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Role of Diet and Exercise in Management of Diabetes Mellitus: A Narrative Review Running Title : Lifestyle Modification Glycaemic Control

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Abstract

Objective: To evaluate the role of diet and exercise as essential non-pharmacological strategies in the management of diabetes mellitus, with emphasis on their effects on glycaemic control, insulin sensitivity, and prevention of complication.

Methodology: This review synthesizes proof from recent clinical researches , population based studies and regional data from Pakistan assessing dietary patterns, micronutrients intake, and physical activity in individuals with type 2 diabetes mellitus (T2DM). The review incorporate findings on micronutrients composition, glycemic index-based dietary planning, micronutrients supplementation, and structured physical intervention, including supervised exercise programs and lifestyle-modification trials [1,2,5,13]. Regional observational studies evaluating dietary habits, socioeconomics factors, and glycemic outcomes among Pakistani diabetic populations were also included [7,18, 23,27].

Results: Dietary strategies focusing on low glycemic index carbohydrates, high dietary fiber, unsaturated fats, and balanced protein intake significantly improve glycemic control and cardiovascular health[1,2,5]. Micronutrients such as vitamins C, D, B-12, folate, and antioxidants further support metabolic regulation and reduce complications [4,16].

Regular physical activity (≥150 minutes/week) improves glucose uptake, insulin sensitivity, lipid profile and blood pressure [1,13]. Evidence from Pakistan indicates that high carbs intake, low fruit and vegetable consumption, sedentary lifestyle and low socioeconomic status are associated with poor glycemic control [7,18,23]. Supervised lifestyle interventions demonstrate greater improvements in HbA1c, insulin sensitivity and lipid parameters compared to unsupervised approaches [13].

Overall, effective diabetes management requires an integrated approach combining pharmacotherapy with individualized diet planning, regular physical activity, patient education and culturally adapted public health strategies for early diagnosis and preventions.

Introduction

Diabetes mellitus is a chronic metabolic disorder characterized by high blood glucose levels due to insufficient insulin resistance. Unhealthy food is a major risk of type 2 diabetes. Moreover, non-food related factors like lack of physical activities, smoking, stress and air pollutants cause diabetes by interfering with the endocrine system [10]. Increase in diabetes is expected by 2030 to 643 million [18]; (11.3%), and by 2045 it
may reach 783 million (12.2%) [12]. T2DM caused by multiple factors, arising by complex interaction between multiple genetic variants and range of environmental factors such as physical activities, unhealthy dietary habits, and psychological stress. Diet plays main role in preventing, managing and progression of T2DM. [15]

With the global rise in diabetes prevalence-especially T2D this increases focus on nonpharmacological methods for disease management. Among these, diet and exercise play a life saving role by managing blood glucose, reduce risk of complications, and improving overall quality of life. Current research and international guidelines, such as those from the American Diabetes Association(ADA), strongly support personalized nutrition and physical activity for

preventing complications and improving glycemic control.[43]

Importance of Lifestyle Management In Diabetes

In glucose metabolism dietary components play an important role in variation of metabolites and microbiomes. Like variation in plasma-branched chain amino acid (BCAA) concentration related to rise of T2DM. Also, specific diets and nutritional pattern change gene function, gene activity patterns and gut microbiome response measures[16]. While medications play a vital role, but with medications effective diabetes management requires an aggressive approach. Diet and exercise are important lifestyle factors that help to gain long-term glycemic control, weight management, cardiovascular health and improve insulin sensitivity.[43]

Role of Diet In Management of Diabetes

Carbohydrates and glycemic index

Carbohydrates are macronutrients that have the most significant effect on increasing blood glucose levels due to their glycemic index (GI) [1,2]. For people with diabetes, it is recommended to choose low-GI foods that release glucose slowly into the bloodstream, thereby preventing sudden increase in blood sugar. This does not mean fruits should be avoided-many fruits not only help keep blood glucose stable also provide essential nutrients and antioxidants that protect against chronic conditions such as stroke, hypertension, obesity and certain metabolic disorders.[1,2]

Consuming carbohydrates from minimally processed food, high in nutrients, foods with lots of fiber such as whole cereal grains, legumes, oats and brown rice-is urged [1,5]. In addition sorghum (jawar) is excellent option due to high fiber and amylose rich starch slow digestion and glucose absorption, helping improve glycemic and insulin responses [19, 20]. The ADA recommends at least 14 grams of dietary fiber per 1,000Kcal consumed [1,2]. Fiber slows carbohydrate digestion, stabilizing blood sugar and improving satiety. Carbohydrate sources that naturally contain micronutrients, such as those with fructose from whole fruits, provide additional antioxidant benefits that may reduce inflammation and improve vascular health [3]. Importantly, managing diabetes is not about eliminating any one nutrient group it is about replacing unhealthy sources with healthier alternatives.[40] The ADA emphasizes that carbohydrates should remain part of balanced diet, as they also provide vitamins, minerals and phytonutrients essential for overall health. Instead of refined carbohydrates like white sugary beverages, carbonated drinks, artificial sweeteners and processed snacks, healthier options such as whole-grain flours, oats, brown rice and legumes should be chosen.[5].

Dietary Fiber

Dietary fiber is a carbohydrate that the body cannot digested or absorb in the stomach and small intestine. Rather, it either passes through the body intact or is degraded in the colon by gut microbiota. During this fermentation process, beneficial metabolic compounds are produced, which can reduce inflammatory responses and aid metabolic health [5].

Consuming more dietary fiber is linked to a reduced risk of type2 diabetes, colorectal cancer, cardiovascular disease and death from any cause. Fiber helps regulate blood sugar by slowing the carbohydrate absorption, thereby preventing rapid spikes in blood sugar and improving insulin sensitivity, which makes it easier for glucose to enter cell [1,2,3,5].

Studies have shown that diets low in fiber and high in fat may contribute to the loss of normal glucose regulation, leading to a hyperglycaemic state [5]. The World Health Organization (WHO) suggests a daily fiber amount of at least 25g for the general population [1]. (Fig 1) Furthermore, protein sources having rich fiber, such as whole grains, vegetables and fruits should be recommended over other sources, suggested by ADA [11]. Excellent sources of dietary fiber include unrefined whole

grains, vegetables, fruits and legumes. Key examples are beans, wheat, onion, artichoke, barely, banana, tomato and soyabean by ADA 2010 guidelines [12]. These foods not only aid in blood sugar control but also supply key vitamins, minerals and beneficial plant compounds that promote whole body health.

Fats In diabetes control by diet quality of fats important than quantity [26]. The American Diabetes Association (ADA) suggests diabetics adopt eating patterns that mostly focus on unsaturated fats, especially monounsaturated and polyunsaturated fatty acids, but not saturated and trans fats [1,5].

A nutritional plan with high intake of vegetables, fruits, legumes, nuts, whole cereal grains and fatty fish often described as a Mediterranean-style diet is one of the best-studied approaches for preventing and managing type2 diabetes. This type of diet have a favorable fatty acid composition in monounsaturated fats relative to saturated fats contain minimal trans fats, and diet rich in fiber, antioxidants and polyphenols [2]. All of these elements reduce oxidative stress, make the body more responsive to insulin and lower the chance of developing heart diseases. Also, because of this eating pattern is low in calories helps to prevent gaining too much weight that is an important factor in type2 diabetes prevention [28].

Unsaturated fats_ both mono and polyunsaturated fatty acids such as those present in olive oil, avocados, fatty fish, nuts and seeds(omega-3 fatty acids for CVD)_ are good health because they help to reduce LDL cholesterol, improve glucose metabolism, and lower inflammation[5]. Research also shows that unsaturated fats can lower blood sugar levels by improving insulin signal performance, make possible for glucose to enter cells more efficiently [3,9]. Polyunsaturated fats, mainly omega 3 fatty acids, provide more benefits such as improving nerve function in type 1 diabetes patients with mononeuropathy[6].

In contrast, **saturated fats** commonly present in foods like red meat, butter, full-fat dairy and processed foods increase insulin resistance and higher blood glucose levels and HbA1c [42]. Diets high in saturated fats leads to cardiovascular disease risk and badly high blood sugar level, so limiting them is important in diabetes management [1,5].

Therefore, the goal is not to eliminate fats altogether but to replace unhealthy fats with healthier options. Substituting saturated and trans fats with unsaturated fats, in combination with regular physical activity, has been associated with lower risk of developing diabetes Type2 and better long-term management of the condition [2].

Proteins

Protein is a vital macronutrient that contributes a critical role in tissue repair, muscle maintenance and satiety. In diabetes management, however, the role of protein is less about quantity and more about ensuring balanced intake within an overall healthy diet.[45]

The American Diabetes Association (ADA) Standards of Medical Care in Diabetes 2024 state there is insufficient strong evidence that support the daily level of protein intake, which is generally 1-1.5g/kg body weight per day, or about 15-20%(as shown in Fig 1) of total daily energy-improves health outcomes in people with diabetes but not having kidney disease[1,4,5,20]. High protein intake leads to increased glucose levels by resisting insulin, gluconeogenesis stimulation and high glucagon turnover[16]. For individuals without kidney disease, moderate protein consumption is considered safe and beneficial as part of a balanced diet. However, for those with diabetic nephropathy, protein intake should be carefully monitored and individualized to avoid worsening kidney function.

Overall, protein-rich foods such as fish, poultry, lean meat, legumes, low-fat dairy and plant-derived alternatives needs to be included in the diet. These sources not only support overall health but also help regulate appetite and maintain muscle mass, both of which are important in weight and glucose control [30].

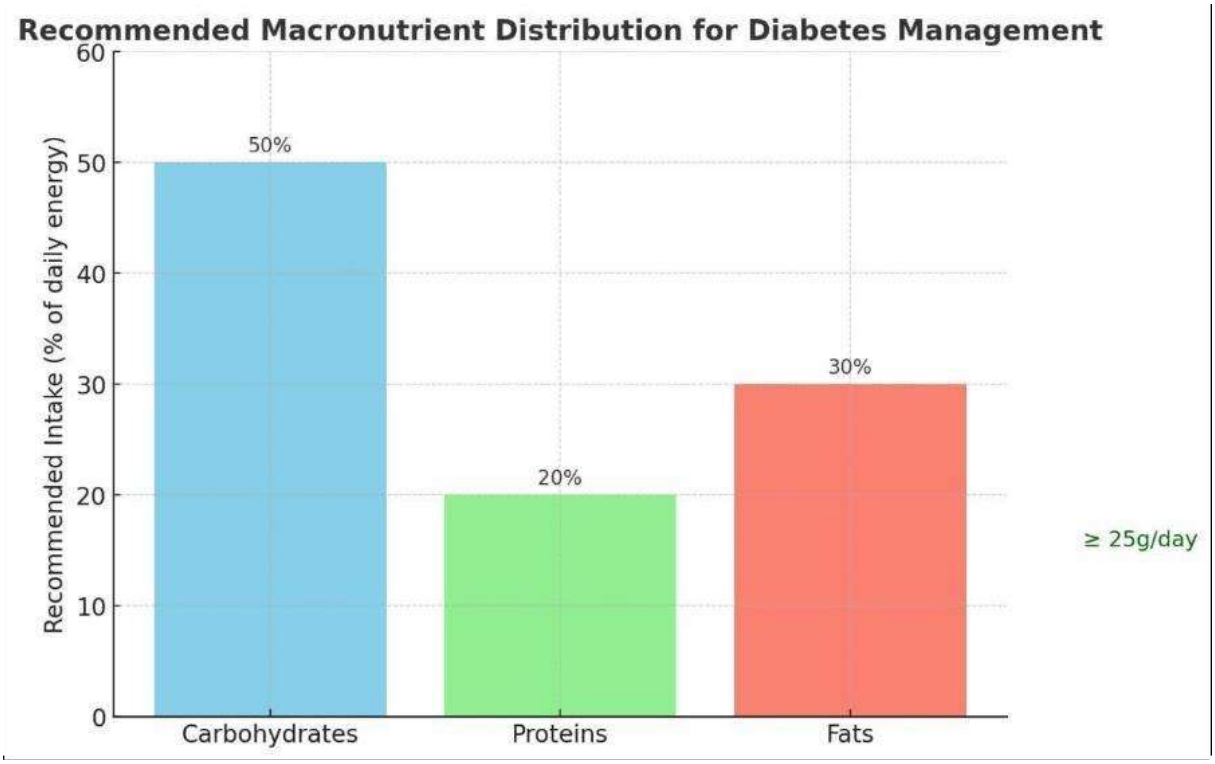


Figure 1 shows the recommended macronutrient distribution for diabetes management:

Carbohydrates: ~50% of daily energy (preferably low GI, high-fiber sources) [22]
Protein: ~20% of daily energy [22]
Fats: ~30% of daily energy (emphasizing unsaturated fats) [4,5,22]
Fiber: WHO recommends >25g/day [22]

Micronutrients

Micronutrients plays a key role in the management of diabetes mellitus by influencing glycemic control, insulin sensitivity and prevention of complications.

Vitamin C : Research combining interventional studies has shown that taking vitamin C supplements can improve blood glucose level in patients with type2 diabetes mellitus. Its antioxidant activity of vitamin C helps lower oxidative stress, which is often elevated in diabetes and contributes to vascular complications [16].

Vitamin B12 and Folate: Patients with diabetes who are on long-term metformin therapy are at risk of vit.B12 and folate deficiencies. This deficiency can result in high level of homocysteine in blood, associated with increased cardiovascular risk. Therefore, periodic monitoring and supplementation may be necessary [4,16].

Vitamin D: Contributes significantly in regulating the insulin resistance pathway. Adequate vitamin D levels may restore the glucose metabolism by enhancing insulin sensitivity, potentially lowering the chances of progression to T2DM [4,16].

Vitamins A and E: These vitamins possess potent anti-inflammatory and antioxidant properties. By lowering inflammation and oxidative damage, they can help prevent or delay complications caused by diabetes such as neuropathy, nerve damage and cardiovascular disease [4,16].

These supplements also regulate immune system and prevent patient from infections [4].

Overall, while micronutrients are not a replacement for pharmacologic or lifestyle interventions, ensuring sufficient dietary intake of vitamins by maintaining a balanced diet or supplementation, when required, can provide additional benefits in

diabetes management.

Physical Activity

Hippocrates, father of medicines, first recognizes the value of exercise for a patient with consumption [14]. Regular exercise is a key component in managing diabetes mellitus, with benefits extending beyond glycemic control to cardiovascular health, weight management and overall well-being.[26] People with diabetes are encouraged to participate daily in minimum 30min of physical activity, walking being one of the most widely recommended and accessible forms of exercise [1]. Evidence suggests that walking within 2hrs after meal may be particularly effective in lowering blood glucose, as active skeletal muscles utilize circulating glucose as fuel, thereby improving postprandial glycemia.

Regular exercise helps the body's cells take up glucose more efficiently, lowering blood sugar levels and reducing insulin resistance. It also aids weight loss and helps control blood cholesterol and blood pressure, both of which are critical in reducing the chances of cardiovascular disease in diabetic patients [1,2]. Advancement in technology leads to absence of physical activities causing obesity and diabetes and taking away from homegrown foods [11].

The benefits of consistent aerobic exercise program include:

Decreased need for insulin and oral hypoglycaemics

Reduced risk of obesity and heart diseases [25]

Improved lipid profile (lower total cholesterol, reduced LDL/HDL ratio, lower triglycerides) [25]

Reduced blood pressure and stress levels[43]

While aerobic activities such as walking, cycling or swimming are most recommended, resistance training also contributes to improved muscle mass and glucose uptake. However, high-intensity exercise should arranged together with the healthcare provider due to the potential risk of hypoglycaemia and cardiovascular strain.

Structural physical activities involve all body movement that burns more energy during exercise. ADA recommends 150min of physical activity per week [13]. Walking is considered one of the simplest, safest and most effective lifetime activities, requiring no special equipment and carrying minimal risk of injury [2].

Methodology

Review Strategy

A narrative literature review according to PRISMA principles incorporates evidence from cross-sectional studies, randomized clinical trials, and regional epidemiological research to assess what role actually the diet and physical activity plays in managing the diabetes , prioritizing studies from last 5 years for current evidence using PubMed/MEDLINE, Web of Science, ScienceDirect, Cochrane Library, and Scopus. Additional regional studies were retrieved from JPMA, Pakistan Journal of Pathology and Pakistan Journal of Medical Sciences, for supportive evidence studies included from ADA, WHO and International Diabetes Federation guidelines and reports , while older foundational studies were including only for background information and supportive context. Secondary and old studies were excluded. One most important cross-sectional study was conducted at the National Institute of Diabetes and Endocrinology in which 301 patients with T2DM were included and assessed for socio-demographic factors, dietary intake using a food frequency questionnaire, laboratory parameters (HbA1c, LDL, HDL, triglycerides), and physical activity levels. The participants had a mean age of 15.6years and mean BMI of 27.2kg/m^2. Most participants reported regular breakfast consumption and intake of whole grains but low fruit and vegetable consumption.

More than 70% consumed over three roties per day, which was significantly associated with higher HbA1c levels (8.6% vs 7.1%, p<0.001), while higher rice intake was also linked with elevated HbA1c. In contrast, individuals who avoided excess cards intake demonstrated significantly improved HbA1c levels [23] (mentioned in table 1). Supporting clinical trial evidence further confirms that low-carb dietary interventions lead to significant reductions in HbA1c after six months of follow-up (net difference was -0.23%, 95
%, CI -0.32 to -0.14 , p<0.001) [3,29].

Socioeconomic determinants were also evaluated, demonstrating that individuals from lower-income groups (~20,000 PKR/month) had poorer glycemic control (HbA1c $\geq$ 7%) compared with higher-income groups (above 50,000 PKR/month), indicating a strong association between socioeconomic status, dietary quality, and blood glucose regulation [7,18,27] (table 1). Additionally, individuals consuming fruits achieved better glycemic control (HbA1c <7%) compared to those consuming bakery products [11] (table 1). Regional epidemiological evidence across Pakistan further highlights the influence of dietary habits and lifestyle on diabetes prevalence. Lower prevalence rates in KhyberPakhtunkhwa have been associated with diets rich in low-glycemic index foods, whereas higher prevalence in Sindh has been linked to unhealthy dietary practices, physical inactivity, and environmental factors. Baluchistan shows a high burden of prediabetes, attributed to limited diagnostic facilities at primary healthcare levels and lifestyle-related risk factors [24,8,27].

Furthermore, evidence from interventional study a 16-week follow-up of 126 individuals with prediabetes compared supervised versus unsupervised exercise and nutrition programs. The supervised group showed significantly greater improvements in insulin sensitivity, HbA1c and lipid profiles, the studies conformed that planned lifestyle changes are more effective in improving biochemical markers and reducing blood glucose levels [13,25].

To support the role of lifestyle modification in diabetes management as a whole, these findings provide a strong evidence base linking dietary patterns, socioeconomic factors, regional variations and planned exercise programs.[45]



Figure 2:
Review Strategy for Diet and Physical Activity in Diabetes Mellitus

Results

Several original researches have confirmed a significant association between diet, exercise, self-care behaviors, and glycemic control among patients with diabetes mellitus. Pakistani studies particularly focused on showing the importance of lifestyle modification and diabetes education in improving HbA1c and blood glucose levels.
According to study that was conducted by Fatima Zahra et al., a statistically significant relationship was observed between physical activity and glycemic control in patient with type 2 diabetes mellitus. Patients who performed regular physical activity had better HbA1c control compared to inactive individuals ($p<0.05$) as presented in table 1 .[31]

Table 1: The table shows the participants' weekly level of physical activity that includes walking, moderate and vigorous activities, sitting time, and reasons for inactivity, measured using the IPAQ-SF questionnaire.

Variables		Mean ± SD Median (min, max)
MET-min/week	Total score	938 ± 1171
MET-min/week	Total score	594 (0-5493
		460 ± 380.8
Levels of physical activity	Walking	429 (0–1386)
		397.3 ± 715.1
(MET-min/week)	Moderate activity	530 (0-3360)
	Vigorous activity	80 ± 310.9
		128 (0-1440)
	Sitting time (min)	8.8 ± 3.6
		9(2-18)
IPAQ-SF	High level	33(10%)
Weekly physical activity level	Moderate	175(53.1%)
	Low	122(36.9%)
Reason of not doing any activity	Lack of time	66(20%)
	Lack of energy	66(20%)
	None	198(60%)

Riaz et al. Found, cross sectional study demonstrated that better patient understanding of diabetes self-care practices, including diet control, exercise, medication adherence, and glucose monitoring, was significantly associated with improved glycemic control ($p < 0.05$).[32]

Qasim et al. demonstrated that Diabetes Conversation Map-based education significantly improved self-efficacy and diabetes management behaviors among type 2 diabetes patients. The intervention group showed significant improvement in glycemic outcomes compared with the control group ($p < 0.001$) . Two sided p values were calculated using the independent sample t test to compare the intervention and control groups

. Table 2 shows[33]

Table 2 Comparison of diabetes management self-efficacy and HbA1c levels among participants (*N* = 112) after 3 months of enrolment

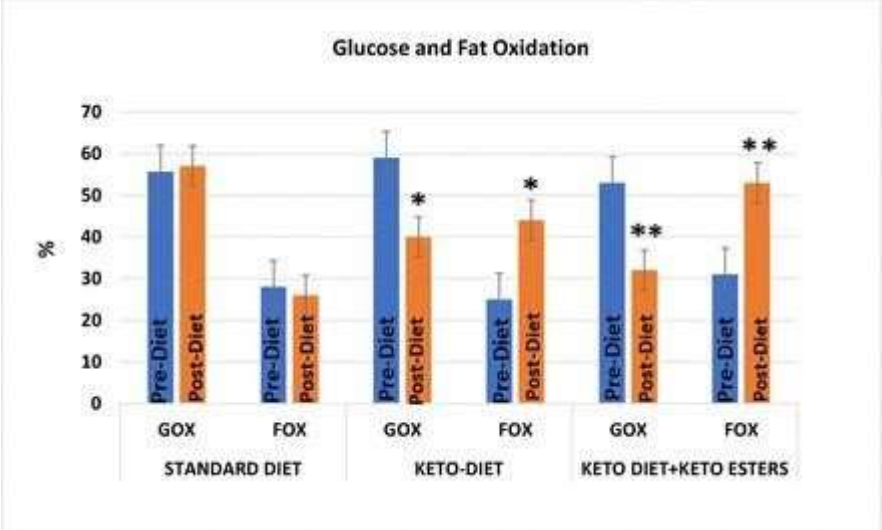
Clinical characteristics	DCM	RC	Difference(95 %CI)	P value
Overall DMSE score after 3 months of enrolment (Mean ± SD)	115.5 ± 18.0	81.9 ± 15.8	33.7 (27.3,40.0)	< 0.001
Factor 1:Exercise & weight control (Mean ± SD)	56.2 ± 10.5	37.1 ± 9.1	19.0 (15.3,22.7)	< 0.001
Factor 2: Health seeking and diabetes treatment (Mean ± SD)	36.1 ± 4.9	28.3 ± 5.6	7.9 (5.8,9.8)	< 0.001
Factor 3:Blood sugar monitoring (Mean ± SD)	16.6 ± 3.1	11.7 ± 2.8	4.8 (3.7,5.9)	< 0.001
Factor 4:Diet control (Mean ± SD)	6.6 ± 2.3	4.6 ± 2.2	1.9 (1.1,2.8)	< 0.001
HbA1c post intervention (Mean ± SD)	8.2 ± 1.4	9.1 ± 1.8	−0.92(−1.68, −0.16)	0.025

Siddique et al. observed that self-care behaviors such as dietary adherence, physical activity, medication compliance, and blood glucose monitoring were significantly associated with controlled blood glucose levels among older diabetic patients ($p < 0.05$).[34]

Tandon et al. demonstrated that that lifestyle intervention played a significant role in preventing the worsening of glycemic status among South Asian women with recent gestational diabetes , with statistically significant findings ($p < 0.05$). Participants following healthier dietary and exercise practices showed improved glucose regulation.[36]

Merovci et al. demonstrated that a weight- maintaining ketogenic diet significantly improved sensitivity for insulin and glycemic control patients having obesity and type 2 diabetes mellitus. Significant reductions in fasting glucose levels and improved metabolic outcomes were observed during the intervention

period ($p < 0.05$) Figer 3 demonstrate the results of ketogenic diet.[36]



Momeni et al. concluded that resistance exercise improved physical fitness and metabolic health among post-menopausal women having type 1 diabetes. Exercise intervention showed beneficial effects on healthy aging and diabetes management ($p < 0.05$).[37]

King et al. reported that aerobic exercise and VO_2 max testing significantly influenced blood glucose regulation among adolescents with type 1 diabetes mellitus ($p < 0.05$).[38] Another study by King et al. establish a significant association between sports participation, physical activity, and lower HbA1c levels among children and adolescents with type 1 diabetes ($p < 0.05$).[39]

Discussion

Recent evidence strongly supports that healthy lifestyle changes are important for controlling and preventing diabetes[44]. Randomized clinical trails demonstrate that low carbohydrate therapeutic diet importantly lower HbA1c and better glycemic results in type 2 diabetic patients [3,41], while digital and web-based dietary programs have also shown meaningful improvements in glycemic control patient adherence [17]. Emerging research highlights the broader role of nutrition infection risk and improving immune and metabolic responses in diabetic individuals [5].

Recent trails from 2025 confirm that structured supervised physical activity programs significantly improve insulin sensitivity, lipid profiles, and glycemic control as compared to unsupervised exercise[13]. Advances in nutrigenomics further report risk of diabetes also effect by gene-diet interactions, with Mediterranean-style diets demonstrating protective effects among genetically different populations [15].

In Pakistan, recent studies highlight that socioeconomic status, health literacy, and access to healthy food leads to noticeable difference in blood glucose levels [18], while national epidemiological data show that urbanization, sedentary behavior and change in eating patterns are main contributors to the increasing burden of diabetes [24]. Additionally, growing proofs on functional and fiber-rich foods shows beneficial effects on glycemic response and antioxidant status in diabetic patients [5,6]. Together, these findings support that complete lifestyle interventions combining diet, exercise and patient education are main components for effective long-term diabetes management.

We examine the importance of personalized nutrition (PN) plans according to the genomic of a population. In this regard, the Genome-Wide Interaction Study (GWIS) shows Mediterranean help in reducing T2DM data used from 136,880 multi-ancestor participants from different ancestral background [15,26].

The reason for the rising prevalence of diabetes are obesity, physical inactivity, family history and psychosocial stress. Urbanization and changing lifestyles are the worse risk factors, especially in developing countries like Pakistan.

To address these issues, diet must be accepted as a main part in diabetes care, whether used itself or togrther with oral hypoglycaemic agents or insulin [2]. However, the high cost of healthy foods, lack of to healthy foods and limited physician training in nutrition interventions are the main barriers[17,18]. Current evidence-based dietary guidelines for diabetes management shows:

Fiber-rich diets with whole and unprocessed foods (whole grains, legumes, fruits, vegetables).

Low-glycemic index carbohydrates and the inclusion of micronutrient rich sources like fruits containing antioxidants and phytochemicals.

Heathy fats, particularly polyunsaturated and monounsaturated fats, while avoiding saturated and trans fats.

Reduced sodium intake, given its importance for cardiovascular health.

In addition to dietary modification, daily exercise important for better insulin signaling, supporting weight management and reducing cardiovascular complications.(Fig 3)

The 2nd National Diabetes Survey of Pakistan (NDSP) reveal the alarming fact that diabetes mellitus has become major public health issue in country [8]. This underscores the urgent need for national strategies, including early diagnosis programs, culturally tailored dietary guidelines and cost-effective diabetes prevention initiatives. Furthermore, training healthcare professionals in nutrition therapy and patient education is crucial for improving long-term outcomes.

Conclusion

This review highlights significant gaps in the management of diabetes in Pakistan, particularly the limited awareness regarding the critical role of diet and lifestyle modification. Despite strong evidence supporting nutritional therapy and physical activity in improving glycemic control and preventing complications, many patients continue to rely primarily on pharmacologic treatment without adopting necessary lifestyle changes. Right now many people with the diabetes mostly depend on medicines skip diet and exercise. That gap leads to poor metabolic outcomes, increased chances of complications and a growing national disease burden.

There is urgent need to fix this, by the better public health literacy regarding the importance of diet and exercise, promote early diagnosis, and empower individuals to actively participate in their disease management. Effective role really needs integrating patient education, culturally appropriate dietary planning, regular physical activity, and professional healthcare guidance is essential for completely control on diabetes. Boosting public awareness about health, easy access to healthy food options, and adding structured lifestyle counselling into routine clinical practice can greatly reduce the glycemic load and improve the quality of life of affected individuals in Pakistan .

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