obesity later in life [15]. A recent meta-analysis of findings from 12 cohort studies reported that the risk of childhood overweight/obesity was significantly

associated with excessive gestational weight gain. The combined odds ratio of excessive gestational weight gain and childhood overweight/obesity was 1.33 (95% confidence interval [CI], 1.18–1.50). The association was found to be robust. Adjustment for maternal BMI, investigation area, age of children, research type, and omission of any single study had little effect on the pooled estimate [16]. The mother–child association for childhood obesity may be partly related to the increased risk of gestational diabetes [15, 17].

A 2012 systematic review and meta-analysis examined the risk factors for childhood obesity that can be identified during infancy based on findings from 30 prospective observational studies that followed up children from birth to at least age 2 years [18]. The study reported significant and strong independent associations between childhood obesity and mothers who were overweight before the pregnancy, high infant birth weight, and rapid weight gain during the first year of life. The meta-analysis compared breastfed infants with non-breastfed infants and found a 15% decrease for breastfed infants in the likelihood of childhood overweight

(adjusted odds ratio, 0.85; 95% CI, 0.74–0.99; $I^2 = 73.3\%$; $n = 10$). For children of mothers who smoked during pregnancy, there was a 47% increase in the likelihood of childhood overweight (adjusted odds ratio, 1.47; 95% CI, 1.26–1.73; $I^2 = 47.5\%$; $n = 7$). The study reported that there was some evidence that the early introduction of solid foods was associated with childhood overweight. Conflicting evidence was found for duration of breastfeeding, socioeconomic status at birth, maternal parity, and maternal marital status at birth. There was inconclusive evidence (due to the limited number of studies) for delivery type, gestational weight gain, maternal postpartum weight loss, and “fussy” infant temperament [18].

A systematic review of 10 studies investigated the relationship between the types of food consumed by infants during the complementary feeding period and risk of overweight/obesity during childhood. The review concluded that high intakes of energy and protein, particularly dairy protein, during infancy could be associated with an increase in BMI and body fatness [19]. Another recent systematic review of 23 studies concluded that there is no clear association between the timing of the introduction of complementary foods and risk of childhood obesity, but that some evidence suggests that very early introduction of complementary foods (before age 4 months), rather than at age 4–6 months or after age 6 months, may increase the risk of childhood obesity [20].

Family environment, socioeconomic status, and parenting

Family environment is important for children’s health behaviours and outcomes. The relationship between family socioeconomic status and

obesity is complex, has changed over time, and varies between countries and even between population groups within the same country [21, 22]. In developed countries, children from a family with low socioeconomic status are more likely to be obese [23], whereas in developing countries, children from a family with higher socioeconomic status have a higher risk of being overweight or obese [24, 25].

The role of the environment in the link between parental obesity and child obesity is difficult to study directly and to quantify, but two lines of evidence suggest a non-genetic component: (i) studies that document dramatic increases in the prevalence of childhood obesity in developing countries where the populations adopt lifestyles typical of industrialized countries; and (ii) studies in developing countries that document the coexistence of underweight and overweight within the same family [26].

A growing number of studies are attempting to examine the effects of parenting practices on childhood obesity, but the understanding remains very limited [27–29].

Lifestyle factors

Dietary intake

Unhealthy dietary patterns, such as those that include energy-dense fast foods and processed foods, are risk factors for obesity [4]. Research, including intervention trials, has indicated that the consumption of sugar-sweetened beverages and the fructose they contain increases the risk of obesity and has contributed to the rising epidemic of childhood obesity [30–32]. Meta-analyses suggest that consumption of sugar-sweetened beverages may increase the risks of obesity, diabetes, metabolic syndrome, and cardiovascular disease in both children and adults [30, 32].

Short sleep duration

Systematic reviews and meta-analyses have reported an association between short sleep duration and risk of obesity in children [33, 34]. Recently, Fatima et al. reviewed 22 longitudinal studies, with subjects from diverse backgrounds, and reported an inverse association between sleep duration and BMI. The meta-analysis of 11 longitudinal studies, including 24 821 participants, showed that children who slept for a short duration had twice the risk of being overweight/obese compared with children who slept for a long duration (odds ratio, 2.15; 95% CI, 1.64–2.81) [33].

Screen time

Screen time is a major source of inactivity among children in many countries. Recently, the source of increased screen time has shifted from television viewing to the use of other devices, including smartphones and tablets. Previously, well-documented evidence, including from intervention trials, has linked time spent watching television with risk of obesity in children [35]. It is likely that the increasing use and influence of social media in children’s lives have also affected their eating patterns and physical activity behaviours, and thus could affect their weight. However, few recent studies have examined the impact of overall screen time and the impact of social media on risk of obesity in children.

Snacking

Children eat snacks often, which may contribute to their total energy consumption, especially in developed countries. The types of foods commonly consumed as snacks are often high in fats (saturated and trans-fatty acids) or sugars (i.e. potato chips, cookies) and thus add

considerably to daily energy intake and may affect energy balance.

Built and social environments

Built environment

The local community and school food environments, facilities, and services affect children's eating and physical activity behaviours. Children may buy food and beverage products from food stores close to home and school. School nutrition services, in particular school lunch, and school physical education affect children's energy balance. In addition, parental concerns about safety issues may limit a child's ability to play outdoors or walk to school.

Social norms and body image

Social norms affect people's behaviours, including eating and physical activity. Peer influence as a part of social norms may have an even greater impact on adolescents. Differences exist between countries and between ethnic groups with respect to ideal body type.

Other risk factors

Adiposity rebound

The timing of the adiposity rebound (the rebound in BMI in childhood) predicts later obesity. An early adiposity rebound in childhood predicts higher BMI levels in adolescence and adulthood and an increased risk for children of becoming obese as adults [36, 37].

The gut microbiota, prebiotics, and probiotics

Recent evidence suggests that the gut microbiota is involved in the control of body weight, energy homeostasis, and inflammation, and thus plays a role in risk of obesity;

prebiotics and probiotics have physiological functions that contribute to changes in the composition of the gut microbiota and may also affect appetite and weight status [38].

Stress

Some research suggests that stress during childhood and adolescence, including peer influence, is associated with obesity risk, but this is still not well understood [39, 40]. It has been suggested that high levels of stress may change eating patterns and increase consumption of highly palatable foods. Repeated high levels of stress and/or chronic stress may alter the biology of stress regulation and appetite/energy regulation; both of these components directly affect neural mechanisms that contribute to stress-induced and food cue-induced overeating of highly palatable foods [40].

Prevention of childhood obesity

Many studies have examined the prevention and management of obesity in children. Most of these studies have been conducted in high-income countries, and very little is known about the situation in low- and middle-income countries. Nevertheless, many useful lessons have been learned and some recommendations have been made (Table 9.2). The growing obesity problem is societal, and thus it demands a population-based, multisectoral, multidisciplinary, and culturally relevant approach [41]. Unlike most adults, children do not have much power to choose the environment in which they live and the food they eat. Furthermore, they also have a limited ability to understand the long-term consequences of their behaviours. Therefore, special attention and efforts are needed to help them develop healthy lifelong habits, to prevent obesity.

Various interventions conducted in countries worldwide have been reviewed to determine which programmes are successful and what research is needed for the prevention of childhood obesity [42, 5, 43, 44]. Many studies have been conducted to study prevention of childhood obesity, and mixed results have been reported [44–46]. Adequate evidence has been accumulated to support that interventions, especially school-based programmes, could be effective in preventing childhood obesity. Even if some of the interventions cannot reduce the prevalence of childhood obesity, they may still result in beneficial changes in other health outcomes, such as lowered blood pressure and improved blood lipid profile, as shown by recent systematic reviews and meta-analyses [42, 45–48].

In the most comprehensive systematic examination of childhood obesity prevention studies reported to date, the effectiveness of various childhood obesity prevention programmes was evaluated [42, 44, 47, 48]. The findings could help various stakeholders to understand the effectiveness of obesity prevention programmes for children and offer insights for future research and intervention development. The evaluation assessed 139 studies conducted in multiple settings in high-income countries during the past three decades, focusing on adiposity-related outcomes and strength of evidence. The strength of evidence varied by intervention strategy and setting. There was at least moderate evidence for school-based interventions, and about 50% of them reported statistically significant desirable effects for adiposity-related measures. The school-based studies that also included a home-based component had the highest proportion of studies with favourable results. Also, interventions conducted in multiple settings had more favourable

Table 9.2. Recommendations for promoting healthy eating and physical activity for obesity prevention in young people^a

Setting	Age group	Recommendations related to nutrition	Recommendations related to physical activity
Home	Infants and young children	<ul style="list-style-type: none"> Breastfeed exclusively for the first 6 months of life. Continuously breastfeed until age 2 years and beyond, complemented with a variety of adequate, safe, and nutrient-dense complementary foods. Avoid the use of added sugars and starches when feeding formula. Accept the child's ability to regulate energy intake rather than feeding until the plate is empty. Ensure the appropriate micronutrient intake needed to promote optimal linear growth. Avoid rewarding children with candies. 	<ul style="list-style-type: none"> Daily "tummy time" for infants younger than 6 months. Adult–infant interactions on the ground each day. Free exploration under adult supervision. Parents joining children in physical activity. Avoid punishing children for being physically active and withholding physical activity as a punishment.
	Children and adolescents	<ul style="list-style-type: none"> Provide a healthy breakfast before each school day. Serve healthy school snacks to children (whole grains, vegetables, and fruits). Promote intake of fruits and vegetables. Restrict intake of energy-dense, micronutrient-poor foods. Restrict intake of sugar-sweetened beverages. Ensure opportunities for family meals. Limit exposure to marketing practices. Teach children to resist temptation and marketing strategies. Provide information and skills to make healthy food choices. 	<ul style="list-style-type: none"> Reduce non-active time (e.g. television viewing, computer use). Encourage safe walking/bicycling to school and to other social activities. Make physical activity part of the family's daily routine, such as designating time for family walks or playing active games together. Ensure that the activity is age-appropriate, and provide protective equipment such as helmets, wrist pads, and knee pads.
Childcare/ school	Infants and young children	<ul style="list-style-type: none"> Provide school food programmes to increase the availability of healthy food in schools. Ensure that food served in schools adheres to minimum nutrition standards. Promote parental involvement. 	<ul style="list-style-type: none"> Use cribs, car seats, and high chairs for their primary use only. Limit use of equipment (strollers, swings, and bouncer seats). Implement activities for toddlers and preschoolers that limit sitting or standing to no more than 30 minutes at a time.
	Children and adolescents	<ul style="list-style-type: none"> Provide health education to help students acquire knowledge, attitudes, beliefs, and skills that are needed to make informed decisions, practise healthy behaviours, and create conditions that are conducive to health. Provide school food programmes to increase the availability of healthy food in schools. Have vending machines only if they sell healthy options, such as water, milks, juices without added sugars, fruits and vegetables, sandwiches, and low-fat snacks. Ensure that food served in schools adheres to minimum nutrition standards. Provide school health services for students and staff of the school, to help foster health and well-being as well as prevent, reduce, monitor, treat, and refer important health problems or conditions for students and staff of the school. Use school gardens as a tool to develop awareness about food origins. Promote parental involvement. 	<ul style="list-style-type: none"> Offer daily physical education classes with a variety of activities, so that the maximum number of students' needs, interests, and abilities are addressed. Offer extracurricular activities. Encourage safe, non-motorized modes of transportation to school and other social activities. Provide access to adequate physical activity facilities to students and the community. Encourage students, teachers, parents, and the community to become physically active.
Health-care providers	All ages	<ul style="list-style-type: none"> Monitor growth in children (consider the rate of weight gain, body mass index [BMI], and parental weight status as risk factors for later obesity). Address weight management and lifestyle issues with all patients, regardless of presenting weight, at least once a year. Counsel on the following: (i) limiting consumption of sugar-sweetened beverages; (ii) encouraging diets with recommended quantities of fruits and vegetables; (iii) eating breakfast daily; (iv) limiting eating at restaurants, particularly fast-food restaurants; (v) encouraging family meals in which parents and children eat together; and (vi) limiting portion sizes. 	<ul style="list-style-type: none"> Counsel parents and children's caregivers on the following: (i) not to permit televisions, computers, or other digital media devices in children's bedrooms or other sleeping areas; (ii) eating a diet rich in calcium; (iii) eating a diet high in fibre; (iv) eating a diet with balanced macronutrients; (v) initiating and maintaining breastfeeding; (vi) participating in 60 minutes of moderate to vigorous physical activity per day for children of healthy weight; and (vii) limiting consumption of energy-dense foods.

Table 9.2. Recommendations for promoting healthy eating and physical activity for obesity prevention in young people^a (continued)

Setting	Age group	Recommendations related to nutrition	Recommendations related to physical activity
Policies and regulations	All ages	<ul style="list-style-type: none"> • Develop and implement assistance programmes to facilitate healthy eating and physical activity for low-income and vulnerable populations. • Establish and monitor the implementation of uniform voluntary national nutrition and marketing standards for food and beverage products marketed to children. • Have sound economic development plans and urban planning to create healthful environments and facilitate healthy eating and physical activity behaviours. 	

^a Some of these are based on experts' opinions.

Sources: WHO (2017) [41], Barlow and the Expert Committee (2007) [49], Davis et al. (2007) [50], IOM (2011) [51].

outcomes than single-setting interventions. The interventions with the highest strength of evidence were physical activity-only interventions delivered in schools with home involvement and combined diet-physical activity interventions delivered in schools with both home and community components. Overall, a greater proportion of multisetting studies demonstrated significant and beneficial results compared with single-setting interventions. For all settings combined, the highest proportion of significant and favourable impacts on adiposity-related outcomes was attributable to diet-only interventions, whereas the lowest proportion of successes was for physical activity-only interventions. The strength of evidence for the effectiveness of interventions in settings other than schools and homes was insufficient.

Both healthy eating and physical activity should be targeted in obesity prevention. Some researchers have argued that it may be more feasible and effective to target energy intake control by use of national policies. Nutrition policies are needed to tackle childhood obesity, promote healthy growth, ensure nu-

tritional security in every household, and protect children from lifestyle choices that lead to inactivity or to the overconsumption of foods with poor nutritional quality [5]. Public health efforts are needed to protect children from the marketing of sedentary activities and energy-dense, nutrient-poor foods and beverages. The governance of food supply and food markets should be improved, and commercial activities need to be monitored and regulated. Childhood obesity prevention efforts need to be broadened to include interventions that change the nature of the food and consumer environment, including the availability, price, and formulation of different types of food products and the marketing practices that influence food choices and preference.

Conclusions

Multiple factors at the individual, family, school, society, and global levels affect children's energy balance-related behaviours and have contributed to the increases in the prevalence of childhood obesity worldwide. Although genetic factors play an important role in affecting individuals'

susceptibility to developing obesity, environmental factors should be the key targets of intervention efforts to fight the epidemic, because they are modifiable.

To prevent obesity, it is recommended that children should do the following: (i) increase consumption of fruits and vegetables, legumes, whole grains, and nuts; (ii) limit energy intake; (iii) limit the intake of high-energy-density foods, such as fried foods, fast foods, processed foods, and sugars, as well as sugar-sweetened beverages; and (iv) be physically active and reduce sedentary behaviours, to accumulate at least 60 minutes of moderate to vigorous activity each day and to limit screen time.

Of greater urgency and importance is developing sustainable and effective interventions to control the childhood obesity epidemic; the collaboration and strong commitment of government, industry, and other stakeholders is needed. These stakeholders can and should play key roles in creating healthy environments by facilitating the availability of healthier options that improve eating patterns and physical activity behaviours among children.

Key points

- Childhood obesity rates have increased over the past two decades in most countries worldwide, while the prevalence seems to have reached a plateau in some high-income countries in recent years, due in part to national campaigns, including policy changes.
- In developed countries in 2013, about 23% of children were overweight or obese.
- The trends in childhood obesity rates and the large variations in the rates and trends between countries provide useful insights into the drivers of the epidemic.
- Many factors have contributed to the increase in the prevalence of obesity in children, including unhealthy eating patterns, lack of physical activity, increased sedentary behaviours (i.e. screen time), and shorter sleep duration, as well as other factors, such as parenting and family factors, school factors, social norms, and community food and physical activity environments that affect children's eating and physical activity behaviours.
- Experiences during early life stages (including prenatal factors, such as exposures that women experience, and postnatal factors, such as infant and young child feeding) can have important, long-term impacts on future health, including risk of obesity.
- Family environment is important for children's health behaviours and outcomes. The relationship between family socioeconomic status and obesity is complex, has changed over time, and varies between population groups and between countries.
- The global childhood obesity epidemic demands a population-based, multisectoral, multidisciplinary, and culturally relevant approach. Children need assistance and special efforts to help them develop healthy eating patterns and physical activity behaviours and maintain an optimal body weight.
- To prevent obesity, it is recommended that children should: (i) increase consumption of fruits and vegetables, legumes, whole grains, and nuts; (ii) limit energy intake; (iii) limit the intake of high-energy-density foods, such as fried foods, fast foods, processed foods, and sugars, as well as sugar-sweetened beverages; and (iv) be physically active and reduce sedentary behaviours (accumulate at least 60 minutes of moderate to vigorous activity each day, and limit screen time).

Research needs

The following list is based on the recommendations from Wang et al. (2015) [42].

- Further research is needed on the key drivers of the childhood obesity epidemic worldwide, their relative effects, and the differences between countries and between population groups within countries.
- Studies are lacking on the changing roles of family and parents and how these affect childhood obesity. Given the many social and environmental changes, including technological development and changes in the labour force, it is likely that parental and family roles may have changed.
- Intervention studies conducted in non-school-based settings are needed. The literature on interventions that do not include a school component is sparse. More studies are needed that test environmental and policy-based interventions. Also, very few preventive studies have taken place in clinical settings, such as within a primary care practice. Primary health-care providers could play an important role in the prevention and management of childhood obesity.
- Innovative study design and intervention approaches are needed. Drawing on established behavioural theories and using innovative intervention strategies when designing interventions may help to increase their success in prevention of childhood obesity.
- Systems science-guided intervention studies are needed. Obesity is the result of a complex mixture of biological, behavioural, social, economic, and environmental factors. An effective and sustainable strategy for obesity prevention may have to target many factors. Applying a systems science approach in intervention design, implementation, and evaluation can take into account multiple risk factors as well as the complex interactions and feedback loops between them.
- The cost-effectiveness of interventions should be assessed. Cost-effectiveness analyses will add important value to the evaluation of an intervention and are also important for the promotion and dissemination of effective interventions.
- The implementation of intervention programmes may also have potential harms, such as unintentionally increasing weight-based stigma when programmes are implemented on a large scale for many children. Few studies have assessed and reported on potential harms.
- There are many promising opportunities and also challenges for international collaboration on childhood obesity prevention. More research is needed to learn about how to effectively facilitate such collaboration and overcome the barriers.

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