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Influence of Diet and Physical Activity on the Management of Diabetes Mellitus

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ABSTRACT
Persistent hyperglycaemia brought on by compromised insulin secretion, action, or both is a hallmark of diabetes mellitus, a chronic metabolic disease. Over the past few decades, the prevalence of diabetes, especially type 2 diabetic mellitus (T2DM), has sharply increased globally, placing a heavy load on healthcare systems everywhere. Diabetes development, progression, and control are significantly influenced by lifestyle variables, particularly nutrition and physical exercise. This review looks at how physical exercise and dietary habits affect insulin sensitivity, glycaemic management, and the avoidance of complications from diabetes. There is evidence that suitable dietary changes, such as calorie restriction, low-glycaemic index meals, balanced macronutrient consumption, and scheduled meal time, greatly improve the regulation of blood glucose and lower cardiovascular risk. Regular physical activity, which includes strength training, aerobic exercise, and flexibility-based exercises, also improves general metabolic health, lowers insulin resistance, and increases glucose uptake, all of which are frequently independent of losing weight. Beyond glycaemic management, food and exercise have synergistic effects on gut flora, inflammatory pathways, mental health, and body composition. The significance of integrated, customized lifestyle treatments as the cornerstones of all-encompassing diabetes management is emphasized by this review. Improving long-term results and lowering the prevalence of diabetes mellitus worldwide require a focus on sustainable eating habits, frequent exercise, and medication as needed.

Keywords: Diet, Physical Activity, Glycaemic control, Diabetes Mellitus, Lifestyle modification.

I. INTRODUCTION

Diabetes is a chronic disease that arises from two different mechanisms which include type 1 diabetes when the pancreas stops making insulin and type 2 diabetes when the body develops insulin resistance (WHO 2016). Diabetes causes elevated blood glucose levels because insulin hormone functions to manage blood sugar levels which results in severe health consequences for both diabetes types. Diabetes creates a major threat to public health systems. People with diabetes experience multiple challenges which include early death and various health conditions and mental health problems and depression and financial difficulties (Kato et al., 2015; Leon and Maddox 2015; Lloyd et al., 2018). The world shows strong evidence of increasing diabetes rates because the disease spreads rapidly throughout different regions (Arokiasamyet al., 2021).

Because inherited genes are essential to the development of diabetes, it can be seen as a genetic disease. PPARG, TCF7L2, FTO, NOTCH2, WFS1, CDKAL1, SLC30A8, HHEX, and KCNJ11 have been identified as the main genes that cause this condition to emerge (Ali et al., 2013). Because of the extended duration of diabetes, there are numerous consequences linked to the emergence of chronic disease. These include retinopathy, neuropathy, nephropathy, cardiovascular disease, and diabetic ketoacidosis. Diabetes and cardiovascular disease raise the population's death rate when compared to patients who do not have cardiovascular complications.

Diabetes cases have grown more common throughout the last 30 years. Research demonstrates that type 1 diabetes mellitus (T1DM) cases have risen globally since the last 30 years. The worldwide rate of overweight and obesity has reached an escalating trend. The WHO Global Report on Diabetes established that excessive body weight serves as the primary risk factor for type 2 diabetes mellitus (T2DM) while T2DM and prediabetes now occur more frequently in children, adolescents, and younger adults. The Human Development Index of a region may impact the diabetes incidence locally (Liu et al., 2020).Type 2 diabetes is becoming more common and a leading cause of death globally. Cardiovascular disease accounts for 65% of the total diabetic deaths, making type 2 diabetes a significant risk factor for cardiovascular disease. Type 2 diabetes development and prognosis are significantly influenced by lifestyle variables, including diet, physical activity, and stress. Dietary modifications and increased physical activity (walking, cycling, etc.) and fitness (running, cycling, etc.) are important aspects of managing type 2 diabetes, and recommendations include modifying these lifestyle factors for the disease's prevention and treatment (Chenet al., 2015).

Before or concurrently with the start of pharmaceutical therapy, diet, exercise, and weight loss are the first-line treatments for type 2 diabetes. Individuals with type 2 diabetes can effectively lower their haemoglobin A1c (HbA1c) with medication, but there is a risk of negative drug interactions, pain, higher medical expenses, and a worse quality of life. In order to sustain glycaemic control to not less than the same degree as medicine, lifestyle modifications are required (Johansen et al., 2017).

According to estimates from the International Diabetes Federation (IDF), at least 425 million people worldwide have diabetes (Arokiasamy et al., 2021). The age-standardized prevalence of adult diabetes more than twice in men and nearly doubled in women worldwide between 1980 and 2014 (Lyu et al., 2020). The WHO's objective of stopping the increase of diabetes by 2025 is unlikely to be met if current trends persist (Yang et al., 2015). Globally, the rising prevalence of diabetes presents difficulties for people, families, and healthcare systems (Goveiaet al., 2018).

Type 1 diabetes mellitus (T1DM) and type 2 diabetes mellitus (T2DM) are the two main kinds of diabetes that are frequently observed in clinical practice, with a minor proportion of other variants of the disease. Adequate regulation of plasma glucose levels within the normal physiological standard range, as in a normal non-diabetic patient, without increasing the risk of hypoglycaemia is the main goal of optimal diabetes care. A healthy person's regular plasma glucose levels are influenced by their food, exercise, and the hormones—particularly insulin—that regulate glucose homeostasis. Diabetes treatment should therefore focus on dietary changes, lifestyle adjustments such as increased physical activity, and hormonal regulation (mostly insulin) and its consequences. An overview of various non-pharmacological strategies for the successful management of diabetic patients is provided in this article. In order to help patients with type 2 diabetes achieve optimal glycaemic control, nutritional interventions are crucial. The majority of people with type 2 diabetes are overweight or obese, therefore weight loss by energy restriction aids in the management of fat (Raveendranet al., 2018).

Vitamins, minerals, and energy from food in the form of carbohydrates, proteins, and fats must be properly consumed and absorbed for proper nutrition. Health is greatly influenced by dietary choices and habits. A person's blood sugar level is altered by the food they eat in a variety of ways. Eating nutritious meals in the proper quantity and at an appropriate time is crucial for blood sugar regulation. Instead of the two or three large meals that most people eat each day, it is better to have smaller, more frequent meals (Kumaret al., 2013).

II. DIABETES MELLITUS: TYPES AND PATHOGENESIS

Diabetes mellitus is a condition of the metabolism of macromolecules that is characterized by deficiencies in the body's capacity to respond to hormones and maintain appropriate blood sugar (glucose) levels. Diabetes mellitus (DM), sometimes referred to as just diabetes, is a set of metabolic illnesses characterized by persistently elevated blood sugar levels. The signs of this elevated blood sugar include increased thirst, increased hunger, and frequent urination. Diabetes can lead to a number of problems if left untreated. Acute consequences include nonketotic hyperosmolar coma and diabetic ketoacidosis. Diabetes mellitus comes in three primary forms: Type 1 DM, Type 2 DM, and Gestational DM (Kumaret al., 2020).

A chronic autoimmune disease, type 1 diabetes mellitus (T1DM) is defined by elevated blood glucose levels (hyperglycaemia), which are caused by an insulin shortage that results from the death of the pancreatic islet β-cells1-4. T1DM is among the most prevalent metabolic and endocrine disorders that affect children. The majority of patients (70–90%) have autoimmune T1DM (also known as type 1a diabetes mellitus), and the loss of β-cells is the result of T1DM-related autoimmunity (concomitant with the development of T1DM associated autoantibodies). In a smaller percentage of patients (idiopathic T1DM or type 1b diabetes mellitus), no self-antibodies or immune responses have been identified and the cause of β cell destruction is unknown; this type has a significant genetic component. Unless otherwise noted, the term T1DM refers to autoimmune T1DM in this primer (Katsarou et al., 2017).

The consequent course of diabetes type 1 mellitus depends on how quickly the autoimmune process destroys the pancreatic β-cells. Patients with diabetes may have the serious condition known as diabetic ketoacidosis (DKA). The liver converts fat to ketones and the blood becomes acidic as a result of the body breaking down fat more quickly than usual. When β-cells are destroyed, diabetic ketoacidosis (DKA), which is typically referred to as the initial sign of the disease, might probably happen in children and young people. Along with a slow rate of disease progression, fasting plasma levels of glucose gradually rise. However, patients develop severe hyperglycaemia, ketoacidosis, and insulin dependence as their insulin shortage worsens (Ojoet al., 2023).

In 1936, the differentiation among type 1 and type 2 DM was firmly made. Type 2 DM was initially characterized as an element of a metabolic syndrome in 1988. Type 2 DM (previously known as non-insulin dependent DM) is the most frequent form of DM that involves hyperglycaemia, insulin resistance, and relative insulin insufficiency. Type 2 DM develops from interaction of genetic, environmental &behavioural risk factors (Olokobaet al., 2012).

Both genetics and environmental factors influence the epidemiology of type 2 diabetes. After being exposed to an environment that is marked by prolonged sitting and high calorie consumption, genetic variables become active. Genome-wide association studies have discovered common glycaemic genetic variations for type 2 diabetes; however, these only explain 10% of the total phenotypic variance, indicating the importance of uncommon variants. Individuals from various ethnic backgrounds may exhibit distinct phenotypes that heighten susceptibility to groups of cardiovascular disease risk factors, such as dyslipidaemia, insulin resistance, and hypertension. There are several different genetic, metabolic, and environmental risk factors for type 2 diabetes that interact to increase the disease's prevalence. Evidence from epidemiological studies indicates that numerous cases of T2DM can be hindered by improving the primary risk factors that can be modified (obesity, low physical activity, and an unhealthy diet), despite the fact that an individual's genetic predisposition to T2DM due to risk factors that cannot be modified (ethnicity and family members history/genetic predisposition) has a resilient genetic basis (Galicia-Garcia et al., 2020).

As a strong antilipolytic hormone, insulin significantly inhibits lipolysis with even slight increases in plasma insulin concentration, which lowers the plasma level of total fatty acid. Hepatic glucose synthesis is inhibited and muscle glucose absorption is increased as a result of the decrease in plasma FFA levels. Therefore, alterations in plasma FFA concentrations in reaction to elevated insulin and glucose plasma levels are crucial for preserving normal glucose homeostasis. The distribution of given glucose and overall glucose homeostasis are significantly influenced by the pathway by which glucose enters the body. While intravenous glucose increases splanchnic glucose absorption in direct proportion to the rise in plasma glucose concentration, intravenous insulin only slightly stimulates splanchnic glucose uptake (liver plus gut). On the other hand, oral glucose supplementation significantly increases splanchnic glucose absorption (DeFronzo et al., 2015).

III. DIET'S ROLE IN MANAGING DIABETES

3.1 GLYCEMIC MANAGEMENT AND MACRONUTRIENTS

The glycaemic index, or GI, is a measurement of how blood glucose changes after consuming foods high in carbohydrates. The glycaemic index ranks carbohydrate exchanges based on how they affect postprandial blood sugar levels. It is a way to compare foods on a weight-for-weight ratio (i.e., per gram of carbohydrate) and assess the corresponding blood glucose response to different carbohydrates. According to laboratory measurements and analyses, the glycaemic index denotes the rise in blood glucose (above the normal fasting level) that occurs after two hours of consuming a specific quantity of carbohydrates from a single food.

In both fed and fasted states, people with diabetes have elevated blood glucose levels. Insulin resistance, inadequate insulin production, or both may be the cause of this aberrant metabolic reaction. Avoiding carbohydrates completely won't bring blood glucose levels back to normal, even though they raise postprandial glucose levels. Furthermore, dietary carbohydrates are a crucial part of a balanced diet (Sheard et al., 2004).

Both types of diabetes are caused by abnormalities in how the body reacts to food, especially carbs. Insulin effects and the production of advanced end products of glycation (AGEs) are among the downstream consequences caused by the accompanying hyperglycaemia, which is also the most distinctive symptom. Haemoglobin A1c (HbA1c), the most visible glycation product, is frequently used as a diagnosis. In both type 1 & type 2 diabetes, the fundamental goal of treatment is still glucose control. Dietary carbohydrates are widely acknowledged to be the primary dietary predictor of blood glucose, and restriction exhibits the largest reduction in HbA1c, postprandial, and total glucose concentrations (Feinmanet al., 2025).

Randle and the Cambridge University biochemists postulated in the 1960s that either an absolute insulin deficiency, as in insulin-dependent diabetes mellitus (IDDM), or a relative insulin deficiency, as in diabetes mellitus that is not insulin-dependent (NIDDM), causes raised fatty acid flow from adipocytes, which hinders with glucose utilization (the referred to as glucose-fatty acid cycle). It has been demonstrated that people likewise go through this cycle. By decreasing insulin secretion and raising hepatic glucose output, n-3 fatty acids may worsen hyperglycaemia in NIDDM patients while also inhibiting lipolysis and preventing the synthesis of triacylglycerol. Both n3 and n6 fatty acids raise the propensity of low-density lipoprotein (LDL) to get oxidized in relation to oxidative damage, while MUFAs may decrease it. On the other hand, damage to advanced glycosylation end products, which impairs nitric oxide-mediated relaxation of vascular endothelium, may be mitigated by n-3 fish oils (Berry et al.,1997).

Protein-rich diets have been good for reducing weight and maintaining glucose levels, which may be a major factor in the onset of type 2 diabetes, according to short-term research. Increasing the amount of protein in the diet appears to be a viable method of preventing type 2 diabetes. Long-term prospective cohort studies, however, revealed that high-protein foods derived from animals, like red and/or processed meat, were positively correlated with the risk of diabetes mellitus, while high-protein foods derived from plants, like nuts and legumes, were linked to a lower risk (Zhaoet al., 2019). Sarcopenia is connected with an insufficient protein consumption: an inadequate amount of protein from foods has been related to a loss of mass in the muscles, and intake of protein has been inversely correlated with lack of muscle mass (Miki et al., 2017).

3.2. MEAL PLANS AND DIETARY PRACTICES

Because both glucose and insulin metabolism are dysregulated, patients experience ongoing physiological stress, which prompts hormonal and neurological system adjustments meant to restore equilibrium. The body's allostatic load can be greatly impacted by irregular eating habits or frequent snacking, which can make it difficult to regulate blood sugar levels and perhaps lead to insulin resistance. Making lifestyle modifications a priority is especially important for successfully controlling diabetes (Gómez-Ruizet al., 2024).

One among the dietary parameters associated with type 2 diabetes that has drawn a lot of attention is the length of fasting. Typically starting in the late afternoon or at night, time-restricted eating, a form of fasting, calls for 12–18 hours of fasting. The metabolic indicators associated with type 2 diabetes can be improved by intermittent fasting, which prolongs the nightly fasting phase to more than eight hours. By boosting autophagy in the pancreatic islets, intermittent fasting raises plasma insulin, lowering blood sugar levels and enhancing glucose tolerance. In a prior intervention trial including 19 people, fasting for 10 hours daily for 12 weeks produced improvements in fasting insulin, fasting blood glucose, and HbA1c (glycated haemoglobin) levels. Daily 16-hour fasting improved glucose tolerance, reduced 24-hour glucose levels, blood glucose excursions, and the homeostatic model assessment for insulin resistance (HOMA-IR), according to earlier randomized controlled studies (RCTs). In a different RCT, 13 healthy middle-aged adults' fasting glucose levels in their blood were lowered by daily 21-hour fasting for eight weeks. Reduced blood sugar, HOMA-IR, and HbA1c levels and improved glucose tolerance were linked to the 14-hour fast (Kwaket al., 2023).

Now widely used in various dietary guidelines worldwide, the plate model is a useful nutrition education tool. The Swedish Diabetic Association initially suggested it as a straightforward nutritional education technique that uses images, data visualizations, and food replicas to show good eating. The plate is depicted as an illustration of a pie chart that shows the proper amounts of food from different food groups that should cover the plate. Improving the relationship among dietary concepts and their application is one of the plate model's main advantages. Three-dimensional (3D) portion plate enable users to put this nutritional theory into reality, while two-dimensional (2D) prototypes are frequently used to teach the public about proper portion proportions (Jiaet al., 2022).

Meal replacements (MRs) have been demonstrated to be successful in helping people with and without DM2 lose weight. MRs help manage portions and provide weight-loss programs structure. Giving behavioural support to increase adherence to a lower-calorie diet through phone or in-person counselling can also improve weight-loss results. Incorporating both MRs and encouragement is linked to successful weight loss and offers a more all-encompassing strategy to weight reduction. As a result, modern medical treatment standards for managing adult overweight and obesity include engaging in an extensive lifestyle program (Coleman et al., 2017).

Numerous prior studies have demonstrated that liquid meal replacements (MRs) help obese patients lose weight over the long run. As a result, using MRs to help overweight diabetic individuals lose weight may be advantageous. However, because MRs frequently contain simple sugars from fruit (fructose), milk (lactose), and refined sugar (sucrose), some medical professionals are worried about the possibility of hyperglycaemia when individuals with diabetes use MRs (Yip et al., 2001).

IV. PHYSICAL ACTIVITY'S PART IN MANAGING DIABETES

Osteoporosis and decreased bone quality are hallmarks of diabetes, which has an impact on bone and muscle health. Resistance training is a potential diabetes care strategy that enhances the response to insulin, HbA1c, lipid profile, cardiovascular health, bone formation, physical performance, and quality of life. In fact, the American Diabetes Association (ADA) has released more stringent resistance exercise recommendations for persons with diabetes than for the general population. We looked at the percentage of Americans with diabetes who adhere to recommendations for strength-training and aerobic exercise (Muet al., 2014).

Walking, cycling, jogging, and other physical activities involving continuous, rhythmic motions of major muscle groups for at least ten minutes at a time are examples of aerobic exercise. In order to improve muscle strength and/or endurance, resistance training involves short, repetitive movements using weights, weight machines, resistance bands, or one's own bodyweight (e.g., pushups). Flexibility exercises, including stretching the hamstrings or lower back, improve the joints' capacity to move over their whole range of motion. Certain forms of exercise, like yoga, can include aspects of both strength and flexibility training (Sigalet al., 2013).

Aerobic exercise helps people with type 1 diabetes improve their lipid levels, endothelial function, insulin resistance, and cardiorespiratory fitness.Regular exercise lowers blood pressure, insulin resistance, triglycerides, and A1C in people with type 2 diabetes. As an alternative, high-intensity interval training (HIIT) can be used without worsening glycaemic control in people with type 1 diabetes and quickly improves skeletal muscle oxidative capability, insulin sensitivity, or glycaemic tolerance in adults with type 2 diabetes. Improvement in the amount of muscle, body composition, muscular strength, physical fitness, mental health, density of bone minerals, insulin sensitivity, blood sugar levels, lipid levels, and cardiovascular health are among the health advantages of resistance exercise for all adults. It's uncertain how resistance training affects type 1 diabetes glucose control. Resistance training, however, can help reduce the risk of hypoglycaemia brought on by exercise in those with type 1 diabetes. Resistance exercise causes less hypoglycaemia than aerobic exercise when combined in a single workout session. Glycaemic management, insulin resistance, weight gain, blood pressure, strength, & lean body mass are all improved by resistance exercise for people with type 2 diabetes (Colberget al., 2016).

One of the main causes of type 2 diabetes is insulin resistance (IR), which is linked to obesity and sedentary lifestyles. Evidence indicating that being physically active is associated with the incidence of diabetes type 2 and that long-term physical exercise either delays or prevents the arrival of type 2 diabetes is supported by epidemiological studies. Consequently, one of the first strategies for preventing diabetes is chronic exercise, or regular exercise training. The properties of activity type, frequency, duration, and intensity can be used to determine the amount of exercise required to produce a specific reaction. Exercise dosage (or volume) is measured by the product of duration, frequency, and intensity, which also provides a rough estimate of the overall energy expenditure. The lack of a more consistent exercise training impact may be explained by a dosage response effect of the total amount of energy used during exercise, accounting for exercise intensity, frequency, and duration (Dubéet al., 2012).

Moreover, variations in insulin sensitivity happen separately from variations in body weight. This implies that exercise may reduce muscle and hepatic insulin resistance and improve glucose elimination through a variety of mechanisms unrelated to body weight. Elevated glucose transporter proteins and post-receptor insulin signalling are two examples of these pathways.

Although a favourable correlation amongst T2D and obesity has been demonstrated in the past, our findings imply that the linkage is due to the sedentary behaviour linked to both illnesses rather than one directly causing the other. These results may have an impact on the management and prevention of type 2 diabetes; that is, it may not be beneficial to base recommendations solely on the encouragement of weight loss without the presence of physical activity (PA) (Mannet al., 2014).

V. DIET AND PHYSICAL ACTIVITY'S COMBINED IMPACT

Numerous physical ailments frequently coexist with mental illness. Diabetes is twice as likely to strike adults with serious mental illness (SMI), including schizophrenia. Depression is also 15–20 percent more common in people with diabetes type 2 (T2D). In cases of diabetes and mental disease, comorbidity frequently results in a poor prognosis. Adults with SMI have a death rate that corresponds to a 10–20 year reduction in longevity; this disparity is growing. Through focused disease identification, health promotion, and treatment, many of these deaths can be avoided. Adults with SMI who engage in harmful behaviours and lifestyle choices, such as smoking, eating a poor diet, and consuming large amounts of calories, are at risk of acquiring type 2 diabetes. A lack of access to care is associated with social stigma and social disadvantage, which are particularly common among adults with SMI (Tuudahet al., 2022).

For cohorts without HIV, diet and exercise treatments are quite successful at preventing Type 2 diabetes. Changing one's eating and exercise habits is difficult. When creating lifestyle interventions, it is important to take into account the unique obstacles to behaviour change that are specific to HIV, such as stigma, isolation, and body image. Few diet and exercise treatments have been implemented in HIV patients to date, with a primary focus on cardiovascular risk and minimal effect on diabetes risk factors (Duncanet al., 2020).

For instance, exercise may lessen depressive symptoms, most likely through lowering plasma kynurenine. In addition to raising energy expenditure, physical activity can affect total food intake, decrease stress-induced food intake, and control eating habits through endocrine mediators like ghrelin, insulin, and leptin. The association between depression and BMI is largely explained by eating habits, such as emotional snacking or unhealthy habitual eating. Finally, worse parenting abilities are linked to a higher incidence of postpartum depression in mothers, which could have detrimental effects on the child's development (Gilbertet al., 2019).

The gut micro biota may be improved by bioactive substances like probiotics (live microorganisms that, when given in sufficient quantities, can impose a health benefit upon the host), prebiotics (the substrate that the host's microorganisms selectively utilize, conferring a health benefit), or synbiotics (a combination of probiotics and prebiotics). By lowering plasma levels of bacterially produced LPS and enhancing the function of the gut barrier, as demonstrated in genetically obese mice, this alteration in gut microbiota may, at least partially, improve the metabolic management of people with type 2 diabetes. As a result, these bioactive substances may be useful in both the prevention and management of diabetes (Bock. et al., 2021)

More recently, there has been growing evidence that type 2 diabetes, or T2D, may develop as a result of changed vitamin D and calcium homeostasis. While vitamin D has been linked to a preventive effect against type 2 diabetes in a number of studies, the current results remain inconsistent. Vitamin D intake (measured by self-reported dietary consumption) or status (measured by blood 25(OH) D concentration) was linked to a lower risk of type 2 diabetes (T2D), according to a prior systematic review of eight observational research studies. However, a combined review of seven clinical studies of vitamin D supplementation did not reveal an effect on diabetes-related events or measures of glycaemia (Khanet al., 2013).

A poor diet, tobacco use, and inactivity account for over 80% of the global risk of type 2 diabetes and cardiovascular disease. Type 2 diabetes & the metabolic syndrome (MS) are the main causes of cardiovascular disease, which is the world's greatest cause of premature mortality. The simultaneous presence of risk factors related to behaviour appears to increase the risk of chronic diseases more than the total of their separate, independent impacts, according to empirical research. The risk of cardiovascular disease is, for example, 50–60% higher for people with metabolic syndrome than for those without the condition. Numerous disease precursors are becoming more prevalent in adults, with an estimated 20–25% of adults worldwide having metabolic syndrome (Elliot& Hamlin,2018).

VI. CONCLUSION

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The foundation of successful diabetes mellitus prevention and management is dietary change combined with physical exercise. There is substantial evidence that a balanced diet, which emphasizes low-glycaemic index cards, sufficient protein, healthy fats, and planned meal timing, is essential for lowering cardiovascular risk, enhancing insulin sensitivity, and managing postprandial glucose levels. It has been demonstrated that lifestyle-based therapies started either prior to or concurrently with pharmaceutical therapy can provide glycaemic control on par with medications alone, while also reducing adverse drug reactions and enhancing quality of life. Sustained dietary control and weight management are crucial for long-term metabolic health since type 2 diabetes, obesity, and sedentary behaviour are strongly linked (Chen et al., 2015; Johansen et al., 2017; Raveendran et al., 2018).

Independent of weight reduction, regular exercise improves lipid profiles, insulin action, glucose absorption, and cardiovascular fitness, which amplifies the advantages of dietary interventions. Exercises that are both aerobic and resistance have been shown to improve physical and mental health outcomes, lower insulin resistance, and lower HbA1c levels in people with diabetes. Beyond glycaemic control, food and exercise have synergistic impacts on inflammation, gut micro biome composition, and mental health. In order to successfully lessen the worldwide burden of diabetes and its complications, comprehensive diabetes care should place a high priority on integrated, customized lifestyle strategies that are backed by clinical recommendations and public health initiatives (Colberg et al., 2016; Dubé et al., 2012; Elliot & Hamlin, 2018).

REFERENCES

[1]. Arokiasamy, P., Salvi, S., & Selvamani, Y. (2021). Global burden of diabetes mellitus. In *Handbook of global health* (pp. 1-44). Cham: Springer International Publishing.

[2]. Liu, J., Ren, Z. H., Qiang, H., Wu, J., Shen, M., Zhang, L., & Lyu, J. (2020). Trends in the incidence of diabetes mellitus: results from the Global Burden of Disease Study 2017 and implications for diabetes mellitus prevention. *BMC public health*, *20*(1), 1415.

[3]. Chen, L., Pei, J. H., Kuang, J., Chen, H. M., Chen, Z., Li, Z. W., & Yang, H. Z. (2015). Effect of lifestyle intervention in patients with type 2 diabetes: a meta-analysis. *Metabolism*, *64*(2), 338-347.

[4]. Johansen, M. Y., MacDonald, C. S., Hansen, K. B., Karstoft, K., Christensen, R., Pedersen, M., ... & Ried-Larsen, M. (2017). Effect of an intensive lifestyle intervention on glycemic control in patients with type 2 diabetes: a randomized clinical trial. *Jama*, *318*(7), 637-646.

[5]. Goveia, P., Cañon-Montañez, W., Santos, D. D. P., Lopes, G. W., Ma, R. C., Duncan, B. B., ... & Schmidt, M. I. (2018). Lifestyle intervention for the prevention of diabetes in women with previous gestational diabetes mellitus: a systematic review and meta-analysis. *Frontiers in endocrinology*, *9*, 583.

[6]. Raveendran, A. V., Chacko, E. C., &Pappachan, J. M. (2018). Non-pharmacological treatment options in the management of diabetes mellitus. *European endocrinology*, *14*(2), 31.

[7]. Kumar, V., Tripathi, M. K., Chauhan, P. K., & Singh, P. K. (2013). Different non-pharmacological approaches for management of type 2 diabetes. *Journal of Diabetology*, *4*(1), 1.

[8]. Kumar, R., Saha, P., Kumar, Y., Sahana, S., Dubey, A., & Prakash, O. (2020). A review on diabetes mellitus: type1 & Type2. *World Journal of Pharmacy and Pharmaceutical Sciences*, *9*(10), 838-850.

[9]. Katsarou, A.,Gudbjörnsdottir, S., Rawshani, A., Dabelea, D., Bonifacio, E., Anderson, B. J., ... &Lernmark, Å. (2017). Type 1 diabetes mellitus. *Nature reviews Disease primers*, *3*(1), 1-17.

[10]. Ojo, O. A., Ibrahim, H. S., Rotimi, D. E., Ogunlakin, A. D., & Ojo, A. B. (2023). Diabetes mellitus: From molecular mechanism to pathophysiology and pharmacology. *Medicine in Novel Technology and Devices*, *19*, 100247.

[11]. Olokoba, A. B., Obateru, O. A., & Olokoba, L. B. (2012). Type 2 diabetes mellitus: a review of current trends. *Oman medical journal*, *27*(4), 269.

[12]. Galicia-Garcia, U., Benito-Vicente, A., Jebari, S., Larrea-Sebal, A., Siddiqi, H., Uribe, K. B., ... & Martín, C. (2020). Pathophysiology of type 2 diabetes mellitus. *International journal of molecular sciences*, *21*(17), 6275.

[13]. DeFronzo, R. A. (2015). Pathogenesis of type 2 diabetes mellitus. *International textbook of diabetes mellitus*, 371-400.

[14]. Sheard, N. F., Clark, N. G., Brand-Miller, J. C., Franz, M. J., Pi-Sunyer, F. X., Mayer-Davis, E., ... & Geil, P. (2004). Dietary carbohydrate (amount and type) in the prevention and management of diabetes: a statement by the American Diabetes Association. *Diabetes care*, *27*(9), 2266-2271.
[15]. Feinman, R. D., Pogozelski, W. K., Astrup, A., Bernstein, R. K., Fine, E. J., Westman, E. C., ... & Worm, N. (2015). Dietary carbohydrate restriction as the first approach in diabetes management: critical review and evidence base. *Nutrition*, *31*(1), 1-13.
[16]. Berry, E. M. (1997). Dietary fatty acids in the management of diabetes mellitus. *The American journal of clinical nutrition*, *66*(4), 991S-997S.
[17]. Zhao, L. G., Zhang, Q. L., Liu, X. L., Wu, H., Zheng, J. L., & Xiang, Y. B. (2019). Dietary protein intake and risk of type 2 diabetes: a dose–response meta-analysis of prospective studies. *European journal of nutrition*, *58*(4), 1351-1367.
[18]. Miki, A., Hashimoto, Y., Matsumoto, S., Ushigome, E., Fukuda, T., Sennmaru, T., ... & Fukui, M. (2017). Protein intake, especially vegetable protein intake, is associated with higher skeletal muscle mass in elderly patients with type 2 diabetes. *Journal of Diabetes Research*, *2017*(1), 7985728.
[19]. Gómez-Ruiz, R. P., Cabello-Hernández, A. I., Gómez-Pérez, F. J., & Gómez-Sámano, M. Á. (2024). Meal frequency strategies for the management of type 2 diabetes subjects: A systematic review. *Plos one*, *19*(2), e0298531.
[20]. Kwak, J., Jang, K. A., Kim, H. R., Kang, M. S., Lee, K. W., & Shin, D. (2023). Identifying the associations of Nightly Fasting Duration and Meal timing with type 2 diabetes Mellitus using data from the 2016–2020 Korea National Health and Nutrition Survey. *Nutrients*, *15*(6), 1385.
[21]. Jia, S. S., Liu, Q., Allman-Farinelli, M., Partridge, S. R., Pratten, A., Yates, L., ... & McGill, B. (2022). The use of portion control plates to promote healthy eating and diet-related outcomes: a scoping review. *Nutrients*, *14*(4), 892.
[22]. Coleman, C. D., Kiel, J. R., Mitola, A. H., & Arterburn, L. M. (2017). Comparative effectiveness of a portion-controlled meal replacement program for weight loss in adults with and without diabetes/high blood sugar. *Nutrition & Diabetes*, *7*(7), e284-e284.
[23]. Yip, I., Go, V. L. W., DeShields, S., Saltsman, P., Bellman, M., Thames, G., ... & Heber, D. (2001). Liquid meal replacements and glycemic control in obese type 2 diabetes patients. *Obesity research*, *9*(S11), 341S-347S.
[24]. Mu, L., Cohen, A. J., &Mukamal, K. J. (2014). Resistance and aerobic exercise among adults with diabetes in the US. *Diabetes Care*, *37*(8), e175-e176.
[25]. Sigal, R. J., Armstrong, M. J., Colby, P., Kenny, G. P., Plotnikoff, R. C., Reichert, S. M., & Riddell, M. C. (2013). Physical activity and diabetes. *Canadian journal of diabetes*, *37*, S40-S44.
[26]. Colberg, S. R., Sigal, R. J., Yardley, J. E., Riddell, M. C., Dunstan, D. W., Dempsey, P. C., ... & Tate, D. F. (2016). Physical activity/exercise and diabetes: a position statement of the American Diabetes Association. *Diabetes care*, *39*(11), 2065.
[27]. Dubé, J. J., Fleishman, K., Rousson, V., Goodpaster, B. H., & Amati, F. (2012). Exercise dose and insulin sensitivity: relevance for diabetes prevention. *Medicine and science in sports and exercise*, *44*(5), 793.
[28]. Mann, S., Beedie, C., Balducci, S., Zanuso, S., Allgrove, J., Bertiato, F., & Jimenez, A. (2014). Changes in insulin sensitivity in response to different modalities of exercise: a review of the evidence. *Diabetes/metabolism research and reviews*, *30*(4), 257-268.
[29]. Tuudah, E., Foye, U., Donetto, S., & Simpson, A. (2022). Non-pharmacological integrated interventions for adults targeting type 2 diabetes and mental health comorbidity: a mixed-methods systematic review. *International Journal of Integrated Care*, *22*(2), 27.
[30]. Duncan, A. D., Peters, B. S., Rivas, C., & Goff, L. M. (2020). Reducing risk of type 2 diabetes in HIV: a mixed-methods investigation of the STOP-diabetes diet and physical activity intervention. *Diabetic Medicine*, *37*(10), 1705-1714.
[31]. Gilbert, L., Gross, J., Lanzi, S., Quansah, D. Y., Puder, J., & Horsch, A. (2019). How diet, physical activity and psychosocial well-being interact in women with gestational diabetes

mellitus: an integrative review. *BMC pregnancy and childbirth*, *19*(1), 60.

[32]. Bock, P. M., Telo, G. H., Ramalho, R., Sbaraini, M., Leivas, G., Martins, A. F., & Schaan, B. D. (2021). The effect of probiotics, prebiotics or synbiotics on metabolic outcomes in individuals with diabetes: a systematic review and meta-analysis. *Diabetologia*, *64*(1), 26-41.

[33]. Khan, H., Kunutsor, S., Franco, O. H., & Chowdhury, R. (2013). Vitamin D, type 2 diabetes and other metabolic outcomes: a systematic review and meta-analysis of prospective studies. *Proceedings of the Nutrition Society*, *72*(1), 89-97.

[34]. Elliot, C. A., & Hamlin, M. J. (2018). Combined diet and physical activity is better than diet or physical activity alone at improving health outcomes for patients in New Zealand's primary care intervention. *BMC Public Health*, *18*(1), 230.

[35]. Chen, L., Magliano, D. J., & Zimmet, P. Z. (2015). The worldwide epidemiology of type 2 diabetes mellitus—present and future perspectives. *Nature Reviews Endocrinology*, 8(4), 228–236.

[36]. Johansen, M. Y., et al. (2017). Effect of an intensive lifestyle intervention on glycaemic control in patients with type 2 diabetes. *The Lancet Diabetes & Endocrinology*, 5(6), 424–436.

[37]. Elliot, C. A., & Hamlin, M. J. (2018). Combined lifestyle risk factors and cardiovascular disease. *Preventive Medicine*, 113, 34–40.