Original Article

International Journal of Food, Nutrition and Dietetics
Volume 12 Number 3, September - December 2024
DOI: http://dx.doi.org/10.21088/ijfnd.2322.0775.12324.4

Harnessing Traditional and Functional Foods for Optimized Diabetes Management: A Comprehensive Review

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How to cite this article:

Seema Jaiswal, Indresh Kumar, Sunil Kumar Tailor & Manisha Rani, Harnessing Traditional and Functional Foods for Optimized Diabetes Management: A Comprehensive Review. Int J Food Nutr Diet. 2024;12(3):126-132.

Abstract

This review-based research employs a traditional review methodology to investigate the role of dietary management in Diabetes Mellitus (DM), particularly Type 2 Diabetes Mellitus (T2DM). Through a thematic analysis of the relevant literature, the study aims to synthesize findings related to dietary interventions, on diabetes management. The qualitative approach involves identifying and reporting patterns and themes within the selected studies, highlighting the importance of personalized dietary strategies and education in enhancing patient outcomes. Limitations of this review include the exclusion of non-English articles and studies unavailable in the selected databases. Additionally, the absence of quantitative meta-analysis restricts the generalizability of some findings. Nevertheless, this research underscores the critical need for tailored dietary approaches and comprehensive management strategies in the prevention and treatment of T2DM.

Keywords: Therapeutic Nutrition; Hypoglycaemic medication; Functional foods; Medicinal foods; Super foods; Clinical nutritionists.

INTRODUCTION

According to the 10th International Diabetes Federation Atlas (2021), diabetes affects more than 1 in 10 individuals globally. In India, Type 2 Diabetes Mellitus (T2DM) is the most common form, driven largely by unhealthy dietary habits, inadequate physical activity, and sedentary lifestyles.[1] Dr. S. Swaminathan, former Chief Scientist at WHO, highlights the urgent need for effective preventive strategies to manage metabolic and degenerative diseases, including diabetes. He attributes the increasing prevalence of diabetes, particularly among the younger population in India, to rising consumption of high-sugar processed foods, limited dietary diversity, sedentary behavior, and various environmental factors.[2]

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Received on: 19-10-2024 **Accepted on:** 21-12-2024

Diet plays a crucial role in the management of diabetes, with therapeutic nutrition being essential for achieving and maintaining optimal blood glucose levels. Key components of nutritional management include regulating energy intake, balancing carbohydrates and proteins, and determining the frequency and portion sizes of meals. Individualized dietary modifications are particularly important for patients using insulin or medications.[3]

Prominent nutritionists, including Robinson, Davidson, Krause, and Antia, have historically advocated for structured dietary choices based on exchange lists, a practice that dates back to the 19th century. Their contributions have established foundational dietary principles that inform the management of both Insulin-Dependent Diabetes Mellitus (IDDM or Type 1) and Non-Insulin-Dependent Diabetes Mellitus (NIDDM or Type 2). For IDDM, a low-carbohydrate intake of less than 150 grams per day is generally recommended, while NIDDM may necessitate even stricter carbohydrate limits of less than 100 grams per day, unless the patient is on hypoglycemic medications.[4] Adhering to these dietary guidelines aids in maintaining blood glucose stability and reduces the risk of complications such as chronic kidney disease, cardiovascular issues, and neuropathy. This reinforces the idea that "food and modified dietary behaviorserve as medicine," empowering individuals to manage and, in some cases, reverse pre-diabetic conditions while improving overall health.[5]

Nutritionists have established clear guidelines regarding foods to include and limit in the daily diets of individuals with diabetes. A balanced and varied diet can be achieved through the food exchange lists developed by organizations such as the WHO and ICMR for Indian populations. While high-glycemic-index foods are to be consumed in moderation, the Diabetic Food Pyramid provides a framework for making informed choices.[6]

Recent advancements in nutritional science have led to the development of specialized diets for diabetics, including functional and medicinal foods often referred to as "superfoods." These diets emphasize the consumption of a diverse range of foods with low glycemic indexes, tailored to individual factors such as the type of diabetes, lifestyle, and anthropometric measurements.[1] A well-planned diabetic diet can help maintain optimal serum glucose levels and prevent complications. In cases where patients have comorbidities, such as cardiovascular or renal diseases, dietary principles must be adjusted to simultaneously manage diabetes and treat these additional health conditions.[7]

METHODOLOGY

This review-based research employs a traditional review methodology, focusing on the analysis of relevant literature to explore the role of dietary management in Diabetes Mellitus (DM). Thematic analysis was employed to analyze the data extracted from the selected studies. This qualitative method involves identifying, analyzing, and reporting patterns (themes) within the data. This review is limited by the exclusion of non-English articles and studies not available in the selected databases. Furthermore, the traditional review methodology does not include quantitative meta-analysis, which may limit the generalizability of some findings.

RESULT

Leveraging Mediterranean Diet Components as Functional Foods for Diabetes Prevention and Management

The Mediterranean diet (MD) is characterized by a high intake of plant-based foods such as fruits, vegetables, and legumes, moderate consumption of fish and dairy, and minimal intake of red meat and red wine. It also emphasizes the use of herbs and spices over salt. While traditionally followed in Mediterranean regions, adherence to the MD is decreasing due to the spread of Western diets. However, its components have been successfully adopted outside this region as well.[8]

Key functional foods in the MD, rich in polyphenols, terpenoids, flavonoids, alkaloids, sterols, pigments, and unsaturated fatty acids, are essential for maintaining health. These foods help prevent various conditions like cancer, depression, T2DM, obesity, asthma, and cognitive decline.[8] Specific to T2DM, these foods offer antioxidant, anti-inflammatory, and cholesterol-lowering benefits, enhance insulin sensitivity, and reduce insulin resistance, making them crucial for T2DM prevention and management.[9]

Numerous epidemiological studies have demonstrated an inverse relationship between MD adherence and the incidence of T2DM and gestational diabetes. Recent systematic reviews and randomized controlled trials also show that

MD improves T2DM management and metabolic health in high-risk individuals, such as those with impaired fasting glucose, glucose tolerance, or metabolic syndrome. For example, MD has been associated with a reduction in HbA1c levels by 0.30–0.47% in T2DM patients, and a reduced reliance on medication by 14.7% and 5% at one and five years post-diagnosis, respectively, compared to low-fat diets. MD's protective effects on T2DM risk are shown to persist even without calorie restriction, despite some MD components being high in energy, such as olive oil and nuts.[10]

The T2DM benefits of the MD are attributed to its rich supply of nutraceuticals, such as monounsaturated fatty acids (MUFA), omega-3 polyunsaturated fatty acids, antioxidants, and fiber. For example, olive oil contains oleic acid, phytosterols, and polyphenols that reduce inflammation and oxidation, improving vascular function and lowering the risk of both T2DM and cardiovascular disease (CVD). Similarly, fruits and vegetables are linked to reduced T2DM risk, while a low intake of these nutrients increases disease risk and mortality.[11]

It is difficult to attribute the T2DM protective effects to a single MD component. For instance, omega-3 fatty acids have been linked to reduced T2DM risk in Asian populations but not in European or North American groups. However, certain MD components, like extra-virgin olive oil and tree nuts, have shown significant protective effects, such as reducing inflammation markers in high-risk individuals.[12]

Polyphenols, especially flavonoids found in MD foods like fruits, vegetables, legumes, and certain beverages (e.g., tea, coffee, red wine), may play a critical role in T2DM prevention through improved insulin resistance and glucose control. Clinical studies have shown that polyphenol-rich foods, such as flaxseeds and olive oil, can reduce insulin resistance and inflammation, supporting their role in T2DM management. Resveratrol, found in grapes, has also been shown to improve glucose metabolism and reduce insulin secretion, adding to MD's protective benefits.[13]

Ultimately, the protective effects of MD against T2DM stem from its unique combination of components, each offering distinct benefits. Therefore, a holistic approach that incorporates all MD elements is recommended for diabetes prevention and management.[8,6]

The Preventive Role of Exercise and Physical Activity in Enhancing the Effects of Functional Foods

Physical activity is widely recognized as a key factor in both primary and secondary prevention of mortality, CVD, and diabetes. Alongside diet, it forms the foundation of lifestyle-based strategies for diabetes prevention.[6] Large-scale lifestyle interventions that combine various forms of exercise with calorie-restricted diets have demonstrated up to a 58% reduction in the incidence of T2DM among high-risk individuals, including those with glucose intolerance across diverse populations, such as multiethnic Americans, Finns, Chinese, and Indians.[14]

With increasing focus on the benefits of functional foods, particularly (MD) components, for T2DM prevention, it i 3.3 The Protective Role of Polyphenols in T2DM

Clinical Role of Herbal Ingestions in T2DM Prevention and Management

Many herbs and plants have demonstrated anti-diabetic properties and have been used in various cultures for centuries. Common examples, such as aloe vera, bilberry extract, bitter melon, cinnamon, fenugreek, ginger, and okra, are even recommended in national guidelines for T2DM prevention. Recent reviews have highlighted several functional foods and herbs such as berberine, honokiol, trigonelline, gymnemic acids, and others that have shown effectiveness in clinical trials for preventing and managing T2DM. These herbs work through various mechanisms, including inhibiting enzymes like α-glucosidase and α-amylase, modulating glucose transport, influencing hormones like adiponectin and resistin, and reducing oxidative stress.[24]

Herbal teas like green tea, black tea, and yerba maté, commonly consumed worldwide, have also been linked to positive outcomes for T2DM prevention. For example, Mauritian black and green teas, rich in polyphenolics, have demonstrated potent anti-diabetic effects in populations predisposed to T2DM, such as the Mauritian population. Clinical trials showed that these teas reduced fasting blood glucose, triglycerides, LDL/HDL cholesterol ratio, and improved antioxidant capacity.[25] Green tea, specifically, has been found to lower waist-to-hip ratio and fasting glucose while enhancing antioxidant levels after 14 weeks of regular consumption.

Studies also reveal that the combination of herbal tea ingestion with exercise can enhance metabolic outcomes, such as increased fatty acid oxidation (FAO) during physical activity. Yerba maté, for

instance, has shown positive effects on FAO and energy expenditure when consumed before exercise, as well as improved mood, satiety, and energy levels.[26]

These findings suggest that incorporating herbs and herbal teas like green tea, black tea, and yerba maté into lifestyle interventions for T2DM prevention may offer additional benefits when combined with exercise and individualized nutrition plans. Future studies are needed to further explore the long-term effectiveness and safety of these herbs, particularly in high-risk populations.[27]

Utilizing Omics to Understand Individual Responses to Functional Foods

To effectively prevent, manage, and treat diabetes where lifestyle plays a crucial role—it is essential to develop personalized and locally-tailored recommendations for diet and physical activity. One promising approach is through the use of "omics" technologies. "Omics" encompasses the comprehensive biological profiling of individuals, including their genetic makeup (DNA sequencing), epigenetics (DNA modifications), transcriptomics (gene expression), proteomics (protein products), metabolomics (metabolic byproducts), and microbiomics (bacterial interactions in the host), across various tissue types.[28]

By applying the omics approach, we can gain insights into how functional foods influence lifestyle related prevention of T2DM and other metabolic disorders. For example, variations in inflammatory markers such as IL-6, TNF-α, and gene expression patterns like DUSP1 have been linked to differing individual responses to exercise interventions.[12] In some studies, a 12-week exercise program resulted in reduced levels of IL-6, TNF-α, and DUSP1, as well as improvements in lipid profiles and glucose regulation for certain individuals, though no significant change in BMI was observed. These differences highlight the existence of responders and non-responders to lifestyle interventions, identified through specific omics markers.[29]

While omics has been applied to some degree in understanding how lifestyle and dietary factors influence diseases like diabetes, its use in nutritional interventions remains underexplored. Some research has indicated that specific genes, such as Dhtkd1, Sptlc3, Klf14, Degs1, Npc, and Cbr1, may affect dietary responses and influence insulin sensitivity and glucose regulation in animals.[10] However, more human-based studies are needed to further investigate these findings and use omics markers to personalize diet, exercise, and lifestyle interventions aimed at preventing and managing T2DM.[30]

Metabolic Surgery Outcomes and Functional Foods in T2DM Management

Bariatric or metabolic surgery, including restrictive procedures like sleeve gastrectomy (SG) and combined methods such as Roux-en-Y gastric bypass (RYGB), is widely regarded as one of the most effective treatments for patients with morbid obesity (BMI >40 kg/m²) or obesity (BMI = 35–40 kg/m²) accompanied by comorbid conditions such as T2DM, hypertension, dyslipidemia, sleep apnea, gastroesophageal reflux, and more. It is even being considered as a viable treatment option for T2DM patients with BMIs as low as 30 kg/m². Given this, the relationship between metabolic surgery and the role of functional foods presents a promising area for exploration.[31]

Recent clinical studies have demonstrated multiple metabolic benefits in T2DM patients undergoing surgery, such as improved glycemic control, sustained weight loss, and reduced diabetes complications. Post-surgery, patients show increased levels of gastrointestinal hormones (GLP-1, GIP, PYY, cholecystokinin), adiponectin, lipid oxidation, branched chain amino acids, and bile acid production. There are also reductions in oxyntomodulin, leptin, meal induced ghrelin, circulating free fatty acids, Orexin A, chronic inflammation, digestive vagal activity, and improvements in the gut microbiota. However, how dietary factors and lifestyle can modulate these outcomes remains largely unexamined.[32,33]

Bariatric surgery has been shown to improve eating behaviors such as binge eating, uncontrolled eating, night eating syndrome, and grazing. It also positively impacts meal size, frequency, taste, and gastric emptying.[34-36] However, nutrient deficiencies, including protein, iron, zinc, and vitamins (B12, D, and thiamine), are common post-surgery due to factors like reduced food intake, poor diet quality, altered digestion, and non-compliance with supplements. For example, deficiencies in fat-soluble vitamins occur in malabsorptive procedures, and thiamine deficiency is often linked to nausea and vomiting. Nutrition education, particularly focusing on functional foods, may help address these deficiencies and further enhance positive eating behaviors post-surgery.[37,38]

Metabolic surgery has shown high success rates in T2DM remission (≈78–86%) and weight loss (≈56%).[37] These outcomes are influenced by factors like age, gender, and genetic variations involved in

metabolic regulation. However, 30–50% of patients do not achieve their weight loss targets, and 20–25% regain weight within 10 years.[39]

The metabolic benefits of surgery, especially antioxidant and anti-inflammatory effects, could be amplified by incorporating functional foods and herbs, which are already commonly used among obesity patients. However, concerns regarding safety and the under-reported use of these foods must be carefully addressed. To date, no research has explored this intersection, highlighting the need for further studies.[40,41]

CONCLUSION

The integration of personalized dietary strategies, combined with education and counseling, is crucial for the effective prevention and management of (T2DM). Advancements in "omics" technologies offer promising potential for tailoring interventions that account for the complex interactions between genetics, lifestyle, and diet. Furthermore, metabolic surgery, especially bariatric procedures, has shown substantial benefits for individuals with both obesity and T2DM, contributing to better glycemic control, sustainable weight loss, and reduced diabetes-related complications. A holistic approach that combines individualized nutrition, physical activity, education, and advanced medical interventions is essential in optimizing diabetes management and enhancing patient outcomes.

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