INTERNATIONAL JOURNAL OF PHARMACEUTICAL SCIENCES
[ISSN: 0975-4725; CODEN(USA): IJPS00]
Journal Homepage: https://www.ijpsjournal.com

OPEN ACCESS

Review Article

Alternative Therapeutic Approaches in Diabetes Mellitus Management: An Evidence-Based Review

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ARTICLE INFO

Published: 25 Aug 2026

Keywords:

Diabetes mellitus; alternative medicine; complementary therapies; medicinal plants; nutraceuticals; mind body interventions

DOI:

10.5281/zenodo.22104993

ABSTRACT

Background: Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycemia and associated with severe microvascular and macrovascular complications, representing a major global health burden. Despite advances in conventional pharmacotherapy, long-term management remains challenging due to adverse effects, high costs and poor patient adherence, necessitating exploration of alternative therapeutic strategies. Methods: A comprehensive literature-based review was conducted to evaluate alternative approaches in diabetes management, including medicinal plants, nutraceuticals, dietary supplements, and mind–body interventions. Relevant experimental, preclinical and clinical studies were critically analyzed to assess mechanisms and therapeutic potential. Results: Plant-derived bioactive compounds, such as flavonoids, alkaloids, and phenolics, demonstrated significant antihyperglycemic effects through enhanced insulin secretion and sensitivity, inhibition of carbohydrate-digesting enzymes, and modulation of oxidative stress and inflammation. Nutraceuticals including chromium, magnesium, omega-3 fatty acids and coenzyme Q10, showed variable effects on glycemic control and metabolic parameters. Mind–body interventions such as yoga, acupuncture and lifestyle modifications were associated with improved glycemic control, insulin sensitivity, and overall metabolic health. However, variability in study design, lack of standardization and limited high-quality clinical evidence remain major limitations. Conclusions: Alternative therapies may serve as adjuncts to conventional diabetes treatment; however, their clinical application is limited by insufficient standardization, safety concerns, and lack of robust evidence. Further well-designed studies are required to validate efficacy and support integration into evidence-based diabetes management.

INTRODUCTION

Diabetes mellitus is a complex and a rapidly growing medical problem throughout the globe, in

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Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

both developed and developing countries. As per WHO report, diabetes is a multifarious group of disorders that disturb the metabolism of carbohydrates, fat and protein and results in a shortage or lack of insulin secretion or reduced sensitivity of the tissue to insulin. Chronic hyperglycemia is linked to long-term damage and dysfunction of vital organs including the eyes, kidneys, nerves, heart and blood vessels leading to significant morbidity and mortality.[1] The global prevalence of diabetes has risen dramatically over the past few decades, and this has been caused primarily by urbanisation, sedentary lifestyles, unhealthy dietary habits and rising obesity rates.[2]

In 2021, according to International Diabetes Federation Atlas, approximately 537 million adults (20–79 years) are living with diabetes. The total number of people living with diabetes is projected to rise to 643 million by 2030 and 783 million by 2045. The figures are expected to rise to 123 million in India itself by 2040. World Health Organization (WHO) has projected that a maximum increase in people with diabetes would occur in India.[3] Amongst them, 80% reside in low and middle-income nations.[4] Despite major progress in conventional antidiabetic pharmacotherapy and structured lifestyle interventions, optimal glycaemic control remains difficult for a considerable proportion of patients.[5] Residual risks for microvascular and macrovascular complications remain even with standard treatment and long-term pharmacotherapy is frequently associated with adverse effects, polypharmacy, poor adherence and limited accessibility in resource-constrained settings.[6] These limitations have contributed to the growing interest in complementary and alternative therapies among patients, either as adjuncts to conventional treatment or in some cases, as substitutes.[7]

In recent years alternative and complementary therapies have attracted increasing scientific interest as potential adjuncts in the management of diabetes mellitus.[8]. This comprehensive review critically evaluates current evidence on alternative therapies employed in the management of diabetes mellitus including medicinal plants, nutraceuticals, dietary supplements and mind-body interventions such as yoga, acupuncture and lifestyle-based practises.[9] These therapeutic approaches are deeply rooted in traditional medical systems and have been used for centuries across diverse cultures to manage metabolic disorders.[10] Renewed interest in the use of alternative therapies is motivated by patient preference for natural products, perceived safety, cultural acceptability, accessibility and the growing emphasis on holistic and integrative healthcare models.[11]

Medicinal plants are one of the most widely studied alternative treatment strategies for diabetes mellitus.[12] Ethnomedicinal and experimental studies have shown that bioactive compounds from plants such as flavonoids, phenolics, alkaloids, terpenoids, glycosides and saponins, have antidiabetic effects through several mechanisms including improvement of insulin sensitivity, insulin secretion, inhibition of carbohydrate-digesting enzymes, modulation of glucose transport and signalling pathways.[13,14]

Several plant-derived compounds and nutraceuticals have shown their antioxidant and anti-inflammatory activity, contributing to the protection of pancreatic ß-cells and their enhanced metabolic homeostasis.[15,16]. Nutraceuticals and dietary supplements such as polyphenols, dietary fibres, omega-3 fatty acids, vitamins and minerals have also been reported to improve insulin resistance, lipid metabolism and oxidative stress when used as adjuncts to conventional therapy.[17,18]

Mind-body interventions and lifestyle-based practises are increasingly being recognised as part and parcel of holistic diabetes management.[19] Practises such as yoga, meditation, acupuncture and structured physical activity programmes have been linked to improvements in glycemic control, insulin sensitivity, stress reduction and overall metabolic health.[20,21] Lifestyle interventions targeting diet modification, weight management and regular physical activity are fundamental to diabetes prevention and management.[22]

Despite promising evidence, the clinical use of alternative therapies is hampered by issues such as lack of standardisation, inadequate high quality clinical trials, and herb-drug interactions [18]. Therefore, a critical, evidence-based assessment of alternative treatment modalities is needed to facilitate their rational integration with conventional diabetes management strategies.

2. Epidemiology of diabetes mellitus

The word 'diabetes' is derived from the Greek word "Diab" (meaning to pass through, referring to the cycle of heavy thirst and frequent urination); 'mellitus' is the Latin word for "sweetened with honey" (refers to the presence of sugar in the urine). Greeks had knowledge of a disease accompanied by polyurea and wasting of body, whereas Aretaeus of Cappadocia mentioned a disease characterized by thirst and polyurea. Subsequently, the knowledge spread to Chinese, Iranians and Arabians. From the Middle East, the knowledge of diabetes mellitus had spread to Spain as a disease characterized by polyurea, polydipsia with sugary flavoured urine. It is the most common metabolic associated disease in the world. NIDDM is the most common form of diabetes constituting nearly 90% of the diabetic population in any country with varying numbers in different geographical regions.[23]

According to ancient Hindu physicians, 'Madhumeha' is a disease in which a patient passes sweet urine and exhibits sweetness all over the body. They had recorded in their observations that 'if too many ants swarm around a spot of urine, then the person have symptoms of diabetes mellitus.[23]

3. Classification of Diabetes Mellitus

Diabetes mellitus is a heterogeneous group of metabolic disorders that are classified based on underlying pathogenic mechanisms and clinical presentation in Type 1 diabetes mellitus and Type 2 diabetes mellitus.[24]

3.1 Type 1 Diabetes Mellitus (T1DM)

Type 1 diabetes mellitus (T1DM) makes up approximately 5-10% of all cases of diabetes and is an autoimmune disorder in which the immune system is responsible for the destruction of insulin-producing ß-cells of the pancreatic islets. This causes an absolute lack of insulin in the body. The development of T1DM is determined by genetic susceptibility and environmental factors such as viral infections, toxins, and dietary components. Although it can happen at any age, it is most common among children and young people.[25]

3.2 Type 2 Diabetes Mellitus (T2DM)

Type 2 diabetes mellitus (T2DM) makes up almost 90% of the cases of diabetes and is mostly characterised by insulin resistance, in which the cells of the body do not respond effectively to insulin.[26] First the body is able to compensate by producing more insulin, but over time this mechanism loses its function and blood glucose levels rise.[27] T2DM is more frequent in people over 45 years of age; however, the prevalence of this disorder is rising in younger populations because of factors such as obesity, physical inactivity, and high-calorie diets. [28-30]

3.3 Gestational Diabetes Mellitus

Gestational diabetes mellitus (GDM) is diabetes mellitus in which the high blood glucose levels are first identified during pregnancy, typically in the latter stages.[31] It can cause complications including hypertension, preeclampsia and increased need for surgical delivery.[32] Infants of mothers with GDM are at risk of macrosomia, respiratory distress and increased risk of obesity and type 2 diabetes later in life [33]. Common risk factors include advanced maternal age, obesity, gaining too much weight during pregnancy, family history of diabetes, and previous pregnancy problems. [34,35]

4. Pathophysiology of Diabetes Mellitus

Diabetes mellitus has a profound adverse effect in quality of life in terms of social, psychological well-being as well as physical health. Diabetic complications are primarily mediated by oxidative stress including elevated ROS generation or defective antioxidant defence systems. Enhancement of lipid peroxidation, alteration in antioxidant enzymes and impaired glutathione metabolism are the leading factors involved in the development of diabetes.[36] Production of free radicals are also involved in the pathogenesis of various type of disease including diabetes mellitus.[37] Increased formation and accumulation of advanced glycation products (AGEs) is also involved in the diabetic complications, such as retinopathy, neuropathy and renal dysfunction through a series of pathological changes.[38] Though there are several hormones involved in the regulation of glucose level in the blood, the most important ones are insulin and glucagon. When imbalanced occur in the level of hormones in the body, sugar starts accumulating in the blood and when concentration of glucone increased in the blood then finally it will passes in urine along with other minerals.[39] In the majority of diabetes, mainly T -cell is responsible for destruction of pancreatic islet ß-cells, and becomes clinically symptomatic when 90% of pancreatic beta cells are destroyed. Serological markers (islet cell, glutamic acid decarboxylase (GAD), IA-2, IA- 2ß or insulin autoantibodies) can be found in 85-90% of subjects in the presence of fasting hyperglycemia. Some of the times environmental triggers, chemical or viral initiated pancreatic ß -cell destruction which can triger consequences and thereby leads to the cause in diabetes mellitus. From the study it was found that enterovirus infection is also associated with development of diabetes mellitus.[40]

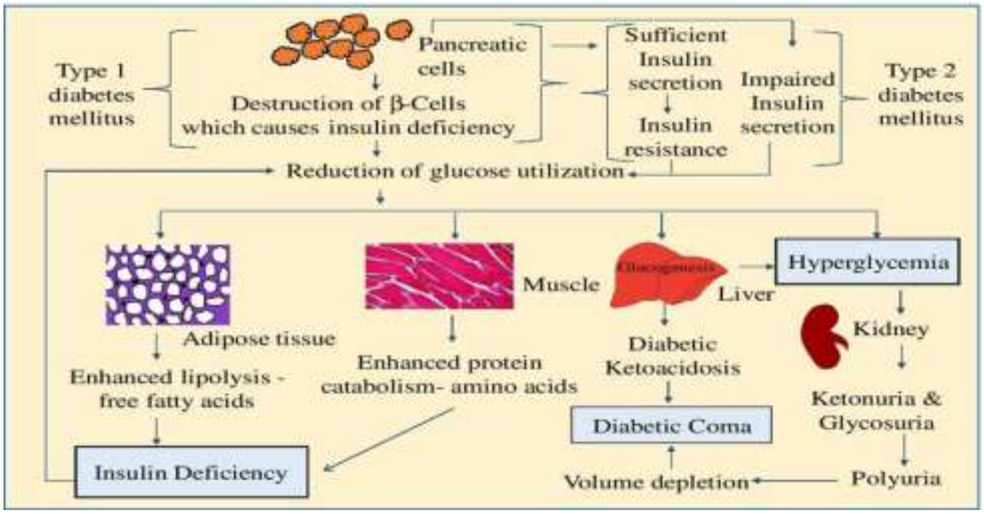

Figure 1. Overview of the pathophysiology of Type 1 and Type 2 diabetes mellitus showing β-cell destruction, insulin resistance, impaired glucose utilization and metabolic complications associated with chronic hyperglycemia.

5. Medicinal Herb

As per ancient literature, more than 800 plants are reported to have antidiabetic properties. Ethnopharmacological surveys indicate that more than 1200 plants are used in traditional medicine for their allied hypoglycemic activity. Some herbs have also been proven to help in regeneration of ß-cells and in overcoming resistance. In addition to maintaining normal blood sugar level, some herbs are also reported to possess antioxidant activity and cholesterol lowering action.[41]

To the date, over 400 traditional plant treatments for diabetes have been reported, although only a small number of these have received scientific and medicinal evaluation to assess their efficacy. The following is a summary of several of the most studied and commonly used medicinal herbs.[41]

Botanical Therapies for the Management of Diabetes Mellitus

5.1 Aloe vera (L.) (Euphorbiaceae)

Aloe vera has been used traditionally in the Middle Eastern and Asian systems of medicine for the treatment of metabolic disorders, including diabetes mellitus. The hypoglycemic potential of Aloe vera is attributed largely to the gel extracted from the inner leaf pulp, which contains polysaccharides, phytosterols, glucomannans and antioxidants. Experimental studies suggest that Aloe Vera gel improves the function of pancreatic b cells, insulin production and the utilisation of glucose in the peripheral tissues, reducing the fasting blood glucose levels.[42,43]

Clinical investigations have shown that oral administration of Aloe vera gel juice for 4-6 weeks led to significant reductions in fasting blood glucose in patients with type 2 diabetes mellitus, especially when used as an adjuvant to the conventional oral hypoglycemic agents.[44,45] However, heterogeneity in preparation methods and limited randomised controlled trials require more standardisation before routine clinical recommendation. The latex part of the leaf is contraindicated because of possible gastrointestinal adverse effects.[46]

5.2 Trigonella foenum-graecum (Leguminosae)

Fenugreek seeds have been used in traditional Indian and Chinese medicine for glycemic control for many years. The extracts, powder and gum of fenugreek seeds and leaves have been reported to have anti-diabetic and hypocholesterolemic properties in both model animals and humans. The antidiabetic effects have been attributed mainly to the soluble dietary fibre, saponins (steroidal compounds) and an amino acid, 4-hydroxyisoleucine, which delay the absorption of carbohydrates and increase the secretion of glucose-dependent insulin. [47,48]

Clinical studies with patients with type 1 and type 2 diabetes have reported reductions in blood glucose levels during fasting and after meals after fenugreek supplementation. [49,50] Despite encouraging results, most trials have methodological limitations, such as small sample sizes and not being blinded, indicating the need for well-designed randomised controlled studies.

5.3 Emblica officinalis Gaertn (Amalaki)

Emblica officinalis (Amla) is a potent fruit rich in antioxidants containing ascorbic acid, hydrolysable tannins and polyphenols. Oxidative stress has a significant role in insulin resistance and β-cell dysfunction. Amla has shown important antioxidant and anti-inflammatory activity in experimental models of diabetes.[51]

Preclinical and limited clinical studies suggest that Amla helps to improve glycemic control by improving insulin sensitivity and modulating key enzymes involved in the metabolism of carbohydrates.[52] In addition, its lipid-lowering and cytoprotective effects may help prevent complications associated with diabetes, playing a role as complementary therapeutic agents.

5.4 Pterocarpus marsupium Roxb (Fabaceae)

It is also known as Vijayasar or the Indian Kino Tree belonging to family Fabaceae. The hypoglycemic effect of various extracts from P. marsupium bark was obvious in alloxan-induced diabetic rats. The results confirmed their efficacy on plasma glucose, total protein, cholesterol, triglycerides, alkaline phosphatase, alanine transaminase and aspartate transaminase. Moreover, butanol sub-fraction a marked hypoglycemic effect by adjusting body metabolism similar to insulin properties.[53] Marsupsin and pterostilbene, phenolic constituents of the heartwood of P. marsupium, significantly reduced blood-glucose level of approaching that of metformin.[54]

5.5 Momordica charantia (Cucurbitaceae)

The plant is a member of Cucurbitaceae, commonly known as kugua, karela, bitter gourd or bitter melon. It is popular herbal resource and is often used to treat diabetes. The antidiabetic potential of Momordica charantia is well established in streptozocin or alloxan-induced diabetic rats, mice and rabbit, genetically diabetic mice and in humans with Type 2 diabetes. Momordica charantia increases the renewal of parital cells in the pancreas or may permit the recovery of partially destroyed cells and stimulates pancreatic insulin secretion. These could likely explain the significant increase in the plasma insulin level when streptozocin-induced diabetic rats were treated with Momordica charantia. Furthermore, Momordica charantia displays insulin-like properties, remarkably stimulating glycogen storage by the liver and improving peripheral glucose uptake.[55]

5.6 Cinnamomum spp (Cinnamon)

It is commonly known as Cinnamon (Lauraceae) and widely used in East Asia and Europe. It is extensively used in folk medicine to treat diabetes. It contains volatile oils, mainly cinnamaldehyde. Cinnamon ingestion decreased total plasma sugar level with insulin sensitivity improvement. It also significantly reduced gastric emptying and profoundly decreasing postprandial glycemic response. In addition, cinnamon aqueous extract revealed a potent antidiabetic effect through its up regulation of uncoupling protein-1 (UCP-1) and enhancing the translocation of GLUT4 in the muscle and adipose tissues. Oral administration of cinnamaldehyde, its chief active constituent, resulted in significant reduction in serum glucose, glycosylated hemoglobin, total cholesterol and triglyceride levels accompanied by a marked increase in serum insulin, hepatic glycogen and high-density lipoprotein in a dose-dependent manner.[56]

5.7 Piper longum L. (Piperaceae)

P. longum is commonly known as long pepper or Pippali has played a pivotal role in traditional medicine systems for centuries, especially in Ayurveda, Siddha and Unani practices, where it is recognized as a Rasayana herb known for its rejuvenating and immunomodulatory properties. It has a wide variety of chemical constituents (alkaloids, amides and lignans) that are responsible for its wide pharmacological range of activities including antimicrobials, cardioprotective, anticancer and antidiabetic activity.[57] Piper longum is believed to be beneficial as an adjunct in polyherbal antidiabetic formulations, but not as a single drug; there is no direct evidence for this.No direct evidence exists, but Piper longum is believed to be useful as an adjunct in polyherbal antidiabetic formulations rather than as a single drug.[58]

5.8 Azadirachta indica (Meliaceae)

It belongs to the family Meliaceae and has been used for a long time in traditional medicine in treating several ailments, including diabetes. Its leaves stem bark and seeds possess hypoglycemic activity via increasing insulin secretion from the beta cells of the pancreas.[59] Its leaves are characterized by the presence of high fiber content that is potent in diabetes management and controlling of post-prandial hyperglycemia through delaying gastric emptying, increasing viscosity of GIT content thus, suppressing digestion and absorption of carbohydrate with no risk of hypoglycemia, hyperinsulinemia and undesirable weight gain.[60]

Table 1. Herbs used in the management of diabetes mellitus

Name	Mechanism of action	Reported side effect
Aloe vera (L.)	Stimulation of pancreatic β-cell activity Increased insulin secretion Improved peripheral glucose utilization	Abdominal pain and diarrhea (latex component) Electrolyte imbalance with prolonged use
Trigonella foenum-graecum	Increased insulin secretion Delayed intestinal carbohydrate absorption	Bloating and diarrhea Contraindicated during pregnancy
Emblica officinalis Gaertn.	Antioxidant activity Reduction of oxidative stress–induced insulin resistance Modulation of carbohydrate-metabolizing enzymes	No significant adverse effects reported
Pterocarpus marsupium Roxb.	Insulinogenic activity Regeneration of pancreatic β-cells Enhancement of endogenous insulin secretion	Limited human safety data No major adverse effects reported
Momordica charantia	Insulin-mimetic activity Suppression of hepatic gluconeogenesis Increased peripheral glucose uptake	Risk of hypoglycemia with antidiabetic drugs Contraindicated in pregnancy Caution in G6PD deficiency

Cinnamon	Increased insulin sensitivity Enhanced insulin receptor signaling Modulation of hepatic glucose metabolism	Generally, well tolerated Gastrointestinal irritation with excessive intake
Piper longum L.	Enhancement of insulin sensitivity Antioxidant activity Bioavailability enhancement of co-administered agents	No significant adverse effects reported
Azadirachta indica	Enhancement of insulin secretion and β-cell function. Increased peripheral glucose uptake. Antioxidant and anti-inflammatory activity reducing insulin resistance.	Gastrointestinal discomfort (nausea, vomiting) in some cases Risk of hypoglycemia when combined with antidiabetic drugs Contraindicated in pregnancy due to potential abortifacient effects

6. Dietary Supplements and Nutraceuticals

6.1 Chromium

Chromium is a trace element that is required for insulin signalling and glucose metabolism. Supplemental studies show beneficial effects on insulin sensitivity, particularly in individuals with high insulin resistance, and there are small improvements in fasting glucose; there is some variability in the quality of the studies and the therapeutic response seems to be dependent on the phenotype. [62, 63]

6.2 Magnesium

Magnesium is extremely important for insulin secretion and glucose transport. Hypomagnesemia is often found in patients with poorly controlled diabetes.[64] Randomised trials show modestly lower values in fasting glucose levels from magnesium supplementation, although long-term effects on HbA1c are inconclusive. [65,66]

6.3 Omega-3 Fatty Acids

Omega-3 polyunsaturated fatty acids are being used widely in the cardiovascular risk reduction of diabetic patients. They have considerable effects on triglyceride levels, but little effect on glycemic control (HbA1c, fasting glucose).[67] High dose supplementation does not significantly affect fasting glucose or HbA1c, but may have a modest effect on LDL cholesterol, so careful patient selection is required.[68]

6.4 Vanadium

Vanadium has insulin-mimetic properties by improving the uptake of glucose and inhibiting the production of glucose by the liver.[69] Despite demonstrated reductions in fasting glucose in small clinical trials, concerns about renal toxicity and a lack of long-term safety data limit its clinical applicability.[70]

6.5 Coenzyme Q10

Coenzyme Q10 is an endogenous antioxidant that is part of the production of energy in the mitochondria. Although good for cardiovascular health, clinical trials do not show significant improvements in glycemic control.[71] Thus, CoQ10 can be considered as a supportive therapy for cardiovascular protection instead of direct glucose lowering in diabetic patients.[72]

Table 2. Dietary Supplements used in the management of diabetes mellitus

Name	Mechanism of action	Reported side effect
Chromium	Enhancement of insulin signaling Increased insulin sensitivity Improved glucose transport	Minimal adverse effects Renal impairment with excessive intake
Magnesium	Improved insulin secretion Increased insulin sensitivity Role in glucose transport and metabolism	Diarrhea and abdominal cramping Risk of toxicity in renal insufficiency
Omega-3 Fatty Acids	Reduction of triglycerides and VLDL Cardiovascular risk reduction No consistent glucose-lowering effect	Increased bleeding risk (>3 g/day) Possible increase in LDL cholesterol
Vanadium	Insulin-mimetic action Enhanced peripheral glucose uptake Suppression of hepatic glucose output	Renal toxicity with long-term high doses Gastrointestinal intolerance
Coenzyme Q10	Antioxidant activity Support of mitochondrial energy metabolism No consistent effect on glycemic control	Generally, well tolerated No major adverse effects reported

7. Mind–body interventions

7.1 Yoga

The description of word yoga is found in Sanskrit. In Sanskrit, Yuj means to unite one's body breath and mind to the universal power. Yoga is an ancient practice that emphasizes balancing of various aspects (like physical, mental, emotional, and spiritual) of an individual. Yoga focuses on the general well-being of an individual by following the path of physical postures (asanas), breathing exercises (pranayamas), and meditation (dhyana). Yoga therapy consists of a specialized set of asanas, pranayamas along with meditation depending on different health problems. Certain sets of asana that have proven to be beneficial for the abdominal area cause rejuvenation/ regeneration of the pancreas, which promotes glucose metabolism along with its utilization through several tissues like peripheral tissues, liver, and adipose tissue via enzymatic activity. Asanas focus on stretching exercises which promote balanced glucose metabolism along with effective enzymatic activities in peripheral organs (liver, adipose tissue, etc.). A study has shown a reduction in the level of blood sugar (a biochemical parameter) and improved metabolic activity (measured as triglyceride uptake by adipose tissues). Yoga postures (asana and pranayama) also improve β-cell sensitivity to glucose signalling and insulin secretion and help in the regulation of body homeostasis.[73]

7.2 Acupuncture

Acupuncture therapy is a common approach to treating diabetes in China. Acupuncture is best known in the United States as an alternative therapy for chronic pain. However, it has been used for the treatment of diabetes and related complication during the past several decades. Acupuncture may be effective in treating not only diabetes, but also in preventing and managing complication of the disease.[41] It is one of the CAMs that have been widely used in the world with minimum side-effects when administered by qualified practitioners, who insert thin needles at specific acupuncture points to stimulate and regulate the balance of Qi and Blood inside the body. Electroacupuncture (EA) is a method of stimulated acupuncture points with an electrical current. EA has been shown to have various effects on released neurotransmitters. The possible mechanism of acupuncture for treating DM occurs through a hypoglycemic effect, improvement in insulin sensitivity and regulation of lipid metabolism.[74]

7.3 Poor sleep

Sleep is a restorative process for both mind and body. There are five stages of sleep: non-rapid eye movement sleep stages 1–4, and rapid eye movement sleep. Of these, the deeper stages of non-rapid eye movement sleep (stages 3 and 4), also called ‘slow wave sleep’, are also the most restorative. Proper sleep is important for normal metabolic and hormonal regulations of the body. Sleep deprivation and poor quality of sleep result in altered metabolic and hormonal function, leading to the development of T2DM. People who sleep less than 6 hours per night are at risk of developing diabetes and it is advised to have 7 hours of uninterrupted sleep per night.[75]

During sleep deprivation, brain glucose use is reduced, and there is hormonal dysregulation, resulting in overall higher GH levels and evening cortisol levels that may contribute to the development of T2DM.[76] Increased sympathetic activity, reduced parasympathetic activity and increased level of inflammatory markers in these cases also may play a role. Sleep deprivation results in weight gain and obesity by multiple mechanisms such as hyperactivity of the orexin system, overeating and reduced energy expenditure.[77]

7.4 Physical activity

Physical activity refers to any body movement that increases energy expenditure above the baseline, whereas exercise is a planned, structured and repetitive physical activity performed with the objective of improving physical fitness. Physical activity improves insulin sensitivity, bodyweight, cardiovascular risk factors, physical fitness, lipid level, blood pressure and overall wellbeing, and reduces the risk of cardiovascular morbidity and mortality.[78]

Physical activity not only improves glycaemic control in patients with T2DM, but also reduces bodyweight and blood pressure. It improves the adverse lipid profile by reducing total cholesterol and low-density lipoprotein (LDL) cholesterol and increasing high-density lipoprotein (HDL) cholesterol. These, in turn, reduce the risk of various cardiovascular events inherent to patients with T2DM. [79]

CONCLUSION

In conclusion, diabetes mellitus remains a major global health challenge requiring effective long-term management. Alternative therapies including medicinal plants, nutraceuticals and mind–body interventions show promising supportive effects in improving glycemic control, insulin sensitivity, and metabolic health through antioxidant, anti-inflammatory and insulin-enhancing mechanisms. However, their widespread clinical use is limited by lack of standardization, insufficient high-quality clinical evidence and safety concerns. Future research should focus on standardized formulations, identification of active compounds and large-scale clinical trials to validate their efficacy and safety. Scientifically validated alternative therapies may serve as valuable adjuncts to conventional treatment for holistic and patient-centered diabetes management.

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HOW TO CITE: Vinayak Pattar, Dr. Vishnu Kangralkar, Kunal Solankure, Alternative Therapeutic Approaches in Diabetes Mellitus Management: An Evidence-Based Review, Int. J. of Pharm. Sci., 2026, Vol 4, Issue 8, 4237-4251. https://doi.org/10.5281/zenodo.22104993