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NUTRITIONAL APPROACHES TO THE PREVENTION OF OBESITY IN CHILDREN

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Abstract. Prevention of obesity in children is a priority way to reduce the prevalence of obesity and, consequently, cardiovascular risk, both in the pediatric and adult populations. Preventive measures are aimed at correcting lifestyle and include optimizing nutrition and increasing physical activity. This review analyzes the effectiveness of modern nutritional interventions used to prevent overweight and obesity in children. Nutritional approaches are most promising from conception to 2 years of age. Encouraging breastfeeding and reducing the amount of protein in a child's diet in the first 12–24 months of life reduces the risk of obesity later in life, and avoiding complementary foods until 4 months of age is also recommended. Starting at 2 years of age, approaches that combine changes in diet and physical activity are used. Obesity prevention interventions carried out in children's educational institutions, including with the participation of the family, are most effective. Promising methods for correcting food stereotypes are the Mediterranean diet, reducing the consumption of sugary drinks and increasing the consumption of fruits, vegetables and foods rich in dietary fiber, which has a positive effect on various health parameters.

Key words: *obesity; children; prevention; breastfeeding; school meals.*

НУТРИЦИОЛОГИЧЕСКИЕ ПОДХОДЫ К ПРОФИЛАКТИКЕ ОЖИРЕНИЯ У ДЕТЕЙ

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Резюме. Профилактика ожирения у детей является приоритетным способом снижения распространенности ожирения и, следовательно, кардиоваскулярного риска как в детской, так и во взрослой популяции. Профилактические мероприятия направлены на коррекцию образа жизни и включают оптимизацию питания и повышение физической активности. В представленном обзоре проанализирована эффективность современных нутрициологических вмешательств, используемых для профилактики избыточной массы тела и ожирения у детей. Подходы, направленные на питание, наиболее перспективны в возрастном периоде от зачатия до 2 лет. Поощрение грудного вскармливания и снижение содержания белка в рационе ребенка в первые 12–24 месяцев жизни снижают риск ожирения в дальнейшие возрастные периоды. Также рекомендуется избегать введения прикорма до 4-месячного возраста. Начиная с двухлетнего возраста применяют подходы, сочетающие изменения в питании и физической активности. Наибольшей эффективностью обладают вмешательства по профилактике ожирения, проводимые в условиях детских образовательных учреждений, в том числе с участием семьи. Перспективными методами коррекции пищевых стереотипов являются средиземноморская диета, сокращение потребления сладких напитков и повышение потребления фруктов, овощей и продуктов, богатых пищевыми волокнами, что оказывает положительное влияние на различные параметры здоровья.

Ключевые слова: *ожирение; дети; профилактика; грудное вскармливание; школьное питание.*

INTRODUCTION

Overweight and obesity in children is increasing worldwide. It is an urgent problem both in high-income and low-income countries [1, 2]. The chronic course of the disease, its persistence in adulthood and the lack of effective treatment methods determine the importance of preventing its outbreak and spread [2–4].

According to H. Jebeille et al. (2022), the prevalence of obesity in the global pediatric population is 5.6% among girls and 7.8% among boys aged 5–19 years [5]. In the Russian Federation, according to a systematic review and meta-analysis that included the results of a survey of more than 350,000 children (2022), the prevalence of obesity is 1.2–25.3%, depending on age, sex, and region of residence [6].

Excess body weight is caused by a prolonged positive energy balance [1]. More than 600 genes have been associated with the risk of developing obesity [7]; however, in most cases obesity has no clear genetic cause because it results from the interaction of multiple factors that disrupt metabolism [8]. It is believed that more than 95% of obesity cases develop due to the inability of genetically predisposed individuals to adjust their behavior to obesogenic environment [7]. The obesogenic (obesity) environment, including high availability of foods with added sugars and saturated fats, cultural traditions and social behaviors of patients and their families, place of residence, inadequate availability of sports facilities, and other factors that contribute to increased energy intake and inadequate energy expenditure, increases the risk of developing obesity through epigenetic regulatory mechanisms over the lifespan. Treatment of obesity is a complex proble. Currently, it does not lead to sufficiently effective results in both adults and children [9, 10].

In contrast, prevention represents a promising strategy to combat obesity [11]. It is generally recognized that prevention of overweight in children and adolescents is a priority way to reduce the prevalence of obesity and, consequently, cardiovascular risk [2, 12, 13]. According to the recommendations of the European Society of Endocrinologists (2017), which most completely illuminate this problem, the prevention of overweight and obesity in children should include interventions aimed at correcting nutrition, physical activity, and lifestyle in general [14]. A large number of programs have been developed to promote behavioral changes from early life (pregnancy, infancy, and early early childhood) throughout childhood and adolescence involving the family, school, society, media, and government agencies [2, 11]. In 2022, methodological recommendations "Early prevention of obesity in children" created by FGBUN "FIC Nutrition and Biotechnology" (the Russian Federation) were published. They include modern approaches to targeted prenatal and postnatal nutritional optimization [15]. The development and implementation of effective intervention strategies and reduction of the long-term negative health effects of obesity is an important task of the modern medical community.

AIM

The aim of the review is to analyze the effectiveness of existing nutritional interventions directed to prevent underweight and obesity in children.

OBESITY PREVENTION IN CHILDREN DURING THE PRE-CONCEPTION PERIOD AND THE FIRST 1000 DAYS OF LIFE

Interventions before conception and during pregnancy

Согласно According to the concept of nutritional programming (metabolic imprinting), the nature of a child's diet determines the metabolic patterns of the child in the following age periods. Nutrition is considered to influence a child most significantly during the "first 1,000 days", from early gestation period up to 24 months. During this period, nutrition can modulate the risk of developing diseases in the presence of genetic predisposition [16].

Insufficient nutrition in the intrauterine period and the birth of an infant with low weight or body length have been shown as risk factors for obesity, arterial hypertension and type 2 diabetes subsequently. Excessive weight gain in women during pregnancy, even in case of initially normal body mass index (BMI), has a programmatic influence as well. Obesity and gestational diabetes mellitus among mothers are the best known risk factors for obesity in offspring [17]. Thus, there is a necessity to correct the nutritional status of women before pregnancy.

The evidence on interventions in the pre-conception period which were directed to prevent non-communicable diseases (NCDs), including obesity in children and adults, is scarce. This is partly due to heterogeneity in the definition of the pre-conception period [18]. In 2019 C.M. Jacob et al. analyzed the way different preventive approaches influence on etiological factors of NCDs during pre-conception period [19]. Thus, it was shown that the use of balanced protein-energy

products in combination with nutritional counseling and physical activity can reduce the risk of giving born to an infant with low length and weight in a certain gestational age by 21% and 27%, respectively, especially in mothers with weight deficiency [20]. A lower risk of developing gestational diabetes was found among women with high levels of physical activity [21]. Pregnant women which received intervention in the form of nutritional counseling and physical activity gained less weight compared to the control group [22].

A number of studies have shown that a pregnant woman's diet with excessive energy and fat content increases the risk of obesity in the offspring. There is no correlation with the nutritional status of the woman [23–28]. Current nutritional interventions during pregnancy show low efficacy in reducing the prevalence of childhood obesity, however, they have a positive effect on maternal and neonatal risk factors for the disease [29, 30]. Excessive weight gain was less common in pregnant women who were counseled on a low glycemic index diet (-24%) or counseled on nutrition and physical activity (-16%). Another study reported that nutritional counseling for pregnant women reduced the risk of developing gestational diabetes by 46% [30].

Interventions in the 0–2 years age group

Breastfeeding

Breastfeeding is one of the most studied aspects of early prevention measures in childhood obesity. The breastfading has a protective effect on the formation of overweight which is confirmed by studies [31]. Breastfeeding reduces the probability of excessive weight gain in childhood and adulthood by 13% [32]. The duration of exclusive breastfeeding has not been confirmed to influence the risk of obesity [31].

The duration of exclusive breastfeeding has not been confirmed to influence the risk of obesity [31]. It is most likely that brief breastfeeding is less protective against obesity than longer breastfeeding, regardless of whether it is exclusive or not. The benefits of prolonged exclusive breastfeeding with regard to obesity, have lack of evidence base due to the heterogeneity of the studies conducted and the lack of analysis of anthropometric data in children [33–36]. In addition, the studies did not take into account the associated factors which may influence the outcome.

Characteristics of formulas

Studies evaluating the relationship between the composition of formula used in the first year of life and obesity risks are mainly focused on the protein content. The use of formula with lower protein content is associated with lower body weight and Z-score of body weight at 6–12 months, BMI between 1 and 6 years, and risk of obesity at 6 years in the absence of conclusive data on body composition [37]. This pattern has been confirmed in many studies; however, there has been noted ambiguity in the criteria used to categorize formulae as low (1.1–2.1 g/100 ml) and high protein (1.5–3.2 g/100 ml) [38, 39].

Thus, reducing the protein content in formulas is a promising approach to obesity prevention. However, further study is required in order to assess its effectiveness in the long term [37]. The protein content of formula for infants under 1 y.o., recommended by the European Food Safety Authority (EFSA) is 1.8–2.5 g/100 kcal [40]. The consensus of the European Society of Pediatric Gastroenterologists, Hepatologists and Nutritionists (ESPGHAN, 2018) recommends adhering to the lowest protein concentration regarding the above mentioned range for children 1–3 years of age [41].

In addition to the protein content of formulas, protein hydrolysates and their possible protective role in children's obesity have been studied. P. Rzehak et al. [42] indicated that children who received formula with high-hydrolyzed casein had a slower increase in BMI in the first year of life. However, further observation of the same children up to the age of 10 years revealed no differences in anthropometric indices compared to breastfed children or those who received standard formula. Moreover, the rate of weight gain did not depend on the degree of protein hydrolysis. J.A. Mennella et al. demonstrated that the use of formula containing highly hydrolyzed protein in infants aged 2.5–7.5 months was accompanied by lower Z-score of body weight to growth compared to children receiving standard formula [43].

The protective effect of other infant formula components (prebiotics, probiotics, long-chain polyunsaturated fatty acids (PUFAs), soy protein) on obesity is currently unproven [31, 44].

Complementary feeding

Introduction of complementary foods and protein intake in infants and toddlers are the most studied controllable risk factors for the development of obesity.

The ESPGHAN consensus on complementary feeding reports an association between the introduction of complementary foods before 4 months of age and an increase in fat mass. The ESPGHAN

consensus recommends to introduce complementary foods not earlier than 4 and not later than 6 months of age [45].

L.A. Daniels et al. summarized the results of 26 studies and showed that the introduction of complementary foods before 4 months of age increases the risk of obesity in children [46]. In contrast, the EFSA consensus (2019) found no significant association between the time of complementary food introduction and the risk of obesity. Additionally, the EFSA consensus (2019) does not define a single introduction time of complementary foods for European children, and recommends focusing on the individual characteristics of children, especially in cases of prematurity [47].

With respect to protein intake, the ESPGHAN consensus [41] suggests not to exceed 15% of total energy intake during complementary feeding in order to prevent overweight and obesity.

Parenting interventions

Numerous studies that examined the effects of family-centered interventions on children's anthropometric measures have heterogeneous characteristics and endpoints, making it impossible to draw general conclusions. In the study by K.J. Campbell et al.,the authors gave parents recommendations on children's diet, physical activity, and duration of television watching and performed a further follow-up [48]. Beneficial effects of this approach were found at the age of 20 months and resulted in low consumption of sugary snacks and decreased TV time, however, no statistically significant effect on BMI was detected. A. Morandi et al. provided parents with information about their children's eating habits, including responsiveness to hunger and satiety cues. Despite a higher frequency of breastfeeding on demand at 3 months of age, there was no statistically significant effect on obesity prevalence at 2 years of age [49]. In the work of L.A. Daniels et al. [50, 51] the intervention began at 4–6 months of age. It was focused on healthy eating and growth patterns. Children in the control group had a higher Z-score BMI at 14 months of age, and their mothers were more likely to use "non-responsive" feeding practices. However, at age of 2 years, there were no significant differences in both Z-score BMI and the prevalence of overweight and obesity although intergroup differences in feeding practices were maintained.

In a study by I.M. Paul et al. [52], parents were trained to recognize the child's hunger and satiety cues and other sources of possible anxiety besides hunger; at the age of 1 year, children in the intervention group had a significantly lower weight-for-height percentile than the control group. The American Heart Association mentions that parental responsiveness to a child's hunger and satiety cues contributes to good "self-regulation of eating" and low risk of obesity [53]. The necessity to create a structured environment that defines dietary rules, food restrictions, availability of healthy foods, and role modeling is emphasized. Educational interventions for parents are required as a part of a strategy to reduce obesity and cardiometabolic risk across the lifespan.

OBESITY PREVENTION IN PRESCHOOL AND SCHOOCHILDREN

It becomes more difficult to combat the risk of obesity in children over 3 years of age, as the child's eating behavior, family eating patterns and parental feeding style have been sufficiently formed by this time.

The nutritional pattern for obesity prevention in children includes adequate consumption of vegetables and fruits rich in dietary fiber, as well as minimization of fast food and sugar-sweetened beverages. Additionally, the amount of fruit juice should be controlled, as exceeding the recommended amount (180–200 ml per day) contributes to excess body weight [54].

In the context of promoting a healthy lifestyle, it is recommended both to adhere to a balanced diet, and to form and maintain healthy eating habits in the family [2, 12, 55]. The daily amount of food should be divided into no more than 5 meals (3 main meals and no more than 2 snacks). It is also recommended to encourage eating at home, as opposed to eating outside [2, 12, 56]. In addition, providing children with a daily breakfast is an important guideline to prevent overweight and obesity [12, 56].

Prevention of obesity in preschool

Regular nutrition classes conducted by a nutritionist or a pediatrician are effective for preschool children. Preschoolers are explained the rules of healthy eating and nutritional behavior.

The most effective interventions are weekly nutrition lessons. They are focused on 5 rules: "drink water", "eat fruits and vegetables", "eat regularly", "make good choices" and "turn off your gadget while eating". The program also included increasing physical activity and modifying the surrounding space for sufficient mobility of preschoolers. The 4-month intervention resulted in a decrease of fat body mass in the main group and no effect on BMI [57]. S.N. Bleich et al. analyzed 5 randomized

controlled trials (RCTs) and 1 pilot study on the prevention of overweight in preschool children [58]. All five RCTs included the family as an additional intervention target. Three studies showed positive results: two of them included only physical activity intervention [59, 60], while the third used a multicomponent intervention with nutritional correction [61]. The positive results referred to decreased BMI in children aged 4–5 years in the first two studies. The third study found a less significant increase in BMI percentile and an increase in fruit and vegetable intake in children in the intervention group compared to the control group. Two other studies evaluated the effectiveness of an obesity prevention program aimed at preschoolers. They focused on both physical activity and nutrition, and reported no differences in outcomes between intervention and control groups [62, 63]. Z. Zhou et al. found a positive effect of a nutrition intervention in preschoolers. The study involved family and neighborhood, and resulted in changes of body composition (decreased body fat and increased muscle mass) after 12 months of follow-up, although no significant changes in BMI and Z-score were observed [64].

Obesity prevention in schools

The school-based interventions are mainly focused on elementary and middle school students. Food stereotypes were corrected by reducing portion sizes in school canteens, increasing the availability and interest in various fruits and vegetables, installing drinking water fountains, and eliminating foods with added sugar and saturated fats from school cafeterias. Lessons on healthy eating were conducted for children and parents as part of prevention programs. The lessons related to food choice, controlling the consumption of fast food and sugary drinks, the importance of breakfast for schoolchildren, and limiting eating outside the home. A number of studies included cooking workshops for schoolchildren and their families. About half of the studies analyzed by Y. Wang et al. in the systematic review demonstrated statistically significant positive effects of nutritional interventions on a number of obesity characteristics [65]. School-based interventions which were maintained at home appeared to be more effective. Only schools have shown moderate evidence of a preventive effect on obesity, when programs with nutrition or physical activity interventions were implemented. Programs involving both school and home environments appeared to be ineffective for isolated nutritional intervention and, in contrast, highly effective for increasing physical activity. A meta-analysis of RCTs examining the role of school-based interventions showed a Z-score BMI trend of –0.05 (95% CI –0.10, –0.01) and BMI of –0.30 kg/m^2 (95% CI –0.45, –0.15). Most of the results had a moderate level of evidence [65].

S.N. Bleich et al. reported that among 24 RCTs focusing on obesity prevention in schools, 17 had statistically significant favorable effects for at least one obesity-related endpoint [58]. Most of the effective programs combined nutrition and physical activity intervention and included the home environment as a secondary intervention target. Differences in BMI between intervention and control groups ranged from –0.33 to +0.05 kg/m^2 with follow-up ranging from 6 months to 6 years. These preventive interventions consisted of various combinations of programs whith increased intensity and duration of physical activity, educational courses on nutrition and self-regulation, and environmental modifications.

A systematic review by C.T. Bramante et al. summarized 33 studies aimed at preventing obesity in children and adolescents, 6 of which were school-based [66]. Five studies included food environment interventions, three of which obtained positive effects on BMI. Interventions with proven effectiveness included programs to provide access to drinking water at school [67], improving the in- and out-of-school nutrition environment [68], and modifying the range of food and beverages available in school cafeterias [69].

Obesity prevention in families and social groups

Y. Wang et al. showed that interventions directed at dietary change solely at home were not effective for obesity-related outcomes [65]. It is worth noting that Interventions conducted by the outpatient health care level were not successful, whereas school and community interventions showed positive results in obesity prevention (moderate level of evidence).

Community-based interventions show conflicting results and have a low level of evidence [58, 70]. The 2019 Cochrane Review reported the effectiveness of both home- and community-based interventions for childhood obesity [71], with lower financial costs per child and greater adherence to recommendations [72]. Approaches which modify the food environment (food advertising, range of vending machines at school, installation of drinking fountains) and facilitate access to physical activity are more appropriate for adolescents [2, 71]. Interventions directed to amend fast food marketing and financial support for low-income population groups are also useful [55].

ROLE OF SPECIFIC NUTRIENTS IN OBESITY PREVENTION

Healthy dietary habits that guide food and meal choices play a key role in the prevention of overweight and obesity. Some of the most studied nutrients in this regard include fat, added sugar, and dietary fiber.

Two recent Cochrane Reviews have focused on fat intake and its impact on body weight. Cohort studies have demonstrated a trend toward an increased incidence of obesity with increasing total fat intake [73]. There have been performed an analysis of three RCTs among children 4–13 years old. It was found out that educational interventions aimed at reducing dietary fat (≤30% vs. >30% of total energy intake) led to a decrease in both total and saturated fat intake, which was accompanied by a decrease in BMI (–1.5 kg/m^2, 95% CI –2.45, –0.55; moderate level of evidence). The protective effect of PUFAs on obesity does not have enough evidence base, since the results of a number of interventions conducted from birth to the first years of life are not sufficient [31].

The effect of total energy intake corection in early childhood which may influence on physical development in subsequent ages has not been proven so far [31].

The WHO Guideline: sugars intake for adults and children (2015) states that there is moderate evidence for an association between reduced intake of free sugars and decreased body weight, as well as weak evidence for an association between increased intake of free sugars and increased body weight [74, 75].

Four systematic reviews have reported the reduction in consumption of beverages with added sugars as a result of nutritional interventions [31, 55, 66, 76].

The results of long-term studies examining the way sugary beverage consumption affects weight gain in the early years of life are contradictory. Probably, weight gain might be explained by other dietary habits of the participants [31]. Nevertheless, reducing the consumption of sugary drinks is likely to have a positive impact on obesity in children [77, 78]. A recent position paper from the World Federation of International Societies of Pediatric Gastroenterologists, Hepatologists and Nutritionists (FISPGHAN) recommends to promote drinking water instead of sugary drinks from early childhood [2]. The effect of sugar substitutes on body weight continues to be debated and their safety in children has not been proven to date [79].

The impact of dietary fiber on health indicators has been analyzed by A.N. Reynholds et al. It was based on the results of 45 observational studies conducted in children aged 1 to 19 years. Increased consumption of fiber and foods rich with fiber content resulted in positive influence on body weight, blood lipid, glucose levels, and blood pressure [80]. A decrease in appetite and triglyceride absorption with dietary fiber supplementation was demonstrated after a single intake in the postprandial period in obese children [81]. Regarding the consumption of fruits and vegetables, C.T. Bramante et al. reported positive results of interventions at school in 2 out of 5 studies conducted [66].

Finally, several recommendations suggest adherence to the Mediterranean diet for obesity prevention [2, 56]. S. Fernández-Barrés et al. [82] demonstrated a positive effect of the Mediterranean diet during pregnancy, since it positively influenced on abdominal circumference in children at the age of 4 years with no effect on Z-score BMI. In contrary, L. Pereira-da-Silva et al. proved an inverse relationship between adherence to the Mediterranean diet and the risk of overweight in children [83].

DISCUSSION

Despite the heterogeneity of the conducted studies and the insufficient length of follow-up, many of the nutritional interventions resulted in new skills, lifestyle and environmental modifications. These changes may have favorable effects on obesity prevention that persist beyond the end of the study [84]. The Cochrane Review by T. Brown et al. emphasized that nutrition and physical activity behaviors learned in childhood persist throughout life [71]. It is plausible that small changes detected in the short term may provide long-term benefits for various aspects of health, including obesity prevention.

Parent-targeted interventions from conception to the first 2 years of life are generally effective in terms of behavior change but do not always have an impact on physical developmental parameters or obesity risk [44, 76]. Interventions at the family level are more effective than interventions at the level of health care providers or the community of a child [55].

The most effective interventions for the prevention of overweight and obesity are provided by pediatric educational institutions [58, 65, 66], including family-based interventions [58, 65]. This may be explained by the fact that children spend a significant part of the day in kindergarten or school and often have more than one meal in these institutions. In addition, school fulfills

the tasks of education and changing habits [72]. Family involvement is also important, taking into account the way family and home environment influence children's health behaviors.

Nutrition-focused interventions appeared to be the most promising approaches to prevent obesity in the age period from conception to 2 years. Encouraging breastfeeding and reducing the protein content of formula and the diet in general during the first 12–24 months of life are effective in minimizing the risk of overweight and obesity at later ages [31, 32, 37, 41, 44, 45, 76]. It is also recommended to avoid the introduction of complementary foods until 4 months of age [31, 45]. Starting from the age of 2 years, approaches combining changes in nutrition and physical activity are applied [58, 65, 71, 72]. Furthermore, a number of studies have shown separate effectiveness of nutrition and physical activity, which depends on the age and the context of application [58, 65, 66, 71]. The universal advice for individuals of all age groups is to adopt a healthy diet with emphasis on the Mediterranean diet model for the prevention of overweight and obesity, since many studies devoted to this topic have been conducted [31, 44, 66, 76, 82, 83]. Reduction in the consumption of sugary drinks may also lead to a lower overweight [77–79]. Consumption of fruits, vegetables and foods rich in dietary fiber has positive impacts on various health parameters (adequate satiety, body weight regulation, glycemic control, blood lipid levels, modulation of intestinal microbiota) [80, 83].

Many studies have confirmed the importance of a multidisciplinary approach to obesity prevention in children in order to improve its effectiveness. The WHO Commission on Ending Childhood Obesity suggests that intervention measures on changing eating behavior are not effective due to the fact they target one individual [85]. The most promising approach involves interventions at the level of a child, family, educational institution, health care providers, community organizations, and public health policy [86].

CONCLUSION

Prevention of childhood obesity is a major challenge for the scientific community. Nutritional interventions, especially in the early stages of child development, can prevent the development of obesity later in life. Long-term complex interventions, combining dietary modification with increased physical activity, appear to be the most effective at the level of the educational institution and the family. There is a strong need for further exploration of promising intervention targets in order to prevent overweight and obesity in children, with a focus on early adolescence. It is advisable to use not only BMI, but also the amount of body fat and muscle mass as well as quality of life as indicators of the intervention impact. Pediatricians monitoring a child from birth play a key role in the implementation of preventive interventions and, if there is a risk of obesity, should implement the above-mentioned measures as early as possible in cooperation with the family.

ADDITIONAL INFORMATION

Author contribution. Thereby, all authors made a substantial contribution to the conception of the study, acquisition, analysis, interpretation of data for the work, drafting and revising the article, final approval of the version to be published and agree to be accountable for all aspects of the study.

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