

Ayurvedic Management of Diabetes Mellitus: A Comprehensive Review

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Diabetes mellitus (DM), referred to as Madhumeha in Ayurveda, has various herbal treatments that require scientific validation. The translational “bedside to bench” approach in biomedical research can effectively apply to traditional medicine, particularly through an “omics” approach. Ayurvedic concepts related to DM align with modern systems biology, where metabolic changes and genetic irregularities contribute to insulin resistance. Further research should explore combinatorial therapies based on Prakriti types and utilize metabolomics and pharmacogenomics to refine diabetes treatment strategies. Ayurveda also introduces the concept of Prameha, a pre-diabetic state, suggesting that urinary lipid levels could be pivotal for screening high-risk populations. This tradition-guided research paradigm can facilitate novel opportunities in drug discovery and systems biology for diabetes management, integrating herbal remedies, dietary changes, lifestyle modifications, and detoxification practices along with their mechanisms of action.

Keywords: Diabetes mellitus (DM), ayurveda.

1. Introduction

Diabetes Mellitus in Ayurveda: A Holistic Approach

Diabetes mellitus (DM), commonly referred to as Madhumeha in Ayurveda, is a chronic metabolic disorder characterized by elevated blood glucose levels due to defects in insulin secretion, insulin action, or both. The World Health Organization (WHO) defines diabetes as a condition where the body cannot properly utilize insulin, leading to hyperglycemia and

potential long-term complications, including cardiovascular diseases, nephropathy, neuropathy, and retinopathy. According to the International Diabetes Federation (IDF), the global prevalence of diabetes was estimated at 537 million adults in 2021, projected to escalate to 783 million by 2045. [1, 2]

Epidemiology and Risk Factors

The prevalence of type 2 diabetes (T2DM) is rapidly rising, with India now having the highest number of diabetes cases worldwide. T2DM accounts for approximately 90-95% of all diabetes cases and is closely linked to obesity, physical inactivity, and unhealthy dietary patterns. The acute manifestations of diabetes include excessive urine production, compensatory thirst, blurred vision, unexplained weight loss, lethargy, and alterations in energy metabolism. Furthermore, it is estimated that 183 million individuals are unaware of their diabetic status, highlighting the need for improved awareness and management strategies. [3]

Ayurvedic Perspective

Ayurveda identifies multiple factors contributing to the development of diabetes, such as:

1. Changes in demographic structure.
2. Sedentary lifestyle (*Ekaasthanasana*), including irregular sleep patterns.
3. Dietary changes.
4. Environmental alterations, encompassing air and water quality, lifestyle habits, and occupational factors, collectively referred to as *Janapadabidhamsana* (epidemic) in *Charaka Samhita*. [4]

Ayurveda provides a comprehensive framework for the management of diabetes, emphasizing a holistic approach that incorporates dietary modifications, herbal remedies, and lifestyle adjustments. Traditional Ayurvedic treatments aim to restore balance among the body's three doshas—Vata, Pitta, and Kapha—while also addressing individual constitution (*Prakriti*) and lifestyle factors.

Mechanisms of Ayurvedic Interventions

Ayurvedic texts highlight that the underlying causes of diabetes include improper dietary habits, sedentary lifestyles, and emotional stress, which result in the accumulation of *Ama* (toxins) and disturbances in *Agni* (digestive fire). This review explores the potential of Ayurvedic interventions, including combinatorial herbal and herbomineral therapies, to enhance the management of diabetes. Such approaches are rooted in the concept of polypharmacology, which may offer innovative solutions for complex metabolic disorders like diabetes. To effectively integrate Ayurvedic principles with contemporary medical practices, it is crucial to rethink the current diagnostic paradigm and focus on preventive therapies aligned with Ayurvedic biology. Clinical trials should be prioritized to incorporate concepts of pharmacogenomics and Ayurgenomics into therapeutic strategies. Observations from clinical studies can inform the development of disease models (in vitro, in vivo, or in silico), taking into account relevant systems biology. [5, 6]

While translating and integrating Ayurveda with modern biomedicine presents significant

challenges, adopting a "bedside to bench" research approach could potentially transform diabetes management. This synthesis of ancient wisdom and modern science may lead to innovative, effective therapeutic strategies that improve the quality of life for individuals with diabetes. [7]

Ayurveda offers a robust framework for the holistic management of diabetes mellitus, emphasizing the importance of lifestyle modifications, dietary interventions, and herbal therapies. Future research should focus on validating these traditional practices through rigorous clinical trials and integrating them into contemporary healthcare paradigms.

Mechanisms of Diabetes Mellitus

Diabetes mellitus is characterized by several interrelated mechanisms that contribute to the development and progression of the disease. The following are some key mechanisms involved in diabetes pathophysiology:

1. Insulin Resistance

In Type 2 diabetes, insulin resistance is a primary pathological feature. It occurs when cells in the liver, muscle, and adipose tissue become less responsive to insulin, resulting in impaired glucose uptake. This resistance is often associated with obesity, particularly visceral fat accumulation, which secretes inflammatory cytokines that interfere with insulin signaling pathways. As a result, despite the presence of insulin, glucose cannot efficiently enter cells, leading to elevated blood sugar levels. [8]

2. Pancreatic Beta-Cell Dysfunction

In Type 2 diabetes, there is a gradual decline in the function of pancreatic beta cells, which are responsible for producing insulin. Initially, the pancreas compensates for insulin resistance by increasing insulin secretion. However, over time, the beta cells become exhausted and fail to produce adequate insulin to meet the body's needs, resulting in persistent hyperglycemia. Factors such as chronic inflammation, glucotoxicity (damage caused by high glucose levels), and lipotoxicity (damage caused by excess free fatty acids) contribute to beta-cell dysfunction. [9]

3. Increased Hepatic Glucose Production

In a healthy state, insulin suppresses hepatic glucose production (gluconeogenesis) and promotes glycogen synthesis. However, in diabetes, the action of insulin is blunted, leading to increased hepatic glucose output. This contributes to fasting hyperglycemia, as the liver continues to release glucose into the bloodstream despite elevated insulin levels. [10]

4. Altered Glucose Metabolism

Diabetes is characterized by disturbances in glucose metabolism. In individuals with diabetes, glycogen synthesis is impaired, and gluconeogenesis is upregulated, leading to excessive glucose production. Additionally, anaerobic glycolysis may be favored due to inadequate insulin action, contributing to the accumulation of lactate and other metabolites. [11]

5. Complications of Hyperglycemia

Chronic hyperglycemia leads to various long-term complications associated with diabetes, including:

- **Microvascular Complications:** Prolonged high blood sugar levels damage small blood vessels, leading to diabetic retinopathy, nephropathy, and neuropathy.
- **Macrovascular Complications:** Increased risk of cardiovascular diseases due to damage to larger blood vessels, contributing to atherosclerosis and hypertension. [12, 13]

Understanding these mechanisms provides insight into the importance of effective diabetes management strategies that address both the symptoms and underlying causes of the disease.

Ayurvedic Management Strategies

1. Herbal Remedies [14-16]

Herbs form the cornerstone of Ayurvedic treatment for diabetes, and various botanicals are recognized for their hypoglycemic properties. Below are some key herbal interventions:

- **Gymnema sylvestre (Gurmar):** Often referred to as "sugar destroyer," this herb has a long history of use in Ayurvedic medicine for managing diabetes. Gymnemic acid, the active compound in Gurmar, has been shown to inhibit the absorption of glucose in the intestines and enhance insulin secretion from the pancreas. Research indicates that this herb can significantly reduce sugar cravings and assist in the management of blood glucose levels.
- **Bitter Melon (*Momordica charantia*):** This tropical fruit has garnered attention for its anti-diabetic effects. It contains several active compounds, including charantin, which has been shown to mimic insulin, facilitating glucose uptake by cells and thus lowering blood sugar levels. Studies have reported that bitter melon can significantly improve glycemic control in type 2 diabetes patients.
- **Turmeric (*Curcuma longa*):** Curcumin, the principal active component of turmeric, is renowned for its anti-inflammatory, antioxidant, and anti-diabetic properties. It has been shown to improve insulin sensitivity and reduce blood glucose levels by modulating the activity of various metabolic pathways.
- **Fenugreek (*Trigonella foenum-graecum*):** Fenugreek seeds are rich in soluble fiber and have been demonstrated to lower blood sugar levels by improving insulin sensitivity and slowing carbohydrate absorption in the digestive tract. Additionally, they may have a beneficial effect on lipid profiles in diabetic patients.

2. Dietary Modifications [17-19]

In Ayurveda, diet plays a crucial role in managing diabetes. Ayurvedic dietary recommendations emphasize the importance of consuming foods that balance Agni and prevent Ama accumulation. Some key dietary interventions include:

- **Incorporating Whole Grains:** Whole grains such as barley (jau) and millet (bajra) are preferred in Ayurveda due to their low glycemic index and high fiber content, which help regulate blood sugar levels and improve overall metabolic health.
- **Increasing Intake of Bitter Vegetables:** Consuming bitter vegetables like bitter melon (karela) and leafy greens can help in controlling blood sugar levels and improving digestion,

which is crucial for diabetes management.

- **Utilizing Spices:** Spices such as cinnamon (dalchini) and ginger (adrak) are commonly used in Ayurvedic cooking. These spices have been shown to possess anti-diabetic properties by enhancing insulin sensitivity and modulating postprandial blood sugar spike.

3. Lifestyle Interventions [20, 21]

Lifestyle modifications are an integral part of Ayurvedic diabetes management. These interventions focus on promoting overall well-being and metabolic health through sustainable practices:

- **Regular Physical Activity:** Engaging in physical activity, such as yoga, walking, or other aerobic exercises, is emphasized in Ayurveda for managing diabetes. Yoga not only improves physical fitness but also reduces stress and enhances metabolic control.
- **Stress Management:** Chronic stress can exacerbate diabetes and hinder effective management. Ayurvedic practices such as meditation and mindfulness techniques can help reduce stress levels, promoting a balanced emotional state that is conducive to effective diabetes management.

4. Panchakarma Therapy [22-24]

Panchakarma, a detoxification process in Ayurveda, plays a vital role in managing chronic conditions like diabetes. This therapeutic regimen involves a series of procedures aimed at eliminating Ama from the body and restoring dosha balance. Key Panchakarma treatments for diabetes include:

- **Virechana (Therapeutic Purgation):** This process involves the elimination of toxins from the body through the gastrointestinal tract, helping to restore metabolic balance.
- **Basti (Medicated Enemas):** Basti therapy can help in balancing Vata dosha and improving digestive health, which is essential for maintaining stable blood glucose levels.

Early Detection and the Pro-Disease Concept of Diabetes in Ayurveda

Madhumeha, or diabetes, is a multifaceted metabolic disorder intricately linked to genetic variations. One traditional Ayurvedic method for early detection involves observing lipid excretion, referred to as Meda Dushti. This can be assessed by combining equal parts of Puskar moola (*Inula racemosa*) with urine and boiling the mixture. A change in color to red after boiling indicates the presence of lipids [25, 26].

To enhance diagnostics, it is essential to adopt a metabolomics approach, utilizing metabolites as markers for disease activity. This strategy could significantly aid in characterizing complex metabolic disorders like diabetes, which can manifest differently across various genetic and demographic groups. Notably, in type 2 diabetes, elevated levels of Apo-B lipoproteins have been identified, correlating with a higher risk of hyperalbuminuria [27].

The evidence supporting the association between urine-related lipid excretion and diabetes suggests that these parameters should be considered as potential biomarkers for screening

both diabetic and pre-diabetic stages. Relying solely on traditional diagnostic criteria such as HbA1c levels may be insufficient. Other contributing factors, including Meda Dhatu Dushti (adipose tissue damage and dyslipidemia), should also be taken into account. This is important as research has shown that diabetes is associated with disruptions in lipid metabolism signaling pathways [28].

In Ayurveda, the selection of treatments for diabetes can be logically tailored to an individual's specific Prakriti (genetic traits). Ayurvedic principles emphasize the connection between the body's morphometric type and symptom complexes, which arise from qualitative and quantitative changes in urine, particularly concerning lipid excretion. This pro-disease state, referred to as Prameha, precedes the development of diabetes [29].

The extent of Meda Dhatu involvement can be assessed early through the aforementioned urine examination technique. Factors such as calorie-dense diets, stressful lifestyles, and sedentary behavior contribute to the formation of Visama Dharmi Meda (adverse fat), which correlates with contemporary concepts of elevated triglycerides and free fatty acids. These conditions can lead to the progression from Prameha to Madhumeha [30].

Thus, implementing early detection methods at this pre-disease stage and intervening in high-risk populations can potentially prevent the onset of diabetes.

Preventive Measures in Ayurveda

Given that Madhumeha is a multifactorial condition, relying on a single-target, single-drug therapeutic approach is inadequate. In Ayurveda, Madhumeha is classified as a type of Vataja Prameha, which arises from an imbalance in the Vata Dosha and develops through a progression of twenty stages or types of Prameha. Personalized dietary and medicinal choices in Ayurveda are based on the Trisutra, which comprises three fundamental elements: Hetu (causes), Linga (symptoms), and Ausadha (therapeutics). [31]

The treatment strategies for patients with Madhumeha can be divided into two categories: (1) Sthula Pramehi (obese) and (2) Krisha Pramehi (lean).

Sthula Pramehi (Obese): For individuals in this category, the treatment should focus on the effective utilization of excess fat. Recommended interventions include:

1. Shodhana (purification processes)
2. Apatarpana (weight reduction through dietary control, medications, or exercise).

Krisha Pramehi (Asthenic): In contrast, the treatment for patients who are lean emphasizes enhancing stamina and vitality, referred to as Brimhana, through appropriate diets and medications. It is crucial for these individuals not to undergo excessive Langhana or Apatarpana, which means they should avoid prolonged fasting.

It is important to note that since Madhumeha is primarily associated with a disorder of the Agnashaya (pancreas), there has yet to be a definitive cure for this condition. Consequently, it is referred to as a Yapya Vyadhi, indicating that while it can be managed, it is not curable. Therefore, it is vital to emphasize preventive measures, particularly through early detection at the Prameha stage [32].

Ayurvedic Translational Research in Diabetes

For centuries, a wide variety of Ayurvedic herbs, herbal formulations, herbomineral preparations, and mineral supplements have been utilized to manage Madhumeha, or diabetes. There are numerous herbs associated with diabetes-related complications, highlighting an important area for further research. However, clinical evidence regarding their efficacy and safety is lacking, primarily due to inadequate methodologies and research approaches in this domain. The assumption that "natural means safe" can often be misleading when it comes to Ayurvedic medications, and the over-the-counter use of these drugs has occasionally resulted in adverse effects [33].

Therefore, there is a pressing need to initiate translational research within the field of Ayurvedic medicine. This type of research is characterized by a two-way process: moving findings from the laboratory to clinical practice and vice versa. To advance research from clinical settings back to the laboratory, we must improve our understanding of human diseases, particularly in the context of Ayurvedic systems biology and diabetes-related complications, which is currently limited.

Various Ayurvedic plants are classified based on Prakriti types and their therapeutic properties, encompassing aspects like taste (Rasa), quality (Guna), potency (Virya), and post-digestive effect (Vipaka). Observational studies on plant-based medications have shown promising reductions in fasting and postprandial blood glucose levels [34].

When it comes to managing diabetes-related complications, specific plants and formulations have been identified for different conditions, such as:

- Angiopathy: Manjistha (*Rubia cordifolia*), Kanchanar (*Toddalia aculeata*)
- Cardiovascular disorders: Kushta (*Saussurea lappa*)
- Neuropathy: Dashamula (a combination of ten herbs, including *Aegle marmelos*)
- Nephropathy: Varuna (*Crataeva nurvala*), Shigru (*Moringa oleifera*), Gokshura (*Tribulus terrestris*)
- Retinopathy: Manjistha, Nagakesara (*Mesua ferra*), Bala (*Sida cordifolia*), Saptamrita Loha, Triphala Loha, Shatavari (*Asparagus racemosus*)
- Diabetic foot: Nirgundi (*Vitex negundo*), Manjistha, Ashwagandha (*Withania somnifera*), Daruharidra (*Berberis aristata*) [35]

Despite these potential treatments, challenges remain in translating findings from preclinical models to human applications, often resulting in failure. Recent studies investigating the role of innate immunity in the response to environmental pathogens in clinical diabetes may offer new insights into preventing type 1 diabetes in the future.

Moreover, the current trend in diabetes management emphasizing intensive insulin therapy has led to increased rates of severe hypoglycemia among patients, particularly those with type 1 and type 2 diabetes. This shift in clinical practice has also contributed to complications such as hypoglycemia-associated autonomic failure (HAAF) and hypoglycemia unawareness. Research on animal models of HAAF is in its early stages, but preliminary results are promising. [36]

The concept of using reverse pharmacology in Ayurvedic drug discovery is being recognized

as a valuable resource for treating chronic inflammatory diseases, including cancer. To further advance Ayurvedic drug research for chronic conditions like diabetes, a comprehensive strategy that incorporates both bedside-to-bench and reverse pharmacology approaches is essential. [37]

This first phase focuses on herboepidemiological observational studies and clinical trials involving Ayurvedic drugs. Advances in human genomics, particularly the idea of Prakriti or Ayurgenomics, offer a path toward personalized medicine, which aims to enhance drug effectiveness and reduce toxicity. By integrating pharmacogenomics into clinical practice, new therapeutic possibilities in Ayurveda may emerge. [38]

Conclusion

The principles of Ayurveda have evolved through centuries, relying on clinical observations and philosophical insights. Consequently, there is an urgent need for interdisciplinary research that validates and translates this ancient knowledge into a dynamic scientific framework. Diagnosis and treatment should align with concepts from systems biology, and modern advancements in “omics” should be integrated into therapeutic approaches.

Research should adopt a "bedside to bench" strategy to gather critical insights. This approach acknowledges the complexity of diabetes, recognizing that key findings from in vitro or in vivo studies may not always translate effectively to patient outcomes. Thus, a cycle of research that flows from patient observations to laboratory studies and back to clinical application is essential for progress.

A significant challenge lies in bridging the ancient knowledge of Ayurveda with contemporary scientific paradigms. Initiatives such as the Standards for Reporting Observational Epidemiology (STROBE) and the Consolidated Standards of Reporting Trials (CONSORT) should be recognized in the methodology of Ayurvedic translational research. Developing epistemologically sensitive methods is increasingly important for this integration.

Clinical efforts, such as herboepidemiological studies, should inform basic research aimed at fulfilling the fundamental principles of Ayurvedic biology. By leveraging traditional knowledge—primarily based on experience and observation—research can uncover novel targets and strategies for drug development. The concept of Ayurgenomics will flourish only if we successfully translate the phenotypic characteristics of Madhumeha (diabetes) and its associated stages.

The conventional approach of targeting a single drug to one pathway may not adequately explain the actions of these multi-targeted herbal medications. Therefore, a metabolomics approach and systems-level expression studies could offer valuable insights. Additionally, similarity-guided ontology could predict network interactions and drug interference pathways.

Modeling disease networks and identifying potential targets for herbal or herbomineral drugs represent crucial steps forward in this research area. Ultimately, this knowledge-driven approach to diabetes management can lead to the development of safe and effective therapeutic options.

Ayurvedic management of diabetes mellitus offers a holistic perspective, addressing not only the symptoms but also the underlying causes of the disease. By integrating herbal treatments, dietary changes, lifestyle modifications, and detoxification strategies, Ayurveda presents promising methods for effectively managing diabetes and enhancing overall health.

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