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The Impact of the Mediterranean Diet (MD) on Adolescent Overweight and Obesity

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Abstract. Adolescent obesity has become a global public health crisis, affecting over 160 million people and significantly increasing the risk of various chronic diseases and psychological problems. At present, although there is an increasing amount of research on the impact of MD on adolescent obesity, systematic mechanism exploration is still relatively limited. This article summarizes the main mechanisms of MD on adolescent obesity, and summarizes the evidence from cross-sectional, longitudinal, intervention, and review studies of multiple types. The results indicate that adhering to a MD can significantly reduce the risk of overweight and obesity in adolescents and improve multiple metabolic indicators. In addition, the article also analyzed the challenges and coping strategies faced by the promotion of this dietary pattern in the adolescent population. However, current research still faces issues such as limited sample age range, single regional coverage, and lack of long-term follow-up after intervention. Future research should broaden the age range of the sample, implement multi regional joint surveys, and design sufficient follow-up periods to provide a solid scientific foundation for the development of adolescent obesity prevention and control strategies in the future.

Keywords: Mediterranean diet, adolescent, obesity

1. Introduction

Obesity is one of the most prevalent chronic diseases of the 21st century and has become a serious public health challenge. This is a major problem especially among the adolescent population. According to the World Health Organization (WHO), as of 2022, the global prevalence of obesity among people aged 5 to 19 will reach 8%, with a total population exceeding 160 million [1]. Adolescent obesity is not only an important risk factor leading to the premature occurrence of cardiovascular and cerebrovascular diseases, diabetes and other chronic diseases, but also closely related to a series of adverse psychosocial consequences such as anxiety and depression [2]. At present, there are various treatment methods for obesity, among which weight loss surgery is one of the effective methods, but due to its accompanying preoperative risks and postoperative complications, it still needs to be implemented with caution [3]. Therefore, adopting safe, effective, and sustainable intervention strategies is particularly crucial. Existing research has shown that limiting total calorie intake combined with a diet structure with potential anti-aging effects is crucial for weight control [4].

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Among numerous healthy eating patterns, the MD is highly regarded globally for its recognized significant health benefits. This dietary pattern advocates fruits, vegetables, legumes, nuts, and olive oil as the main dietary components, promotes moderate intake of fish, and limits the consumption of dairy products, red meat, and processed meat. Although the role of MD in adult obesity control has been widely studied, there is a relative lack of in-depth research on its application in adolescent obesity prevention and control. Given the high incidence of adolescent obesity and its profound health effects, this article aims to systematically explore the impact of the MD on adolescent obesity, and provide scientific reference for global prevention and control of adolescent obesity.

2. The mechanism of the impact of the MD on adolescent obesity

There are various factors contributing to teenage obesity, among which dietary factors play a central role. Regarding food types, the high consumption of ultra-processed foods, sugary beverages, and refined carbohydrates increases calorie intake; in terms of dietary behaviors, skipping breakfast, eating at night, and frequent dining out all lead to fat accumulation; as for dietary structure, insufficient intake of vegetables and whole grains, and excessive intake of sugar and fat result in nutritional imbalance; concerning the society and environment, the presence of unhealthy food stalls around schools, parents' bad dietary behaviors and lack of cooking skills further increase the risk of teenage obesity.

2.1. MD

The MD is mainly based on plant-based foods, emphasizing fresh, natural and minimally processed foods, and focusing on family meals and the slow food culture. Figure 1 shows the new version of the traditional MD pyramid produced by the Italian Society of Human Nutrition (SINU).

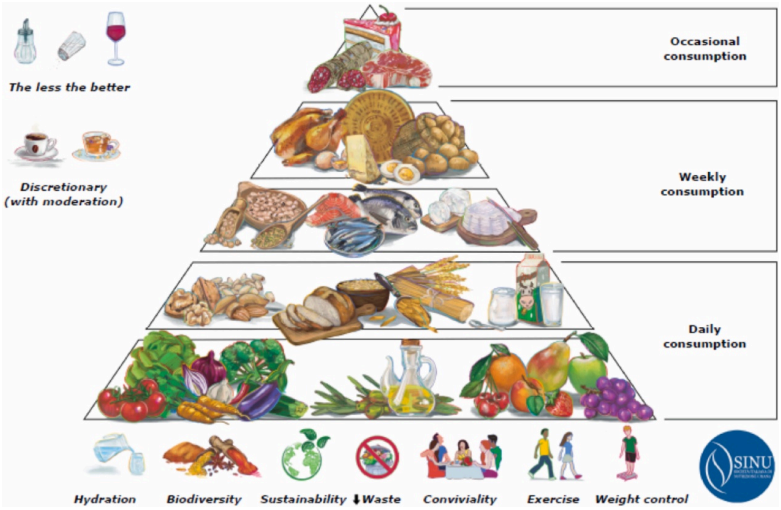


Figure 1. SINU MD pyramid [5]

2.2. Mechanism of MD's impact on adolescent obesity

The protective effect of the MD on metabolic health is mainly achieved through anti-inflammatory and regulation of the gut microbiota mechanisms. The plant-based foods in the MD are rich in a large amount of non-vitamin antioxidants such as polyphenols, flavonoids, and anthocyanins, which can neutralize reactive oxygen species generated during physiological processes and effectively

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eliminate free radicals and reduce oxidative stress, which may be a potential factor in the development of metabolic diseases. For example, flavonoids in citrus peel inhibit fat accumulation by reducing the production of cholesterol and fatty acids in liver cells. In addition, fish and nuts are rich in omega-3 polyunsaturated fatty acids, which have the effect of inhibiting inflammation and improving vascular function. Moreover, the monounsaturated fats in olive oil can reduce the numbers of Parabacteroides merdae, Ruthenibacterium lactatiformans, Flavonifractor plautii, Ruminococcus torques, and Ruminococcus gnavus in the gut, which has a positive impact on blood pressure regulation, lipid metabolism, and glucose homeostasis [6]. Furthermore, the satiety and metabolic regulation effects of dietary fiber. This dietary pattern is marked by high intake of vegetables, fruits and legumes, providing abundant dietary fiber. Dietary fiber can prolong chewing time and stimulate the release of cholecystokinin, enhance satiety, and naturally reduce calorie intake; On the other hand, it can promote the production of short chain fatty acids in the intestine, thereby improving blood sugar and fat metabolism, increasing the diversity of intestinal flora, and maintaining intestinal health. MD restricts unhealthy foods and reduces calorie intake from the source. The MD effectively reduces the intake of sugar and saturated fat by restricting the intake of sweets, fast food, red meat, and processed meat products, cutting off the supply of excess calories from the source and reducing the raw materials for liver fat synthesis. Meanwhile, high capacity, low energy density foods such as vegetables, whole grains, and nuts in this dietary pattern need to be chewed longer to further increase satiety. The high-quality fats and antioxidants in olive oil, fish, and nuts can effectively lower cholesterol and blood sugar levels. In addition, dietary fiber helps stabilize blood sugar and lower insulin levels, thereby preventing the formation of fats. In addition, this dietary pattern can reduce inflammatory mediators, enhance immune function, and overall improve metabolic health.

3. Research evidence on the impact of the MD on adolescent weight

3.1. Cross-sectional study

The plant-based foods in the MD are rich in antioxidants such as flavonoids, tocopherols, carotenoids, and ascorbic acid, which can eliminate free radicals, reduce oxidative stress, and thus protect metabolic health. A study on 203 overweight or obese adolescents showed that higher adherence to the MD is significantly associated with a reduced risk of metabolic unhealthy obesity. Whether in the unadjusted model (OR = 0.17, 95% CI: 0.08–0.37) or in the model after fully adjusting for confounding factors (OR = 0.33, 95% CI: 0.13–0.84), there were significant changes [7]. Meanwhile, a study involving 5934 adolescents found that after adjusting for multiple potential confounding factors, multivariate analysis indicated that a higher MD score was significantly associated with a reduced risk of adolescent overweight (OR = 0.96, 95% CI: 0.91–0.99, p = 0.049), that is, for every 1 point increase in the Mediterranean score, the risk of overweight decreased by 4% [8]. Consequently, existing cross-sectional studies consistently indicate that adhering to the MD pattern helps prevent and reduce adolescent obesity. However, research has not delved into the independent roles of various dietary components in the MD and has not established a causal relationship between dietary quality scores and the risk of overweight/obesity. Future studies should explore the independent roles of various dietary components in the MD in weight regulation and confirm the causal relationship between MDary quality scores and the risk of overweight and obesity in adolescents.

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3.2. Longitudinal studies

The MD can increase the diversity of gut microbiota, maintain intestinal health, and reduce weight by producing beneficial metabolites. A 6-month follow-up study of 85 healthy adolescents showed that consistent intake of healthy foods such as olive oil, fish, and nuts significantly reduced fasting blood glucose ($p=0.0001$), total cholesterol ($p=0.0004$), and LDL ($p=0.0012$); Simultaneously restricting the intake of fast food, baked goods, and sweets resulted in a significant decrease in total cholesterol ($p=0.0011$), LDL ($p=0.0047$), and fasting blood glucose ($p=0.0001$) [9]. In addition, a 15 month follow-up study involving 1371 participants found a significant positive correlation ($p<0.001$) between MD adherence and adolescent health-related quality of life: daily intake of fruits ($p=0.038$), vegetables ($p=0.037$), legumes ($p=0.039$), and high adherence ($p=0.001$) can significantly improve health-related quality of life and reduce weight [10]. Therefore, longitudinal research results indicate that adhering to a MD has a positive effect on improving adolescent obesity, but the sample size of the article is relatively small and limited to children aged 8-10, lacking a wider age range. Future research should address the aforementioned research gaps.

3.3. Intervention studies

The MD increases dietary fiber intake, which not only enhances satiety and reduces calorie intake, but also stabilizes blood sugar and lowers insulin levels, thereby inhibiting fat synthesis. A MD intervention study on 44 adolescents found that after a 12-week intervention, the MD led to a weight loss of 5.6 kg in obese adolescents and maintained their lean body weight [11]. Moreover, an intervention study involving 142 Polish adolescents confirmed that after a one-year intervention, with each receiving a consultation from a qualified nutritionist every 6 to 8 weeks, the total cholesterol of the obese group decreased from 195.54 to 175.87 mg/dL, LDL from 99.00 to 87.35 mg/dL, triglycerides from 99.89 to 85.79 mg/dL, blood sugar from 86.84 to 81.92 mg/dL, and insulin resistance index from 3.32 to 2.93. All metabolic abnormalities related to adolescent obesity were significantly improved [12]. Therefore, intervention experiments consistently show that the MD has a positive alleviating effect on adolescent obesity. Yet, the geographical scope of the research samples is relatively narrow and lacks long-term follow-up after the intervention, making it impossible to assess the long-term sustainability of the nutritional education and dietary intervention effects. Future experiments should expand the survey geographical scope and set up follow-up periods.

3.4. Review studies

The vegetables, whole grains, nuts and other foods rich in the MD have the characteristics of high volume and low energy density, requiring longer chewing time. This feature can enhance the feeling of fullness, thereby naturally reducing calorie intake. A meta-analysis that included 15 experiments proved that compared with the control group, the MD intervention significantly reduced the BMI of adolescents by 0.14 units (95% CI: -0.26 to -0.01), and the obesity rate decreased significantly by 12% (risk difference = 0.12, 95% CI: 0.01 - 0.23) [4]. Another systematic review that included 8 studies found that compared with children and adolescents who adhered to the MD, children and adolescents with low adherence to the MD had a 2.18 times higher risk of developing "metabolic syndrome" (95% CI: 1.45 - 3.28, $p < 0.001$) [13]. Hence, the MD is an effective intervention strategy for improving adolescent obesity. However, the articles lack a separate analysis of the impact of MD intervention on the anthropometric indicators of children and adolescents and are

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uncertain about the contribution of each component of the MD. In the future, it is necessary to independently analyze the impact of MD intervention on the anthropometric indicators of children and adolescents and deeply explore the contribution of each component.

4. Challenges and strategies for implementing the MD among adolescents

4.1. Main challenges

Although the MD offers numerous benefits for the health of teenagers, it still faces multiple obstacles in actual promotion. Firstly, individual preferences and the food environment jointly constitute the main challenge. Teenagers generally prefer high-sugar and high-calorie foods, and have a low acceptance of healthy foods such as vegetables and whole grains. Their taste habits are difficult to change in the short term [14]. Moreover, the prevalence of fast food culture further reinforces this preference. Nowadays, high-energy and low-nutrition fast food can be found everywhere, and its convenience and attractiveness continuously undermine the competitiveness of healthy eating. Additionally, peer dietary behavior has a significant influence on teenagers. When friends around them generally choose unhealthy diets, it is difficult for individuals to stick to healthy choices. This adverse dietary environment will interfere with their dietary choices. These factors collectively constitute the real challenges in promoting the MD among teenagers.

4.2. Countermeasures

In response to these challenges, many countries are currently implementing relevant policies and have achieved initial success. For example, Italy conducted a long-term experiment under the framework of the "School Fruit Program", in which trained teachers used teaching packages to provide interdisciplinary nutrition education to students, accompanied by free distribution of fruits and vegetables. The results showed that children's high compliance with the MD significantly increased from 24.4% before intervention to 43.3%, while low compliance decreased from 15.0% to 3.9% [15]. In addition, multiple large-scale cross-border projects are underway: the "DELICIOUS" project funded by the European Union is being carried out in five countries including Spain, Portugal, Italy, Egypt, and Lebanon. School canteens are improving their menu, developing healthy snacks, and using mobile applications for parents to enhance the compliance of children and adolescents aged 6-17 with Mediterranean cuisine. In addition, Portugal's "Revitalgarve" project focuses on providing teachers with teaching materials related to Mediterranean cuisine, integrating healthy eating into campus courses, and enabling students to better understand. Overall, many countries have achieved positive results by establishing policies, adopting school family linkage and curriculum integration strategies.

5. Conclusion

In conclusion, the MD significantly reduces the risk of overweight and obesity in adolescents and improves metabolic indicators such as blood sugar, blood lipids, and insulin resistance by regulating gut microbiota, enhancing satiety, and limiting unhealthy food intake through multiple mechanisms. Through different types of research, it is an important dietary pattern to improve adolescent obesity. In addition, the study identified the challenges of implementing a MD for adolescents and summarized coping strategies. This article confirms that the MD is a safe, effective, and sustainable nonpharmacological intervention strategy, providing a scientific basis for the development of

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adolescent obesity prevention and control policies. However, there are still shortcomings in this field, such as limited sample age range, single regional coverage, and lack of long-term follow-up. Future research should broaden the age and geographical range of the sample and design sufficient follow-up periods to verify the long-term sustainability of the MD intervention effect.

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