

Prediabetes Intervention Strategies and Mechanisms Based on Different Dietary Patterns

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Abstract: As a key transitional stage in the development of diabetes, prediabetes has become an important focus in China's public health field. This article systematically analyzes the intervention effects and mechanisms of three major dietary patterns, namely low-carbohydrate diet, high-fiber diet and Mediterranean diet, in people with prediabetes, aiming to provide a scientific basis for individualized nutritional intervention. The study found that although the prevalence of prediabetes in China is high, the dietary fiber intake of residents is generally low, only 12.3g/day, which is far below the recommended standard. In this context, the dietary intervention strategy proposed in this article not only helps to enrich the theoretical system of diabetes prevention, but also provides guidance for the formulation of clinical nutritional intervention programs. In particular, the mechanism by which the monounsaturated fatty acids contained in olive oil in the Mediterranean diet improve insulin resistance by inhibiting the NF- κ B pathway has expanded the idea of localized intervention. Despite this, existing studies still have shortcomings in the evaluation of long-term intervention effects, individual genetic background and intestinal flora differences. Future studies should combine multi-omics technology to conduct large-sample, long-term randomized controlled trials to explore more accurate and effective strategies for prediabetes intervention.

Keywords: Low-carbohydrate diet, high-fiber diet, mediterranean diet.

1. Introduction

Diabetes, as a major challenge in the global public health field, does not occur overnight. Prediabetes, as a crucial transitional stage in the development of the disease, has become a key focus of the academic community. Prediabetes is an intermediate state in which the body's sugar metabolism and lipid metabolism are disordered. At this time, the body's insulin sensitivity decreases, and the ability to regulate blood sugar is impaired. Although it has not yet reached the diagnostic criteria for diabetes, it significantly increases the risk of developing type 2 diabetes (T2D) and is also an important risk factor for complications such as cardiovascular diseases.

Epidemiological research data reveal the severity of the prediabetes problem in China. At present, the prevalence of prediabetes among Chinese adults is within the range of 12.6% to 13.5% [1], and it shows a significant increasing trend with age. The prevalence rate among people over 40 is about three times higher than that among young people. This phenomenon is closely related to the decline

in physical functions, the slowdown in metabolism, and lifestyle changes that come with aging. Against the backdrop of accelerated urbanization, factors such as reduced physical activity and increased intake of high-calorie diets have further exacerbated the rise in the number of people with prediabetes, highlighting the urgency of the diabetes prevention and control situation in China.

Given the large number of people with prediabetes and the potential harm of the disease's development, it is extremely urgent to carry out scientific and effective intervention for this group. Among various intervention methods, dietary intervention has become an important strategy for the prevention and control of prediabetes due to its advantages such as low cost, easy implementation and no side effects. By scientifically adjusting the diet structure and reasonably controlling the food intake, it is possible to effectively lower blood sugar and lipid levels, lose weight, increase muscle mass, enhance insulin sensitivity, improve insulin resistance, and thereby prevent or even reverse the occurrence and development of diabetes.

Although the significance of dietary intervention in the prevention and control of prediabetes has been widely recognized, there are still many urgent problems to be solved in terms of specific intervention models, implementation effect evaluation, and adaptability to individual differences at present. Therefore, deeply exploring the application effect of dietary intervention in the prediabetic population and systematically sorting out the relevant research progress not only helps to improve the theoretical system of prediabetes prevention and control, but also provides a theoretical basis for formulating scientific and effective personalized dietary intervention plans. It has important practical significance and far-reaching public health value for reducing the incidence of diabetes and alleviating the social medical burden.

2. Different dietary patterns

Prediabetes is a crucial stage in the development of diabetes, and dietary patterns play a significant role in it. Relevant surveys show that although patients with prediabetes are less likely to change their physical activities after diagnosis, most of them attempt to improve their health by adjusting their diet. Studies show that a healthy dietary pattern can significantly reduce the risk of prediabetes progressing to diabetes by up to 40% to 70% [2]. Specifically, a higher intake of whole grains is closely associated with a lower risk of prediabetes. When formulating individualized dietary plans, multiple factors such as the patient's metabolic indicators, comorbidities, dietary habits and cultural background should be comprehensively considered. Under the premise of ensuring a reasonable ratio of macronutrient energy supply, precise nutritional intervention should be achieved. These findings provide important theoretical basis and practical guidance for the dietary management of prediabetes [3].

2.1. Low-Carbohydrate Diet (LCD)

Carbohydrates serve as the primary source of energy for the human body. They encompass sugars and starchy foods, which are metabolized into glucose and stored accordingly. Following digestion and absorption, carbohydrates can be converted into glucose or other monosaccharides. The glucose generated through the breakdown of intestinal bacteria may either directly enter the bloodstream or be transformed into glycogen by the liver for storage [4]. In the context of diabetic dietary intervention, numerous studies have provided valuable insights into the efficacy of LCDs. A meta-analysis encompassing 25 randomized controlled trials with a total of 2,421 participants revealed that a LCD (with a carbohydrate energy contribution of less than 26%) significantly reduced glycated hemoglobin levels at 3 and 6 months post-intervention, underscoring its effectiveness in

short-term glycemic control. However, when the intervention period was extended to 12 to 24 months, no significant difference was observed in glycemic control outcomes between the LCD and a balanced diabetic diet containing 45% to 60% of energy derived from carbohydrates [3]. This conclusion aligns with findings from other studies, indicating that while a LCD may offer short-term benefits in improving blood glucose levels, its long-term efficacy remains comparable to that of a conventional balanced diabetic diet [5–7].

2.2. High dietary fiber

Dietary fiber is a polysaccharide that cannot be broken down by human digestive enzymes, including water-soluble dietary fiber and non-water-soluble dietary fiber. Soluble dietary fiber can dissolve in the gastrointestinal tract, absorb water, cause food to expand, increase a feeling of fullness, prolong gastric emptying time, and lower post-meal blood sugar. Dietary fiber plays an important role in prediabetes intervention. Studies have shown that a high-fiber diet (25-36 g/d or 12-14 g/1000 kJ), especially one rich in soluble fiber (10-20 g/d), can effectively control blood sugar levels. Large-scale prospective studies have found that consuming whole grain products rich in grain fiber (30-40 g/d) can reduce the risk of diabetes by 20% to 30% [8]. However, the intake of grains and dietary fiber among the Chinese population is on a downward trend. Currently, the average intake is only 12.3g /d, which is far lower than the 30.2g /d recommended by the Chinese Nutrition Society [3]. Given the health benefits of dietary fiber, it is recommended to increase the intake of fiber-rich foods such as whole grains, legumes, vegetables and fruits in accordance with the Chinese Dietary Guidelines for Residents, in order to improve the blood sugar metabolism of patients with prediabetes and reduce the risk of diabetes.

2.3. Mediterranean Diet (MD)

The MD is a healthy dietary pattern developed based on the traditional dietary structure of the residents in southern Italy and most of Greece. Its core lies in effectively preventing and controlling metabolic diseases through a combination of foods rich in antioxidants and healthy fatty acids. This dietary pattern mainly consists of olive oil, vegetables, fruits, fish, seafood, beans and whole grains, and is combined with an appropriate amount of red wine and garlic to form a nutritional synergy effect. Among them, extra virgin olive oil, as a core source of fat, is rich in up to 75% MUFAs (mainly oleic acid), which can not only lower the level of low-density lipoprotein cholesterol (LDL-C), but also reduce vascular inflammatory responses. Elevated LDL-C is not only a core risk factor for atherosclerotic cardiovascular disease, but has also been confirmed to accelerate the progression from prediabetes to T2D by activating vascular inflammatory responses. When the level of plasma LDL-C increases, especially when the subtype of small and dense LDL (sd-LDL) is dominant, it is prone to pass through the damaged vascular endothelium, be phagocytosed by macrophages to form foam cells, trigger signaling pathways such as NF- κ B and NLRP3 inflammasome, and promote the release of pro-inflammatory factors such as IL-1 β and TNF- α . On the one hand, these inflammatory mediators intensify serine phosphorylation of insulin receptor substrates (IRS), inhibit the PI3K-Akt pathway, and lead to insulin resistance; On the other hand, by disrupting the function of endothelial nitric oxide synthase (eNOS), it reduces the production of nitric oxide (NO), triggers microvascular dysfunction, and lowers the uptake of glucose by skeletal muscle and adipose tissue. This forms a vicious cycle of "elevated LDL-C - vascular inflammation - insulin resistance - hyperglycemia", which becomes an important link in the pathogenesis of diabetes. It is recommended that the daily intake of vegetables and fruits reach more than five servings, providing rich dietary fiber, vitamin C

and flavonoids, delaying the absorption of carbohydrates and enhancing antioxidant capacity. Eating fish and seafood 2 to 3 times a week, especially deep-sea fish rich in omega-3 polyunsaturated fatty acids (such as EPA and DHA), can regulate lipid metabolism and lower triglyceride levels.

In terms of food selection, the MD clearly avoids fried foods, high-sugar candies, baked cakes and other high-GI foods, as well as processed meats (such as sausages and bacon) and other high-salt and high-fat products. This dietary structure reduces the inducing factors of insulin resistance from the source by limiting the intake of saturated fat and refined sugar. It is worth noting that moderate consumption of red wine (no more than 150ml for men and 100ml for women per day) has been incorporated into the dietary system. The polyphenols it contains, such as resveratrol, have potential cardiovascular protective effects, can activate the SIRT1 gene, and improve cellular energy metabolism.

Multiple clinical studies have confirmed the significant effect of the MD in the prevention and control of diabetes. A prospective study by Esposito et al. indicates that people who follow the MD for a long time can increase insulin sensitivity in peripheral tissues by 18% to 22% and reduce the incidence of vascular endothelial cell dysfunction by 35% [9]. This is attributed to the abundant anti-inflammatory components in food (such as oleuropein in olive oil and sulfur-containing compounds in garlic), which can inhibit the NF- κ B signaling pathway and reduce the release of pro-inflammatory factors such as tumor necrosis factor - α (TNF- α), thereby breaking the vicious cycle of "inflammation - insulin resistance". After a 4.8-year follow-up, the Greek ATTICA study found that prediabetic individuals who strictly adhered to the MD had a 47% lower incidence of T2D compared to the control group, and their high-density lipoprotein cholesterol (HDL-C) levels significantly increased, further verifying the comprehensive regulatory effect of this dietary pattern on glucose and lipid metabolism.

Based on sufficient evidence-based medical evidence, the MD has been listed as a recommended dietary plan by authoritative institutions in many countries, such as the "American Diabetes Association Guidelines" and the "Chinese Dietary Guidelines for Residents". It not only demonstrates good feasibility and compliance in clinical practice, but also promotes the popularization of a healthy lifestyle through the infiltration of dietary culture, providing an intervention strategy that is both scientifically based and culturally adaptable for the prediabetic population.

3. Conclusion

This article systematically analyzes three main dietary patterns (LCD, high-fiber diet and endemic disease). The intervention effect and mechanism of action of Zhonghai Diet on the prediabetic population are significant in providing a scientific basis for personalized dietary intervention for the prediabetic population. In view of the current situation in China where the prevalence of prediabetes is high but the intake of dietary fiber is insufficient (only 12.3g/d), the dietary strategy proposed in this article not only helps to improve the theoretical system of diabetes prevention and control, but also can guide the formulation of nutritional intervention plans in clinical practice. In particular, in-depth analysis of the mechanism of action of the MD (such as the monounsaturated fatty acids in olive oil improving insulin resistance by inhibiting the NF- κ B pathway) has provided new ideas for the development of localized dietary intervention plans. However, this study has certain limitations: First, the long-term effects (>2 years) of different dietary patterns are insufficiently evaluated; Second, the influence of factors such as individual genetic background and differences in intestinal flora on the effect of dietary intervention has not been fully considered. Future research should conduct randomized controlled trials with larger samples and longer cycles, and combine multi-

omics technologies such as genomics and metabolomics to explore precise nutritional intervention strategies. At the same time, it is necessary to develop an improved MD plan suitable for Chinese dietary culture and study the synergistic effects of different dietary patterns to more effectively prevent the progression of prediabetes to T2D.

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