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Diet, Lifestyle Behaviours and Bioactive Nutraceuticals in Glycemic Control Among Indian Type 2 Diabetes Patients

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ABSTRACT: Background: In India, type 2 diabetes mellitus (T2DM) affects an estimated of 101 million adults and a substantial number of treated T2DM patients are unable to achieve the recommended glycemic target. The current review is a narrative review which investigates the relationship between dietary patterns, lifestyle behaviours and natural bioactive compounds with glycemic control (represented primarily by glycated haemoglobin - HbA1c) among Indian adults with T2DM. Methods: PubMed, Scopus, ScienceDirect and Google Scholar were used to search literature, which included community- and hospital-based studies and clinical trials and national cohort studies conducted in India, primarily in the past two decades, focusing on plant-derived nutraceuticals. Results: High carbohydrate diets (mainly based on refined cereals and extra sugar) are repeatedly shown to be linked with increased HbA1c levels, and pulses, whole grains and increased dietary diversity are associated with better control. Each of these – low physical activity, long periods of sitting, inadequate sleep, psychological stress or tobacco and alcohol consumption – is associated with suboptimal glycemic outcomes on its own. Traditional Indian herbs and spices such as fenugreek (Trigonella foenum-graecum), bitter gourd (Momordica charantia), curcumin derived from turmeric, cinnamon and Gymnema sylvestre have been found to produce clinically significant decreases in HbA1c and fasting glucose in random trials and meta-analyses, and represent a natural-resource based approach to complement existing dietary and lifestyle guidance. Summary: The glycemic control of Indian T2DM patients is influenced both by their daily diet and lifestyle as well as the bioactive properties of the Indian food culture and traditional herbs. The combination of evidence-based nutraceuticals and culturally adapted lifestyle interventions appears to be a promising, yet under-explored approach to improving diabetes outcomes in India.

1. INTRODUCTION

Diabetes mellitus is no longer a disease of affluent people and has become a problem in all socio-economic groups in India. The Indian Council of Medical Research–India Diabetes (ICMR-INDIAB) study, which was conducted in all states and union territories between 2008 and 2020, reported a weighted prevalence of 11.4% for type 2 diabetes and 15.3% for prediabetes which translates to approximately 101 million people with diabetes and an equal number with high risk of developing diabetes (Anjana et al., 2023; Anjana et al., 2017). Diabetes, too, had previously been considered a disease of the urban better-off population, and some less-developed states had already revealed diabetes prevalence rates that approached those of the more industrialised south (Anjana et al., 2017; Anjana et al., 2011).

The clinical primary target for long-term glycemic control in T2DM is, and always will be, glycated haemoglobin (HbA1c) which is directly related to the risk of microvascular and macrovascular complications. However a large number of Indian patients on treatment fail to reach the recommended goals (HbA1c) target. In community and hospital-based studies conducted across the country, the percentage of treated patients who were not achieving the recommended HbA1c target of 7% has been consistently higher than half—even approaching three-quarters in some settings—but this frequency is not seen in non-treated patients (Mathur et al., 2022; Verma et al., 2025; Alwani et al., 2024). However, this gap is not always attributed to unavailability of drugs, or to factors at the level of the physician; there is an increasing literature in India and South Asia that suggests diet, the daily lifestyle behaviours, and the underutilization of naturally available bioactive food resources as more proximal determinants of day-to-day glycemic fluctuation.

India is a particularly promising environment for this exploration, both because the traditional diet is high in carbohydrates (cereals like rice and wheat, and added sugars can make up more than 60% of the total daily energy intake (Anjana et al., 2025)) and because the country's traditional food and herbal practices, in particular Ayurveda, have long relied on specific plants and spices as natural hypoglycaemic agents, with a few of these now supported by clinical-trial evidence. The purpose of this narrative review is to collate Indian and South Asian evidence of dietary pattern and lifestyle behaviours related to glycemic control and complete it with a synthesis of clinical evidence on natural bioactive compounds and nutraceuticals of relevance to the Indian diet, highlighting a natural-resource-based integrated approach for glycemic management.

2. MATERIALS AND METHODS

This is a narrative synthesis rather than a systematic review, conducted with that scope explicitly in mind. A structured search was carried out across PubMed, Scopus, ScienceDirect and Google Scholar using combinations of the terms 'type 2 diabetes', 'glycemic control', 'HbA1c', 'dietary pattern', 'physical activity', 'sedentary behaviour', 'sleep', 'diabetes distress', 'depression', 'smoking', 'nutraceutical', 'fenugreek', 'Momordica charantia', 'curcumin', 'cinnamon', 'Gymnema sylvestre' and 'India'. Priority was given to studies conducted in Indian populations; where Indian data on a specific behaviour or compound were sparse, well-conducted South Asian, Asian, or international randomised trials and meta-analyses were included for context and are identified as such in the text. Cross-sectional, cohort, randomised controlled trial, and systematic review or meta-analytic articles published predominantly between 2000 and 2026 were considered. Articles were included if they reported a quantitative or clearly described association between a dietary, lifestyle, or nutraceutical variable and a glycemic outcome (HbA1c, fasting plasma glucose, or postprandial glucose) in adults with T2DM or prediabetes. No formal risk-of-bias scoring or meta-analytic pooling of effect sizes was undertaken; findings are grouped thematically and discussed in relation to one another.

3. RESULTS AND DISCUSSION

3.1 Epidemiological burden and the case for a behavioural and natural-resource lens

Diabetes is a population level issue in India due to the magnitude of the diabetes burden. The study revealed that about 61% of the respondents were physically inactive, with 43% being overweight, 26% being obese, and carbohydrates contributing to nearly 62.3% of the total energy intake, with refined cereals and milled whole grains constituting about 45% of the intake (Anjana et al., 2025). The risk of newly diagnosed T2DM was 30% greater and the risk of prediabetes was 20% greater among participants with highest intake of carbohydrates compared to those with the lowest intake (Anjana et al., 2025). In a north Indian community-based STEPS survey, the prevalence of diabetes and prediabetes among those screened was nearly 90% (Tripathy et al., 2017); and a recent meta-analysis of Indian observational studies demonstrated a direct correlation between increasing obesity and hypertension and T2DM (Babu et al., 2018). The figures make it clear why dietary and lifestyle exposures have been a subject of current research on diabetes in India, along with the still untapped therapeutic possibilities of natural food components.

3.2 Dietary patterns and glycemic control

The most consistent theme of Indian literature is the importance of the quantity and quality of carbohydrates in the diet. Over 18,000 adults with detailed dietary data were included in the ICMR-INDIAB survey-21 analysis which identified that Indian diets are dominated by low quality carbohydrate sources, such as white rice, milled whole grains and added sugars, and have relatively high intakes of saturated fats and low intakes of protein (Anjana et al., 2025).

Importantly, replacing refined cereal with whole wheat or millet flour (without decreasing the amount of carbohydrate) did not result in a reduced risk for T2DM, indicating that the total amount of carbohydrate consumed is as important as the type of grain (Anjana et al., 2025). The glycemic index (GI) of Indian staple foods adds to any easy answer between wheat and rice. In this study, 155 T2DM patients were fed with 600g of boiled rice and 600g of whole wheat chapatti, and the authors found that rice had an even lower postprandial glycemic and insulinemic response than wheat chapatti which was attributed to the lower starch granule size, higher amylopectin/amylose ratio, and greater moisture content of rice (Paharia and Sen Ray, 2017). This is in line with the classic rule that GI rankings derived from the same amount of carbohydrate measurements are not necessarily the same as those obtained from the same amount of food (Jenkins et al. 1981). In separate studies, agronomic studies with Indian rice cultivars revealed that not every rice cultivar has an equally unfavourable glycemic load, as there is an inverse correlation between the content of resistant starch and glycemic index (Deepa et al., 2010; Govindaraju et al., 2025). A detailed consensus exercise on Asian Indian food patterns identified a combination of the high consumption of carbohydrate energy, poor quality of protein, low fibre consumption and poor fat quality as the most likely to be responsible for the region's high prevalence of diabetes and not any particular grain per se (Misra et al., 2011).

In several Indian studies data-reduction techniques have been employed to obtain empirical dietary patterns directly from food-frequency information. The Chennai Urban Rural Epidemiology Study (CURES-162), which included 573 adults with known diabetes, found that the 'non-vegetarian' and 'vegetarian' patterns were positively associated with poor control (HbA1c), while the pattern that included more pulses and vegetables than refined cereals was inversely associated with poor control (Priya et al., 2022). A similar hospital-based study of 860 community-managed T2DM patients showed that the patterns enriched with whole grains, plant protein, nuts and fruits were linked to good glucose control, while those with refined-grain or sugary-beverage patterns were linked to poor control (Zheng et al., 2026). A larger study of over 16,000 adults in Delhi, Chennai and Karachi in South Asia also found a positive association between dietary diversity and a more favorable cardiometabolic risk profile (Kapoor et al., 2018).

In addition to the statistical pattern of diet, there is not a consistent adherence to the dietary advice. Overall, alcohol avoidance was well adopted, sugary drinks and high-GI foods were not well adopted, and the level of adherence decreased with age, in a cross-sectional study of 450 T2DM patients in NCD clinics in western India (Patel et al., 2024). This knowledge-practice gap also exists in literature from the S. Asian context (Hakeem et al., 2018; Sendekie et al., 2025), which supports the fact that there are gaps in dietary counselling and socio-cultural eating norms play an important role in poor glycemic outcomes.

3.3 Lifestyle behaviours and glycemic control

Being physically inactive is one of the most modifiable factors of glycemic control among Indian T2DM. In fact, data from the National ICMR-INDIAB study showed that approximately 60% of Indian adults with diabetes have risk factors for inactivity (Anjana et al., 2025), and facility-based studies identified structural barriers to participation in recommended walking levels, such as lack of time, unsafe walking conditions and physical discomfort (Jayasuja et al., 2026; Pati et al., 2019; López Sánchez et al., 2019). A cross-sectional survey of Indian adults with diabetes similarly found that just over half engaged in regular weekly physical activity, with participation notably higher among men and those with better English proficiency, underscoring how demographic and socio-cultural factors shape activity levels alongside structural barriers (López Sánchez et al., 2019).

Skeletal muscle glucose uptake can increase during activity without insulin, and moderate activity can achieve a significant increase in glucose uptake relative to a sedentary state (Dhait et al., 2022). Importantly, sedentary time, in isolation from moderate-to-vigorous activity accumulated elsewhere in the day, is related to poorer glycemic outcomes (Sardinha et al., 2017) and the systematic review of interventions targeted at reducing sedentary behaviour revealed that most interventions were associated with improvements in at least one glycemic or cardiometabolic marker (Smith et al., 2024) — a distinction that is pertinent for the many Indian patients who are in sedentary occupations.

In comparison to other parts of the world, sleep has been studied relatively little in India, but the evidence from the region and Asia is consistent. Based on a cross-sectional primary-care study, poor sleepers showed significantly higher HbA1c than good sleepers (Borzouei et al., 2024), which was corroborated by a systematic review and meta-analysis of Asian T2DM cohorts association between short sleep duration and poor sleep quality with higher HbA1c (Azharuddin et al., 2020). A cross-sectional study in Japan also reported associations between shorter sleep durations and longer sleep latency with the highest quartile of HbA1c, after adjusting for other covariates, and between variability in sleep duration and subjective sleep quality with HbA1c (Sakamoto et al., 2018). A large cohort study in the United States also reported meaningful associations between sleep-duration variability and subjective sleep quality with HbA1c, after multivariate adjustment for other covariates (Reutrakul et al., 2020).

Psychological burden as a determinant of glycemic control is gradually gaining recognition as an adverse effect. In a cross-sectional NCD-clinic study in North India, 596 patients participated, with the results showing that 19.7% experienced diabetes distress, the emotional domain being the most common, and that distress was linked to poorer glycemic status (Verma et al., 2025). A community study conducted in Delhi also revealed that diabetes distress is related with self-care deficits and glycemic control (Alwani et al., 2024), while a national systematic review and meta-analysis found a significant pooled prevalence of diabetes distress among T2DM patients in India (Sinha et al., 2024). Perceived stress has been shown to be independently associated with increased HbA1C and decreased treatment adherence (Hilliard et al., 2016), and a classic meta-analytic review found that depression is significantly related to poor glycemic control in all settings (Lustman et al., 2000).

In all populations, smoking is known to have a negative impact on glycemic control. A matched cohort study of newly-diagnosed male T2DM patients showed that those who smoked reduced their HbA1c levels less than matched non-smokers after 1-year follow up (Sia et al., 2022) and a large community study in China revealed that cigarettes smoked per day were associated with increased fasting glucose and HbA1c over 1 year (Su et al., 2017). Smoking and dietary indiscipline were also both identified as modifiable behaviours that could be addressed with combined lifestyle counselling, in a South Asian case-control study, while regular exercise was also identified as a protective factor for poor glycemic control, in a hospital-based study in Ghana (Masoom, 2022; Hadi et al., 2025), respectively.

3.4 Natural bioactive compounds and nutraceuticals relevant to the Indian diet

A very interesting aspect of Indian diet and therapy is the use of certain plants, spices and seeds as natural hypoglycaemic agents which are referred to as hypoglycaemics and are used in day to day cooking. In fact, there is increasing clinical evidence to support several of these traditional remedies from randomised controlled trials and meta-analyses, which make them a complementary approach to conventional dietary and pharmacological treatment and a natural resource-based treatment, not a replacement.

Fenugreek (Trigonella foenum-graecum) is one of the most well-researched. There was evidence of a glycaemia reducing effect of fenugreek seeds in T2DM patients in one early Indian double blind placebo controlled trial, which was thought to be due to the presence of soluble fibre in fenugreek seeds which slows the digestion and absorption of carbohydrates, and to the presence of 4-hydroxyisoleucine, an amino acid with insulin promoting activity in a concentration-dependent manner (Gupta et al., 2001); a subsequent meta-analysis of clinical trials confirmed that fenugreek intake had a significant effect on glycaemia reduction in T2DM patients, as a result of its soluble fibre content, and the effect of 4-hydroxyisoleucine, an amino acid that stimulates insulin release in a glucose-dependent manner (Neelakantan et al., 2014).

Momordica charantia is a popular vegetable in Indian cooking, and is a source of insulin mimetic steroidal saponins called charantin. The effects of M. charantia on reducing fasting blood glucose and HbA1c levels have been corroborated by another recent systematic review and meta-analysis, showing that it significantly lowered fasting blood glucose and HbA1c in patients with prediabetes and T2DM, although there was variation in results between different trials that varied in preparation and dosage (Zhang et al., 2024). The results are largely consistent with a previous 2025 study by Mkhize et al., which concluded that M. charantia significantly decreased blood glucose and HbA1c levels in prediabetes and T2DM patients.

Turmeric (Curcuma longa) is a spice commonly found in almost every Indian household that has been found to have anti-inflammatory and antioxidant properties, which has a potential mechanism for improving insulin sensitivity via the downregulation of pro-inflammatory cytokines and activation of endogenous antioxidant pathways. In a T2DM, prediabetes, and metabolic syndrome patient population, an umbrella review and updated meta-analysis of randomised controlled trials revealed that curcumin supplementation produced significant reductions in fasting blood glucose and HbA1c, which was similar across the different forms of supplementation (Pathomwichaiwat et al., 2023).

Cinnamon, which is commonly used in Indian curries and medicinal uses, has had a much more mild but noticeable effect. Eleven previous meta-analyses of RCTs were identified and analysed in a meta-meta analysis, suggesting that cinnamon supplements had a significant effect on reducing fasting plasma glucose, insulin, HOMA-IR, and HbA1C in T2DM patients (Zarezadeh et al., 2023).

Gymnema sylvestre, locally known as gurmar, which literally means 'sugar destroyer' is one of the plants used in Ayurvedic anti-diabetic formulations which is believed to inhibit the sugar absorption in the intestine and stimulate insulin secretion from the pancreas. After conducting a systematic review and meta-analysis of RCTs, the researchers concluded that Gymnema sylvestre supplementation was effective in reducing glycemic control, lipid profile, and blood pressure in adults, further supporting its centuries-old traditional applications with recent clinical evidence (Zamani et al., 2023).

The combined evidence presented herein indicates that multiple bioactive compounds that are already well known in the Indian diet and pharmacopoeia, and not just folklore medicines, have been shown to have an effect on glycemic parameters in a number of trials. The inclusion of their functional food recommendations (e. g., bitter gourd, fenugreek seeds in cooking, turmeric and cinnamon as regular food items) or their use as standardised nutraceutical formulations in dietary counselling, is a natural-resource-based approach that is not fully exploited compared to evidence and fits well into patients' traditional cultural and culinary habits.

3.5 Interlinkages between diet, lifestyle, and natural bioactive compounds

One of the common themes that reappear in all the literature is that exposures to diet, behaviour and phytochemicals seldom occur alone. Diabetic population having poor sleep quality has been associated with eating disorders and diabetes distress is consistently correlated with worse self-care behaviours and not only dietary compliance but also physical activity. Diabetic individuals with poor sleep quality have been shown to have eating disorders and both diabetes distress and depression have been found to be linked with lower levels of self-care behaviour, including physical activity and dietary control. To date, few Indian studies have modeled four domains of lifestyle—namely, diet, physical activity, sleep, and psychological distress—as well as nutraceutical use in the same model, so it is likely that most published associations, though important in isolation, underestimate the combined effects of these four lifestyle factors on HbA1c. The interconnectedness of the picture implies that a single dietary and nutraceutical counselling approach that solely focuses on diabetes diet may not be very effective and a multi-component approach, combining conventional diabetes diet, physical activity, sleep and psychological counselling, with evidence-based natural bioactive compounds that form part of the patient's food culture, is likely to be more effective for the care of diabetes in India.

3.6 Gaps in current evidence and future directions

There are several recurrent drawbacks in this literature. Longitudinal cohorts and lifestyle-intervention trials are relatively scarce and the majority of Indian studies on dietary patterns and lifestyle behaviours have been cross-sectional, which hinders causal inferences. Most nutraceutical trials, however, are small, have been poorly designed (heterogeneous in preparation and dosage) and have seldom been performed in Indian population as such, where several of the involved plants are natural habitat and traditional use origin. Only a few studies integrate dietary, behavioural and phytochemical variables into one analytic model. Priority directions for future Indian study include standardisation of nutraceutical formulation, dose-ranging studies in India's T2DM population, and pragmatic trials of integrating dietary counselling, physical activity, sleep and mental health support with evidence-based natural bioactive compounds.

4. CONCLUSION

Diabetic controls of Indian adults with type 2 diabetes mellitus is significantly influenced by the routine food choices, lifestyle habits and largely untapped potential of natural bioactive compounds deeply rooted in the Indian food culture and traditional medicine. There are strong, independent relationships between a diet high in carbohydrates and lower HbA1c, physical inactivity, inadequate sleep, and untreated psychological stress on glycemia, and there are clinical-trial-supported relationships between fenugreek, bitter gourd, curcumin, cinnamon and glycemia. This growing problem of diabetes in India needs a multifaceted intervention – culturally appropriate dietary and lifestyle advice along with evidence-based natural resources, backed by the type of long-term, interventional and nutraceutical-standardisation studies that are in scarce supply at the moment.

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