

Childhood obesity and food intake

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Background: The prevalence of obesity among children is growing in China at present. Childhood obesity reflects complex interactions of genetic, environmental, social and behavioral factors. Foods, nutritional components, and food intake patterns may be associated with the increasing obesity rate in children.

Data sources: Articles about the relationship between childhood obesity and food intake were collected from the databases including Web of Knowledge, PubMed, Elsevier and Google Scholar.

Results: Foods and nutritional components such as calcium, dietary fiber are inversely related to obesity, whereas others such as vitamin B and sugar-sweeten beverages play a positive role in obesity development. The differences in food intake pattern also influence the risk of obesity.

Conclusions: Food intake is an important factor influencing childhood obesity. One strategy to prevent childhood obesity is to take foods of moderate amount in a proper pattern.

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Introduction

Obesity is now undoubtedly a growing worldwide health problem. According to the statistical data from 2003, about 30% of the adults and 15% of the children (2-19 years old) globally were classified

as obesity.^[1] Childhood obesity is not only epidemic in developed countries, such as Western European countries, Australia and USA, but also in developing countries.^[2] In the USA, an astonishing 1/3 of children and adolescents (about 23 million) are overweight or obese. Even in China, the obesity rate in children is increasing dramatically during the last decade.^[3] The possibility for a child being obesity to become an obese adult is as high as 80%.^[4] And the more obese in childhood the more likely will obesity persist into adulthood.^[5]

The high prevalence of obesity has aroused people's concern. Firstly, obesity in general and childhood obesity in particular cause many health problems, such as hypertension, high cholesterol, asthma, sleep disorders, liver disease, type 2 diabetes, coronary heart disease, stroke and cancer.^[6,7] Researchers^[8] found it even worse that many obesity-related diseases once considered exclusively in adulthood are now being seen in children with an increasing frequency. For example, type 2 diabetes, also called adult-onset diabetes, is now appearing in children of eight years old. That means these children have to cope with such chronic illness for an unusually extended period of time. Secondly, obesity is an economic issue. It was reported that health care expenses and medicines expenses of obese adults were 36% and 77% higher than those non-obese people, respectively.^[9] Wang et al^[10] reported that estimates of hospital costs for treating children obesity-related conditions rose from \$35 million to \$127 million (in 2001 constant dollar values) from 1979-1981 to 1997-1999. And the estimates are rising rapidly. Therefore, the high prevalence of childhood obesity and the severe consequences have led to a consensus that paramount attention should be paid to this epidemic global problem.^[11,12]

Genetics is undoubtedly an important factor for childhood obesity. The probability for a child with one obese parent to become an obese adult is three times higher than those with no obese parents.^[13,14] However, children obesity, on the whole, reflects complex interactions of genetics and other factors, such as environmental, social and behavioral factors, which will affect the energy intake and expenditure.^[15,16] Ultimately, the imbalance between energy intake and expenditure is the determining factor for the high obesity rates.^[17] It is hard to prevent childhood obesity from the

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genetic point of view; however, it is obviously effective to prevent the disease by taking more physical exercises and proper foods of moderate amount. In this review, we will systematically review the publications from the databases about the relationship between childhood obesity and food intake, including the types of food, the types of nutritional components and the food intake patterns.

Types of food related to childhood obesity

Beverages

Sugar-sweetened beverages (SSBs)

The consumption of SSBs is increasing dramatically among children and adolescents over the recent decades. Several epidemiologic studies^[1,18] have found a positive link between SSBs consumption and long-term weight gain and obesity. A two-year prospective cohort study^[19] in more than 10 000 boys and girls aged 9 to 14 years found that consumption of SSBs was associated with less body mass index (BMI) (kg/m²) gains during the corresponding year, probably due to their contribution to total energy intake. A pilot study^[20] of the effect of less SSBs consumption on body weight found that changes in the BMI, adjusted for gender and age, were 0.07-0.14 kg/m² for the decreased consumption group and 0.15-0.21 kg/m² for the control group after 25 months of intervention. Another longitudinal study^[21] (4 to 8 weeks) of the effects of excessive SSBs consumption on children (6 to 13 years old) energy balance and nutrient intake showed that excessive SSBs consumption (>12 oz/day), displaced milk from children's diets, resulted in higher daily energy intake and greater weight gain compared with those who consumed less SSBs (<12 oz/day). Other studies^[22-24] also found similar results that the obesity might be aggravated by the increased intake of SSBs. In a review article, Malik et al^[18] reported that SSBs provided little nutritional benefit and the consumption of SSBs that causes weight gain was due to the low satiety of liquid carbohydrates, thus resulting in incomplete compensation of energy at subsequent meals. They concluded that the consumption of SSBs, particularly among children and adolescents, should be discouraged.

Fruit juices

Fruit juices are considered as healthy beverages and consumed in high quantities among children. Longitudinal studies^[25,26] on fruit juice intake showed no influence on weight gain. However, others showed that there is a positive link between fruit juices and obesity. Dennison et al^[27] reported that consumption of ≥ 12 fl oz/day of fruit juice by children aged 2-5 years was associated with short stature and with obesity. They

also found that the effects were probably due to the high content of fructose (13.9 g/8 oz serving) and sucrose (4.2 g/8 oz serving) in the apple juice.^[28,29] Their results were consistent with those indicating the particular role of fructose and sucrose in adiposity.^[23,30]

Milk and dairy products

Studies^[31,32] found that milk and dairy products were effective in weight control and milk has long been considered as an essential beverage for children because it contains nutritive proteins, calcium and vitamins A and D.^[33] There is a claim that two servings of milk intake per day could reduce the risk of overweight by up to 70%. However, the effects of milk and dairy products on weight are controversial. The dairy calcium might promote weight loss, whereas estrone and whey protein might cause weight gain. Berkey et al^[34] reported that large amounts of milk may provide excessive energy to some children. Children with large amounts of milk intake gained more weight during a longitudinal study. They also found that there was no difference between whole milk and skim milk, indicating that dairy fat is not associated with children obesity. As a special type of milk, breast milk performs differently. Several studies^[35-37] showed that an infant fed with breast milk instead of infant formula has a lower risk of overweight or obesity in later childhood and adolescence. Moreover, it seems that the longer period of breast milk feeding, the more effective in preventing childhood and adolescence obesity.^[38,39]

Snacks

According to a survey by the Chinese Disease Control Center in 2007, 60% of the children (aged 3 to 17 years) have snacks every day. Surveys from other countries also found similar increasing trend in snack consumption among children.^[40,41] Foods with increased energy density might lessen the satiety of food intake, resulting in passive overconsumption and obesity.^[42-44] Therefore, the energy-dense snacks were viewed as a cause for childhood obesity.^[45] Zizza et al^[46] reported that there was a strong possibility that snacking has contributed to the epidemic of obesity in children of the USA. However, in the 4-year longitudinal study of initially non-obese girls aged 8 to 12 years, Phillips et al^[47] found that energy-dense snacks did not affect weight or fatness.

Fast food

Fast food consumption is associated with lower dietary quality.^[48,49] Paeratakul et al^[48] reported that fast food consumption would lead to higher energy and fat intake but lower intake of healthful nutrients such as

vitamins, milk, vegetables and fruits. Similar results were observed in the research of Bowman et al,^[49] who found that fast food consumption among children might affect dietary quality that could plausibly increase the risk of obesity. Although higher energy intake from fast food may lead to the increasing incidence of children obesity,^[50,51] it still lacks of adequate proof.^[1]

Vegetables and fruits (VFs)

VFs have been recommended to prevent obesity because of their low energy dense, high water and fiber content.^[52] Epstein et al^[53] reported that the percentage of overweight in families with increased VFs consumption was significantly lower than that in those with decreased high-fat/high-sugar consumption. The inverse association between VFs intake and pediatric obesity was also reported.^[54,55] In a 2-year longitudinal study, overweight children (aged 6 to 13 years) with higher VFs intake were less likely to remain overweight during the experimental years, compared with those with lower VFs intake.^[54] In a similar study by Field et al,^[55] the inverse association between VFs intake and BMI change was found in boys, not in girls. However, other studies^[56,57] found that there was no or positive relationship between VFs and children obesity. This finding suggested that VFs alone are not the cure for preventing obesity. It is the replacement of energy dense foods with VFs that produces the anti-obesity effect.^[58]

Types of nutritional components related to childhood obesity

Vitamins

Recently, the intake of vitamins from plants, animals or artificial sources has been increasing. Moreover, many foods and infant formulae are fortified with vitamins. The increasing intake of vitamins might have a positive relationship with the prevalence of children obesity.^[59] Existing evidence showed that increased B vitamins (B1, B2 and niacin) intake was strongly correlated with the prevalence of obesity and diabetes,^[59-61] because B vitamins can enhance fat synthesis.^[62] Infant formula fortified with excess B vitamins may lead to rapid infant weight gain and childhood obesity.^[60,63] Other than B vitamins, antioxidative vitamin C and E were also found to increase reactive oxygen species. Thus, over intake of these vitamins may also contribute to the development of obesity.^[64] There are a plenty of evidences from genetic and animal studies that vitamin D may play a positive role in inhibiting adipogenesis.^[65,66] Follow-up^[67-69] of preadolescent children showed that vitamin D was

inversely associated with the indicators of adiposity, and adequate vitamin D intake is crucial to prevent childhood obesity.

Proteins

Excess protein intake during infancy is positively related to childhood obesity.^[70] A randomized trial by Weber et al^[71] reported that infants who received a higher protein content formula (HP group) in the first year of life showed a significantly higher BMI at 6 years of age than those who received a lower protein content formula (LP group) and those who were breast-fed. Moreover, the risk of obesity in the HP group was 2.43 times higher than that in the LP group. Long-term studies^[72,73] showed that during the period of complementary feeding (aged 6 to 18 months), higher protein intake would lead to increased BMI at 4 to 7 years and greater risk of later obesity. Intervention and observational studies^[74,75] supported the hypothesis that high protein intake promotes rapid weight gain during the childhood.

Fat

Over-consumption of dietary fat (mainly triglycerides) from foods or cuisines can lead to obesity.^[76] Since the rate of obesity in adults and children is increasing, dietary fat should be reduced to balance energy consumption and energy needs, and there is a special need for fat-modified food.^[77] For another special kind of fat, the dairy fat, however, it is not the case. Dairy fat is commonly viewed as the contributor of dairy product to the development of obesity because of its high energy dense, cholesterol content and saturated fatty acid. Kratz et al^[78] concluded that high dairy fat intake is inversely associated with obesity. They reviewed 16 observational studies conducted around 1999 to 2011 in the USA and Europe, but none of the 16 studies reported a positive relationship between baseline consumption of dairy fat or high-fat dairy foods and obesity at baseline or over time. Moreover, 11 of the 16 studies showed that with more dairy fat and/or high-fat dairy foods consumption at baseline, participants gained less weight over time than those with less consumption of dairy fat and/or high-fat dairy foods.

Dietary fiber

Dietary fiber is beneficial for energy intake control and reducing the risk of obesity.^[79,80] The physical and chemical properties of dietary fiber are effective in promoting satiation while prolonging signals of satiety. Dietary fiber could prevent excessive food intake and fat deposition by decreasing the caloric density of diet, slowing the rate of food ingestion, increasing the effort

in eating, promoting intestinal satiety, and interfering slightly with the efficiency of energy absorption.^[80] The recommended dietary fiber consumption for children is about 14 g/1000 Kcal.^[81] Dietary fiber comes from a variety of sources, such as vegetables and grains. Du et al^[82] reported that the lowering of body weight was due to dietary fibers from grains rather than from fruits or vegetables. Several reports^[83-85] confirmed the effects of dietary fiber in lowering body fatness. A 2-year follow-up study^[84] of children aged 7 to 11 years showed that there was a 10% increase of visceral body fat with decreasing fiber intake.

Calcium

Existing evidence shows that increasing consumption of dietary calcium is associated with lower body weight, BMI and obesity. The mechanism of dietary calcium in reducing body fat may be the result of lipolysis stimulation and lipogenesis inhibition.^[86] High intake of dietary calcium would suppress adipocyte lipid accretion during overconsumption of an energy-dense diet and increase lipolysis and preserve thermogenesis during caloric restriction, thereby markedly accelerate weight loss.^[87,88] A clinical study^[89] of 4-year observation found significant negative associations between calcium intake and weight gain. Moreover, a 1000 mg difference in calcium intake was found to be associated with an 8 kg difference in mean body weight. Zemel et al^[90] reported that obese patients received increasing dietary calcium for 1 year would have a loss of body fat of 4.9 kg. They also found that increased calcium intake would suppress adipocyte intracellular Ca²⁺, modulate energy metabolism and attenuate obesity risk. Longitudinal studies^[91-93] in children showed that higher mean longitudinal calcium intake (mg/day) and more dairy servings per day were associated with reduced body fat and children obesity. And the body fat reduced effect was more significant in males than in females.^[91]

Food intake patterns

We have addressed the issue "What to eat in order to prevent childhood obesity?". Children must absorb enough nutrition to maintain their growth and development. Dieting and restriction to palatable foods are not suitable for the treatment of children obesity.^[94-96] Foods and nutritional components that can reduce the risk of obesity should be the smart choices. However, for young children, their choices of food usually follow their parents' example.^[13,35] That explains why obese parents have a higher risk of raising obese children, because children would follow the preference choices of high-fat, energy-dense foods as their parents. At this point, the

parents' awareness of a "good diet" is important to the food choice of their children.^[12,16,97] Beyond this, the issue of food intake pattern should be involved, that is, "How and when to intake the food with how much amount?". The development of food intake pattern of children is affected by a number of factors, such as parent's guide, advertising, built environments, etc.^[97-99] The following are suggested food intake patterns from the reported studies:

Maintaining a good breakfast habit

Breakfast is the most important meal in a day. Breakfast skipping is unsuitable for weight control. Studies^[100,101] showed children who skip breakfast have higher BMI or weight gain than those who have regular breakfast. On the contrary, maintaining a good breakfast habit can not only receive adequate nutrition but also reduce the risk of obesity. Therefore, a daily breakfast containing a variety of foods, especially high dietary fiber, fruits, and dairy products is recommended.^[100]

Avoiding binge eating, high-fat night meals

Binge eating should be avoided. Binge eating means eating large meals without control, eating despite fullness or eating without hunger. Binge eating is not only harmful to health but also leads to obesity.^[102] High-fat night meals also should be avoided. Short-term food intake regulation is readily overcome by sudden increase of energy-dense food, especially during the night. High-fat night meals allow no compensatory adjustments until the next day, a great risk to become obesity.^[102,103]

Avoiding infrequent meal pattern and increasing meal frequency

Infrequent meal pattern ("meal feeding", "intermittent feeding", "gorging") is considered as a possible factor of obesity.^[104] Experiments showed that infrequent feeding resulted in a net increase of total body fat over that in ad libitum-fed controls, when an isocaloric food supply was ensured. Infrequent loads of food induce complex changes described as adaptive hyperlipogenesis leading to the development of obesity. Therefore, infrequent meal pattern should be avoided. It is recommended to increase meal frequency when possible. Experiments on obese patients showed that serum lipids and overweight tended to decrease as the meal frequency increased.^[104] Individuals with five or more meals per day were unlikely to gain excessive weight. Also, those with increased meal frequency remained stable weight when they were subjected to overeating. An inverse relationship was also observed between the prevalence of childhood obesity

and meal frequency.^[105]

Avoiding eating while watching TV

Eating while watching TV usually leads to more energy intake (eating high energy-dense snacks and drinking sugar-sweetened beverages) and less energy expenditure (sedentary position).^[106]

Conclusions

There is a relationship between childhood obesity and food intake. The smart choice of food and nutritional components and proper food intake patterns are important to the prevention of childhood obesity.

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